ERIK DEN HARTIGH

Increasing Returns and Firm Performance

An Empirical Study

Increasing Returns and Firm Performance:

An Empirical Study

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An Empirical Study

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“I stepped into an avalanche
it covered up my soul”

Leonard Cohen, Avalanche,
from the album Songs of Love and Hate, 1971

PREFACE

The journey that has resulted in this thesis started somewhere in 1992. At the time I was studying business economics with about 1700 fellow students. Business economics was fashionable then, causing our large university auditorium to be crowded with students. Until then, I had a relatively easy time getting through the exams by keeping to a disciplined schedule of studying. Keeping to this schedule would have almost certainly made me a well-educated yet somewhat superficial 21-year old economist.

Then, a few things happened that would radically change this tight schedule. First, I became fundamentally interested in economics: I had learned, superficially, about many models and theories, but I knew nothing about how economics really worked. Why where there no courses on this important issue? Second, I read *Chaos*, a popular scientific book by James Gleick championing chaos theory as a radical scientific revolution. It hit a sensitive note: what if the economy was also a chaotic system? What would the consequences be? Unable to apply to this issue any of the models and theories I had learned, I asked some of the teachers, but few of them seemed to have any knowledge of or interest in the direction my thoughts were taking me. Finding no answers, I let the subject rest, but it stayed in my mind. Third, I chose to follow electives in economic sociology and in industrial economics. The contrast with the first two years of study could not have been greater. Instead of crowded classes and standard textbooks, I now found small groups of students and we were encouraged to ask questions about how the world, social or industrial, worked. Often we found that our teachers did not know, nor did they pretend to know, the answers. They taught us that it was more important to pose the right questions, supported by the right arguments, than it was to find the answers. Such an enquiring way of studying suited me very well. At this point I would therefore like to thank my teachers from this period for encouraging me and teaching me in me this way of doing science. Special thanks to Professor Moerman, who taught the industrial economics classes and who supervised my master thesis on this subject.

After graduation I started exploring the labor market with the notion of maybe doing a PhD in the back of my head. Within a year I was back at the university, working as a research assistant at the department where I had graduated. There I met Fred Langerak, now my good friend and co-promotor, and through him I met Harry Commandeur, my promotor. I cannot thank both of them enough for recognizing and stimulating my academic curiosity at that time. With Harry and Fred, I talked about the possibility of doing a PhD and we exchanged some ideas on possible subjects. During this process Harry introduced me to Ton van Asseldonk, who was at that point starting his PhD thesis on mass-individualization. In my search for an appropriate PhD subject, it would be helpful, Harry thought, if I assisted Ton with his thesis for one year.

Meeting Ton I soon recognized that he was not just your typical consultant looking for a quick PhD. All the things I had been interested in over the past years came back in this man's thesis: the social, economic and industrial way companies worked, connected to theories of chaos and complexity science. I look upon the year of assisting Ton as one of the most profound learning experiences of my life. After this year, I knew that my thesis would be about increasing returns, one of the basic mechanisms of economic and business complexity. Ton offered me a job that enabled me to realize this academic ambition, spending half of my time as a consultant for his company, TVA developments, and half of my time as a PhD student at the Erasmus University. Ton, I cannot thank you enough for this.

Over the years, TVA developments and the people in and around it have provided the intellectual environment that is, in my view, crucial to doing good science: broad minded, enquiring, well-read, with a deep knowledge of practical issues and at the same time academically sound. I am grateful that over the past years we have been able to preserve, renew and extend this environment through our quarterly meetings. Therefore, I would like to thank Anjo, Bert, Jan, Leon, Lout, Marc, Meindert, Simon, Ton and all the others who contribute to shaping this enriching environment.

There is a long list of people and institutions that I would like to thank for their contribution to this thesis. Any that I have forgot to mention, I thank them here and ask their forgiveness.

I would like to thank the *Erasmus University Rotterdam* and the *Delft University of Technology* for providing the facilities that have enabled me to work on my PhD.

I would like to thank the *Erasmus Research Institute of Management* for facilitating and financially supporting the PhD thesis.

I would like to thank my colleagues at the *Erasmus University Rotterdam* and at the *Delft University of Technology* for their interest and their help.

Preface

I would like to thank all my students at the *Erasmus University Rotterdam* and at the *Delft University of Technology* for their interest in my research. Special thanks to Ties Arts, my first student graduating with a masters thesis on increasing returns and someone who is still interested in this topic, and to Robert Meijer, who delivered a valuable contribution to the empirical part of this thesis.

I would like to thank the *Goldschmeding Research Center of Economics for Increasing Returns* of *Nyenrode University* for supporting the research. I thank the members of the research center, especially Dr. Goldschmeding, for the interesting discussions and the opportunity they gave me to present my research findings.

I would like to thank all the people in the companies that participated in my research for their interest and for the time and effort they spent in testing and filling out my questionnaires. You have delivered the single most valuable contribution in validating the concepts and measurements of increasing returns.

I would like to thank all the people from *USP Marketing Consultancy Rotterdam* for helping me out with acquiring the survey data for the empirical studies.

I would like to thank Miranda Aldham-Breary for checking my use of the English language in this thesis and for improving my English in the process. Miranda, I feel that your academic background, combined with the unique style in which you suggest language improvements, has contributed not only to the readability of the thesis but to the quality of the argumentation as well. Besides, I like working with you and I hope we can continue to work together in the future.

I would like to thank all the members of my PhD committee for their willingness to be my supervisors, for the time they spent reading the manuscript and for their useful comments on the concept version. With some of you the discussions were tough, especially on the definitions and use of macro-economic concepts on the firm level. These discussions have only confirmed my belief that we may attain great things together if we succeed in bridging the gap between economics and management science.

I would like to thank all my friends, academic and non-academic, for their enduring interest in the project and for their patience and their understanding when I had to tell them time and again that "it would be finished somewhat later".

I would like to thank my good friends Özge, Stefan and Sem (in particular for sharing his small house with me during summer, enabling me to work quietly) for all the emotional support and all the good times we have had together in the past seven years. Let's have a good glass of wine (or juice) to celebrate our friendship. And may the good times continue!

I would like to thank my promotor, Harry Commandeur, for the time and effort he invested in supervising and guiding the entire process, for making all kinds of unexpected connections and for providing all kinds of unforeseen opportunities. But most importantly I would like to thank him for his ability to stimulate and motivate me to persist with this project while at the same time leaving me considerable freedom to determine my own way and explore my own subjects. Harry, I know of no-one else who synthesizes these two characteristics as perfectly as you do.

I would like to thank my co-promotor, Fred Langerak, for the incredible amount of time and effort he has invested in this project, for being an academic partner and a very good friend. I hope that we can write many more papers, and spend many more enjoyable hours together!

I would like to thank TVA developments and all the people connected to it, now and in the past, for their generous support; first, of course, for providing the lion's share of the financial and facilities support; but most importantly, for providing the emotional and intellectual support and a great working environment that kept me going over the years. Thank you Anita, Bea, Désiré, Ellen, Marjo, Mieke, Miranda, Anjo, Bert, Leon, Marc, Theo and Ton!

Finally, I would like to thank my parents for their continuing support, their unfailing belief that I would finish this journey, for their encouragement and their support for all the decisions that I took along the way, and, not least, for sharing the house for weeks on end with a son who was obsessively, and probably sometimes very unsociably, working on this thesis. I can never thank you enough.

Erik den Hartigh
Rotterdam, August 2005

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“The case of increasing returns has never been properly explored in economic theory […] economists in general shied away from exploring the consequences. However, businessmen could never ignore the existence of diminishing costs.”

Nicholas Kaldor, 1981 [1989, p.330]

“In a constant returns economy, the firm is an artificial entity.”

Martin L. Weitzman, 1982, p.791

1. INTRODUCTION

This thesis is about increasing returns, positive feedback effects in markets and firms.[1] We address the reasons for studying increasing returns in the first section of this chapter. In the second section we turn to the expected implications of increasing returns for market structure, firm behavior and firm performance. On the basis of these expected implications, we outline the central problem of this thesis, we give the research questions and we address the research approach in section three. We address the scientific and managerial contributions aimed at in this thesis in section four. In section five we provide an integrative definition of increasing returns that will be used throughout the thesis. We discuss the research design in section six. We provide insight into the structure of the thesis in section seven. In section eight we provide a glossary of some of the most important concepts addressed in this thesis.

1.1 Why study increasing returns?

The *law of diminishing returns* is one of the most prominent laws in economics. Originally expressed in relation to agriculture by Anderson (1777) and later by Malthus (1815) and Ricardo (1815), the law of diminishing returns states that, for an economic system, output will (eventually) increase less than proportionally with input. The effects of extra input will eventually die out, meaning that *negative feedback* prevails.

It should be noted that economics, being a social science, does not have that many laws (Solow, 1985; Commandeur, 1999). Rather, the predicate 'law' is reserved for a relatively limited number of phenomena, for example Say's law, Gresham's law, the law of demand and supply, Gossen's first and second laws. The law of diminishing returns meets the four criteria for a relationship to be called a law (Hunt, 1991): (1) it is a general condition for economic transformation processes, (2) it has been empirically tested and confirmed, (3) it is a theoretically logical phenomenon and (4) it is systematically integrated in economic theory. Yet in this thesis, we deal with exactly the opposite of diminishing returns, namely with *increasing returns*.

[1] Positive feedback is a term used in systems thinking to describe a response in which changing output conditions in the system stimulate further growth in the input. Note that this conceptualization of *increasing returns as positive feedback effects* is different from the common economic conceptualization of increasing returns. For further discussion of these definition issues, see sections 1.5 and 5.1.

Generally, there are increasing returns when the output of an economic system increases more than proportionally with a rise of input. In other words, effects of extra input will be magnified, meaning that *positive feedback* prevails.

Why would we want to study increasing returns when the law of diminishing returns is so strong and prominent? There are four reasons for this. The first is that there is growing evidence that increasing returns actually do exist, at least in the relevant business domain of firms, see, e.g., Garud & Kumaraswamy (1993), Brynjolfsson & Kemerer (1996), Gupta, Jain & Sawhney (1999) and Makadok (1999). While this may seem obvious, increasing returns is still by no means an integrated part of management theory.

The second reason to study increasing returns is that it is becoming more relevant in the increasingly information and knowledge based business environment of today. The rising information and knowledge intensity of the business environment is expressed in the rising prevalence of the services sector, rising prevalence of information products, e.g., software, and the increasing amount of knowledge required to configure and execute business processes. The economic characteristics of information and knowledge endow them with an inherent possibility of increasing returns when used as input factors (Romer, 1986; Glazer, 1991). These characteristics do not automatically imply that increasing returns will be present, as information and knowledge will always be used in combination with other (diminishing returns) input factors, yet they are likely to enlarge increasing returns opportunities.

The third reason for studying increasing returns is that it is a very appealing concept for individual firms and for the economy as a whole. We put something in and we will get progressively more out in return! This sounds like a 'free lunch', a compelling yet doubtful concept. Yet, if we look more carefully, the presence of increasing returns seems to be a precondition for economic growth to occur at all. If output always rises just proportionally or less than proportionally to input, where will growth of an economic system come from when it cannot be ascribed to exogenous factors?[2] This kind of reasoning is the basis for endogenous growth theory; see, e.g., Romer (1986; 1990b).

---

[2] Exogenous reasons for economic growth, i.e., not incorporated in the model, such as population growth or newly discovered natural resources, are unlikely to provide the full explanation for differences in growth between different economic systems (Solow, 1957; Romer, 1993).

The fourth reason is that leading economists over the past *250* years have found the topic worthy of study. Starting with the classical economists, we can see forms of increasing returns being addressed in the work of Petty (1690), Turgot (1766) and of course in the work of Smith (1776). In the neoclassical era we can see Marshall's (1890) struggle with increasing returns, followed in the 1920's and 1930's by the papers of Sraffa (1926), Young (1928), Robertson (1930) and Hicks (1939). In the 1950's to 1970's, we see it prominently in the work of Kaldor (e.g., 1966, 1972) and we find it in some of the work of Arrow (e.g., 1962). In the last few decades it can be found in international trade theory, e.g., Helpman & Krugman (1985), in economic growth theory, e.g., Romer (1986; 1990b), in industrial organization theory, e.g., Farrell & Saloner (1985; 1986), Katz & Shapiro (1985; 1986), in complexity science, e.g., Arthur (1988; 1990), Brock & Durlauf (2001) and even in marketing, e.g., Gupta, Jain & Sawhney (1999), Dickson, Farris & Verbeke (2001).

Still, despite the growing attention for increasing returns in economics, in complexity science and in the management sciences, there are some limitations to the current body of knowledge on increasing returns. First, theoretical specifications have been fragmented over different theoretical domains. The consequence is that there are many definitions of increasing returns, often addressing different mechanisms of increasing returns and yet an integrative approach is lacking. Second, empirical measurement of increasing returns remains underexposed, especially at the firm level. Evidence of increasing returns is often anecdotal and systematic empirical research is scarce (David & Greenstein, 1990). Third, relatively little is known about the influence of increasing returns on firm performance. Concluding, there are clearly reasons for studying increasing returns and there is a need for an integrative theoretical specification, for empirical measurement and for research into the implications of increasing returns for firm performance.

1.2 Increasing returns, market structure, firm behavior and firm performance

The question *Why are some firms more successful than others?* is a classic one in the strategic management literature (Rumelt, Schendel & Teece, 1994). It is also the foundation of the research reported on in this thesis. The reason to pose a variant of this classical question yet again is that theory and existing research suggest that the presence of increasing returns has important implications for market structure, market outcomes and, as a consequence, for the behavior and the performance of firms that are active in those markets, see, e.g., Arthur (1996), Schilling (1998), Shapiro & Varian (1999).

Increasing returns, i.e., positive feedback effects, play an important role in many markets and firms. In markets, they appear for example in the emergence of fashions and fads, e.g., Abrahamson & Rosenkopf (1997), Bikhchandani, Hirschleifer & Welch (1992) and in technology adoption and standardization, e.g., Arthur (1989), Katz and Shapiro (1985). In firms they appear for example in the production and commercialization of information and knowledge intensive products, e.g., John, Weiss & Dutta (1999), Shapiro & Varian (1998) and in technological process improvements, e.g., Amit (1986), Hatch & Mowery (1998). We will refer to the mechanisms causing positive feedback effects in the market as *market-based mechanisms of increasing returns* and to the mechanisms causing positive feedback effects in the *firm as firm-based mechanisms of increasing returns*.

The presence of market-based mechanisms of increasing returns has important consequences for market structure (Arthur, 1989; Farrell & Saloner, 1985; 1986; Katz & Shapiro, 1985; 1986). Market structure in increasing returns markets is characterized by:

- *battles for the technological standard*, i.e., competition between multiple technology networks
- *winner-take-all situations*, i.e., very asymmetric distribution of market shares
- customer *lock-in* on technological standards, i.e., when the cost of switching to another technology – even though it may be technically superior – is too large for the switch to take place
- unpredictability of market behavior, e.g., *excess inertia*, i.e., stalemates in the market, or *excess momentum*, i.e., explosive growth, in the adoption of technologies
- *path dependence*, i.e., disproportional influences of historical small events and of factors of chance
- the possibility of *market imperfections*, i.e., it is not assured that the 'best' technology will prevail

The presence of firm-based mechanisms of increasing returns has important consequences for firm behavior, which is characterized by, for example:

- decisions regarding the optimal scale of production and the speed of extension of this scale

- decisions regarding product and process improvements
- decisions regarding the firm's value proposition in the market, e.g., cost-leadership or differentiation strategies

Besides their separate influence on market structure and firm behavior, these market-based and firm-based mechanisms of increasing returns will likely be related in multiple ways:

- regarding the capabilities the firm needs to understand the consequences of increasing returns for market structure and for competitors' behavior and to strategically act upon those consequences
- regarding the scale and growth of operations the firm can realize as a consequence of market outcomes
- regarding the decisions the firm has to take on investments to be made and strategic actions to be taken to exploit acquired advantages

All of these effects together will eventually determine the performance of firms, products and technologies (Arthur, 1988; Hill, 1997):

- sponsoring of new technologies and commercialization of new products will become an increasingly risky process
- product, technology and firm performance will become less predictable
- product, technology and firm performance may be path dependent, i.e. heavily dependent on initial conditions that are often irreversible

Whether all of the consequences for market structure and firm behavior mentioned above will be present in increasing returns markets and what the implications are for firm performance, is still debated. We aim to deliver a contribution to this debate with this thesis.

1.3 Central problem and research approach of the thesis

1.3.1 Central problem

Following the reasoning in the previous sections, the central problem dealt with in this thesis is:

> ***What is the effect of market-based mechanisms of increasing returns on firm-based mechanisms of increasing returns and what is their joint effect on firm performance?***

The following research questions will be addressed.

1. How can market-based and firm-based mechanisms of increasing returns be defined and theoretically specified?
2. How can market-based and firm-based mechanisms of increasing returns be measured?
3. What is the effect of market-based mechanisms of increasing returns on firm-based mechanisms of increasing returns?
4. What is the joint effect of market-based and firm-based mechanisms of increasing returns on firm performance?

1.3.2 Industrial organization approach

In answering these research questions, we adopt a *behavioralist approach* to the *industrial organization theory of the firm*. Within this approach, we will adhere to the *Harvard tradition*, allowing for market imperfections and for the influences of firm-specific behavior.

In 1926, Sraffa predicted that Robinson's (1933) and Chamberlin's (1933) theories of imperfect competition would be the logical road to fit increasing returns into economic theory (Sraffa, 1926). Based on, among others, Robinson's and Chamberlin's theories of imperfect competition, *industrial organization theory* emerged. The basic assumption of industrial organization theory is that market structure influences firm performance through the conduct of the firm. This has become known as the *structure-conduct-performance paradigm* (Bain, 1959). In the *structuralist* approach to industrial organization theory, this assumption is taken to the extent that market structure is so constraining on firm conduct that individual management action can be virtually ignored (Spanos & Lioukas, 2001). For our analysis, the major objection to this approach is that it virtually ignores the increasing returns mechanisms that might occur within the firm and the ability of the firm to take strategic action.

In response to the limitations of the structuralist approach, a modified industrial organization framework gradually emerged, which is referred to as the behavioralist approach to industrial organization (Brouwer, 1991). The works of Scherer & Ross (1990) and Porter (1980; 1985; 1990; 1996) are exemplar for this approach. According to Spanos & Lioukas (2001), Porter's work differs from the structuralist approach in three important ways. First, he follows the strategic management tradition by focusing on firm performance rather than on industry performance. Second, he does not regard industry structure as completely exogenous or stable, but rather as dynamic and partly subject to being influenced by the firm's actions. Third, he explicitly recognizes the role of firm conduct in influencing performance.

Analyzing increasing returns by making use of the behavioralist industrial organization approach therefore enables us to address specifically both market-based and firm-based mechanisms of increasing returns. The adoption of the behavioralist approach to industrial organization theory also implies that in this thesis we focus on *firm* performance rather than *industry* performance, that we do not consider industry structure to be completely stable and fully exogenous and that we assume that the firm can, by its conduct, influence its performance. Hence, this is the theory of the firm that we will adopt for the remainder of this thesis.

1.3.3 Analytical framework

The combination of the central problem and the chosen industrial organization approach results in the analytical framework shown in figure 1.1.

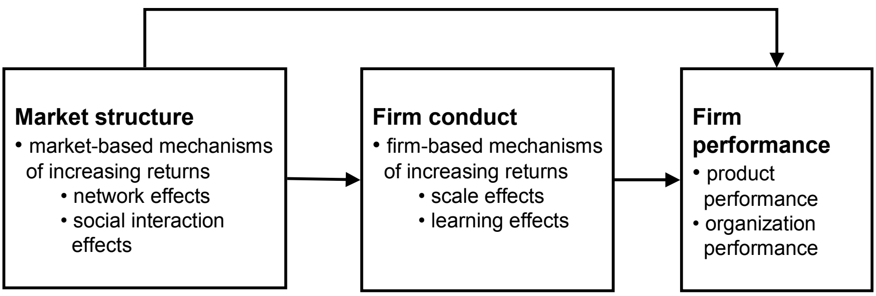

Figure 1-1: Analytical framework

This analytical framework is based on the structure-conduct-performance paradigm discussed above. We consider market-based mechanisms of increasing returns as determinants of market structure and firm-based mechanisms of increasing returns as determinants of firm conduct.[3] This implies that the market-based mechanisms of increasing returns influence firm performance at least partly through the firm-based mechanisms of increasing returns.

[3] See chapter three for the reasons why.

1.4 Contribution of the thesis

1.4.1 Existing literature streams on increasing returns

The subject of increasing returns has been addressed in literature from three different perspectives, i.e., economics, complexity science and management science. Theories have been developed on different mechanisms of increasing returns from each of these perspectives.

Historically, theory on increasing returns has mainly been developed in economic literature. However, most of the economic research into increasing returns suffers from one or more of the following shortcomings: it is generally not integrative, i.e., it mainly addresses the *firm-based* mechanisms of increasing returns, it often makes far-reaching abstractions from reality, which often hampers the managerial relevance, it is often exclusively theoretical, empirical research is relatively scarce and it does little to address the consequences of increasing returns for firm performance.

A promising new literature stream for enriching the theory of increasing returns is that of complexity science, especially because complexity science[4] literature often explicitly incorporates positive feedback as a concept. Similar to the economic literature, most of the research into increasing returns in the complexity science literature suffers from one or more of the following shortcomings: it is generally not integrative, i.e., it mainly addresses the *market-based* mechanisms of increasing returns, it is often little related to management problems, it is often exclusively theoretical, empirical research is relatively scarce and it does little to address the consequences of increasing returns for firm performance.

In the past decades, many additions to increasing returns theory have been made from the management sciences. The management science literature focuses on the firm and its interaction with the environment. Still, most of the theory on increasing returns in the management literature suffers from one or more of the following shortcomings: it is generally not integrative, i.e., it addresses either *firm-based* increasing returns mechanisms *or market-based* increasing returns mechanisms, but it rarely addresses both, it is to a large extent conceptual, empirical research is relatively scarce, empirical evidence is mainly anecdotal, i.e., based on case examples, and it does little to address the consequences of increasing returns for product and firm performance.

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[4] We follow the terminology used by the *Santa Fe Institute* (Anderson, Arrow & Pines, 1988) for their conference proceedings, i.e., *studies in the sciences of complexity*.

1.4.2 Perspective and aims of this thesis

In this thesis, we will take a management perspective. As explained in section 1.3, the management perspective will be operationalized by taking the *structure-conduct-performance paradigm* as a research framework. The *structure-conduct-performance paradigm* enables us to make a connection between the existing literature streams on increasing returns, i.e., from complexity science, from economics and from the management sciences (see figure 1.2). This connection enables us to overcome the shortcomings of the individual literature streams.

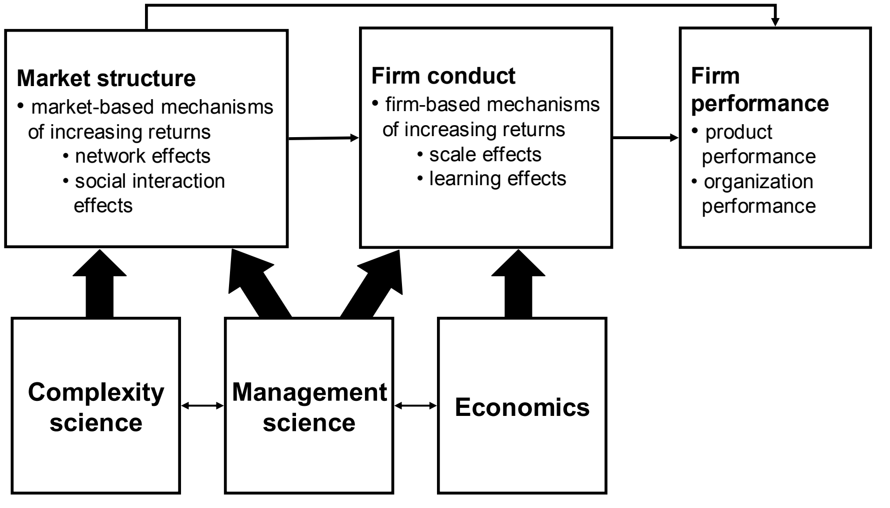

Figure 1-2: Perspectives used in the thesis

We had four aims in writing this thesis.

The *first scientific aim* was to contribute to the development of increasing returns theory from a management perspective in an integrative way, i.e., by addressing market-based and firm-based mechanisms of increasing returns and their interrelations. To achieve this aim we made use of existing concepts from the economics perspective, the complexity science perspective and the management perspective.

The *second scientific aim* was to develop methods for measuring the market-based and firm-based mechanisms of increasing returns.

The *third scientific aim* was to analyze empirically the relationships between market-based mechanisms of increasing returns and firm-based mechanisms of increasing returns and their joint effects on firm performance.

The *managerial aim* was to provide managers with the building blocks of a framework that will enable them to understand the implications of increasing returns for the structure of their market, for the behavior of firms in these markets and for product and firm performance in these markets. This understanding should enable managers to take conscious strategic action upon the consequences of increasing returns to increase the performance of their firm and its products.

1.5 A managerial definition of increasing returns

Taking a management perspective, we searched for a managerial definition of increasing returns. Furthermore, because we aimed at contributing to the development of increasing returns theory in an integrative way, such a definition had to comprise the different mechanisms of increasing returns, i.e., the market-based mechanisms and the firm-based mechanisms.

1.5.1 Existing definitions of increasing returns

When we look at existing increasing returns literature, a widely varying array of definitions of increasing returns is available, coming from the economic perspective, from the complexity science perspective or from the management perspective. A few examples will illustrate this; see also Commandeur (1999).

> "The law of Increasing Returns may be worded thus: an increase of labour and capital leads generally to improved organisation, which increases the efficiency of the work of labour and capital." (Marshall, 1890, IV, VIII, 2).

> "Increasing Returns is a relation between a quantity of effort and sacrifice on the one hand, and a quantity of product on the other." (Marshall, 1890, IV, VIII, 2).

> "The basic conception of returns in relation to the variation of factors is now essentially this: that successive equal additions, or doses, of the variable factor, or input, applied to the definite quantity of the factor held constant, yield, up to a certain amount of input, successively larger increments of

return; further amounts of input yield successively diminishing increments of returns." (Wolfe, 1929, p.580).

"Positive feedbacks in the economy." (Arthur, 1990, p.80; 1999, p.108).

"Economic processes can be self-reinforcing" (Cowan & Gunby, 1996, p.521).

"Increasing Returns are the tendency for that which is ahead to get further ahead: for that which loses advantage to lose further advantage. They are mechanisms of positive feedback that operate – within markets, businesses, and industries – to reinforce that which gains success or aggravate that which suffers loss." (Arthur, 1996, p.100).

"Economists use the phrase increasing returns to refer to this kind of self-reinforcement. Increasing returns implies that the more successful a firm is at getting its technology accepted as a standard, the more successful it will become in the future; in an increasing returns world, success begets success!" (Hill, 1997, p.9).

"Whatever the reason one gets ahead – acumen, chance, clever strategy – increasing returns amplify the advantage. With increasing returns, the market at least for a while tilts in favour of the provider that gets out in front." (Teece, 1998, p.58).

"[…] an element of self-enforcement that transcends its historical cause […] in escalating it out of proportion (increasing returns)." (Kretschmer, Klimis & Choi, 1998, p.S61).

1.5.2 Definitions of the separate mechanisms

A systematic study of the literature (see chapter three) shows that four generic mechanisms can be distinguished that bring about positive feedback effects (cf., Arthur, 1988): (1) network effects, (2) social interaction effects, (3) scale effects and (4) learning effects.[5] Of these mechanisms, social interaction effects and network effects are market-based, while scale effects and learning effects are firm-based. For

[5] Arthur (1988) mentions four *sources of increasing returns*: (1) large set-up or fixed costs, (2) learning effects, (3) coordination effects and (4) adaptive expectations.

each of these four mechanisms it is possible to draw up a definition that is in accordance with the dominant definitions that are available in the literature.

Network effects occur when to an economic agent, e.g., a consumer of a firm, the utility of using a product or technology becomes larger as its network of users grows in size (Farrell & Saloner, 1985; Katz & Shapiro, 1985). The network effect may set in motion a positive feedback loop that will cause a product or technology to become more prevalent in the market.

Social interaction effects occur when an economic agent's preference for a product or technology is dependent upon the opinions or expectations of other economic agents. The social interaction effect may set in motion a positive feedback loop that will cause agents to expect that a certain product or technology will become more prevalent in the market.

Scale effects occur when there is a positive static relationship between the size of output of a firm and its productivity. This is reflected in a downward slope of the firm's average total cost curve (Amit, 1986). Scale effects may bring about a positive feedback effect when the firm can convert the cost advantage acquired through large production volumes into increasing sales volumes.

Learning effects imply that there is a positive dynamic relationship between the firm's growth of output and its growth of productivity (Kaldor, 1966). This is reflected in downward shift of the firm's average total cost curve (Amit, 1986; Day and Montgomery, 1983). Learning effects may bring about a positive feedback effect when the firm can convert the cost advantage acquired from productivity growth into further output growth.

1.5.3 Towards an integrative definition of increasing returns

The next step towards an integrative definition of increasing returns is to find the common denominator of the definitions of the separate mechanisms. In this case, the common denominator is the possibility of each of the mechanisms to bring about a positive feedback effect. We therefore follow Arthur (1990) in defining increasing returns as:

Positive feedback effects in markets and firms.

Note that this definition is different from the common economic definition of increasing returns.

The choice of this definition has important implications for what we mean by increasing returns, namely that *to be able to speak of increasing returns the positive feedback loop has to be closed*. For firm-based increasing returns this means that scale effects and learning effects create potential increasing returns but are not increasing returns as such, contrary to the common economic definition. They only become so when they are used by the firm in such a way that further cost improvements or further productivity growth lead to better product propositions, resulting in larger market share and larger production volume. For market-based increasing returns it means that network effects and social interaction effects create potential increasing returns but not increasing returns as such. They only become so when they lead to increased prevalence of products or technologies in the market.

In this thesis we will refer to scale effects, learning effects, network effects and social interaction effects as the *mechanisms of increasing returns*. These mechanisms of increasing returns, and the ways in which they cause positive feedback effects, are sketched in figure 1.3.

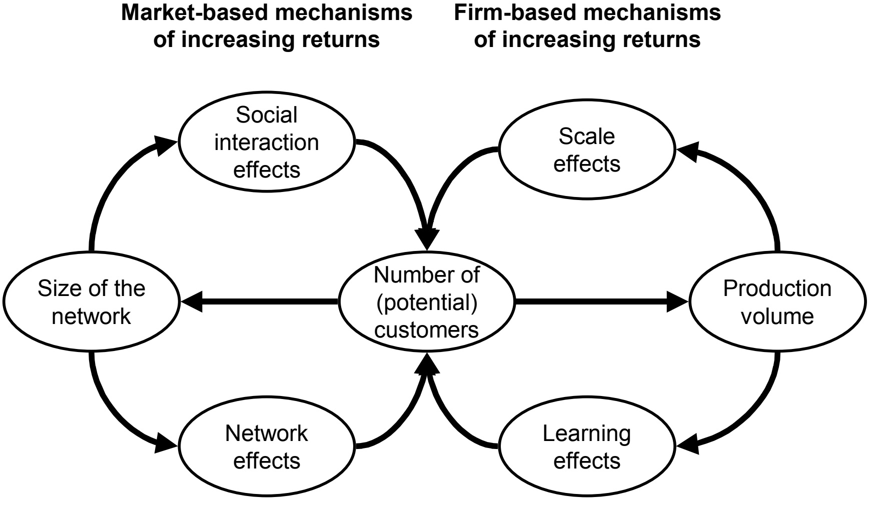

Figure 1-3: The mechanisms of increasing returns and their feedback loops

1.6 Research design of the thesis

According to Churchill & Iacobucci (2002) we can distinguish four types of research design: exploratory, descriptive, explanatory and predictive. These can be looked upon as stages in a continuous process in which exploratory studies are often seen as the initial step. This step generates tentative explanations or hypotheses that serve as specific guides to descriptive, explanatory or predictive studies.

Descriptive and explanatory research designs have been used in this thesis. First the concepts to be studied have been described using a literature study. Subsequently, a research model and hypotheses were formulated on the basis of this literature study. Finally, the relationships between the concepts, i.e., the testing of hypotheses, were explained using three empirical studies.

In the first empirical study, a cross-sectional management survey was conducted among *257* Dutch industrial firms to collect primary data. In the second empirical study, a cross-sectional management survey was conducted among *36* large Dutch-based firms listed on the *Amsterdam Stock Exchange* and objective financial data from these firms' annual reports were measured.[6] In the third empirical study, a firm-level specification of the *Verdoorn law*[7], measuring the relationship between the growth of output and the growth of labor productivity, and a productivity-performance relationship were analyzed for *118* large Dutch-based firms listed on the *Amsterdam Stock Exchange* using objective financial data from these firms' annual reports.

How do these three empirical studies relate to each other? In this thesis, both *within-method and between-method triangulation* was used (Jick, 1979). The *within-method triangulation* becomes clear when comparing the first and second empirical studies. The surveys in these studies were conducted with different, independent samples, but using the same measurement scales of the market-based mechanisms of increasing returns. The *between-method triangulation* becomes clear when comparing the first empirical study with the second and third empirical studies. While starting from the same basic research model, there are some marked differences in the collection and the analysis of the data. First, in the first empirical study we used subjective scales for the measurement of the firm-based mechanisms of increasing returns and for the

[6] These *36* firms are a subset of the *118* firms from the sample for the third study.
[7] The *Verdoorn law* (Verdoorn, 1949; Kaldor, 1966) is a linear relation between the growth of output and the growth of labor productivity of an economic entity that can be used to measure scale and learning effects.

measurement firm performance, whereas in the second and third empirical studies we used publicly available financial data to do so. Second, for the analysis of the data of the first empirical study the research model was estimated using structural equation modeling, while for the second and third empirical studies regression analysis was used.

1.7 Structure of the thesis

This thesis contains a theoretical and an empirical part (see figure 1.4). The theoretical part comprises chapters two, three, four and five. In this part we focus on answering the first research question of this thesis, i.e., the definition and theoretical specification of the market-based and firm-based mechanisms of increasing returns. In chapter two we provide an introduction to the history of thought about increasing returns. In chapter three we provide an overview, a typology and a critical assessment of the literature on increasing returns to date. In chapter four we develop a theoretical specification of the market-based mechanisms of increasing returns, i.e., network effects and social interaction effects. This chapter is built mainly on management theory complemented with some concepts from complexity science. In chapter five we develop a theoretical specification of the firm-based mechanisms of increasing returns, i.e., scale effects and learning effects. This chapter is built on management theory complemented with economic concepts.

Chapter six is the linch-pin between the theoretical and the empirical part of the thesis. In this chapter we provide a generic research model that is based on the theoretical specifications of the chapters four and five. From this research model, we derive the hypotheses that will be tested in the empirical part of the thesis. Finally, in this chapter we address the research designs of the empirical studies used for testing these hypotheses.

The empirical part of the thesis comprises chapters seven, eight and nine. In the empirical part we focus on answering the second, third and fourth research questions of this thesis, i.e., the measurement of the market-based and firm-based mechanisms of increasing returns, the relationships between them and their relationship with firm performance. Chapter seven contains a report on the results of the first empirical study, a management survey among *257* Dutch industrial firms. Chapter eight contains a report on the results of the second empirical study, the management survey and financial measurement of *36* large Dutch-based firms listed on the *Amsterdam Stock Exchange*. Chapter nine contains a report on the results of the third empirical study, the analysis of the Verdoorn law and the productivity-performance relation for *118* Dutch-based firms listed on the *Amsterdam Stock Exchange*.

We conclude the thesis in chapter ten by answering the main problem and the research questions, by explaining the limitations of the research, by drawing management implications from our findings and by providing suggestions for further research.

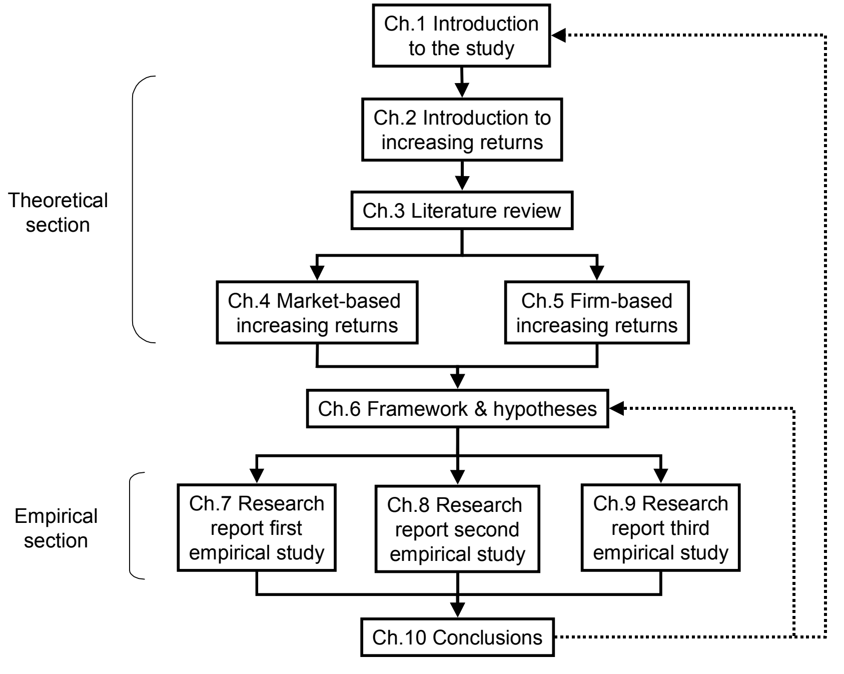

Figure 1-4: Structure of the thesis

1.8 Glossary

Below we provide a list of concepts and their definition as they have been used throughout this thesis. Note that these definitions and meanings may in some cases differ from commonly accepted meanings and definitions used in economics, complexity science or management science.

Adapter strategy (also: follower strategy): this involves joining the dominant technology by acquiring a license for developing products based on this technology. This may enable a firm that is not a *shaper*, i.e., a sponsor of the dominant technology, to profit from the potential for scale and learning effects created by the dominant technology.

Compatibility means that products or technologies function in harmony with *complementary* products, because they share a common technological infrastructure.

Complementarity means that products or technologies are (meant to be) used together and that in this way they have for customers a higher value than when used separately. Economically this means that we may expect a positive cross-elasticity of demand between these products.

Critical mass means that the technology network is so large that its network value outweighs that of competitive technologies or of a possible negative inherent value that customers may have towards it.

Economies of scale are related to the cost savings from producing a larger number of units of the same product.

Economies of scope are related to the cost savings from producing a variety of different products, i.e., it is cheaper to produce different products together in one plant than in separate plants.

Economies of sequence are related to cost savings from vertical integration.

Follower strategy: see adapter strategy.

Increasing returns are defined in this thesis as positive feedback effects in markets and firms.

Increasing returns to scale means that, in a production function, the output rises more than proportionally with an increase of all the input factors to the same amount.

Inertia, excess: this refers to a market stalemate in which both suppliers and customers wait for others to decide first. This impedes a collective switch from an existing technological standard to a possibly superior new standard of technology.

Installed base is a firm's existing population of (loyal) customers.

Learning effects imply that there is a positive dynamic relationship between the firm's growth of output and its growth of productivity. This is reflected in a downward shift of the firm's short-run average total cost curve, or a movement along the firm's long-run average total cost curve.

Learning effects, autonomous: learning that results from the automatic improvement in productivity of input factors as accumulated production increases. It is also referred to as *learning-by-doing* or as the *experience curve*.

Learning effects, exogenous: learning that results from effects that are external to the firm.

Learning effects, induced: learning that results from conscious managerial action to improve the productivity of the input factors.

Licensees are firms that do not own property rights to the technology, but instead buy the right to use the technology in their products.

Lock-in and lock-out describes a situation in which the cost of switching to another technology – even though it may be technically superior – is too large for the switch to take place. The existing technology is therefore *locked in* and the alternative technology is *locked out*.

Momentum, excess: this refers to a situation of explosive growth in which the investments of some suppliers and customers lead to massive investments by others. The market may quickly *lock in* to one single, possibly inferior, technological standard.

Network effects occur when, to an economic agent, e.g., a consumer or a firm, the economic utility of using a product or technology increases as its network of users grows in size.

Network effects, direct: when a product's economic utility increases as more customers start using it, this is referred to as a *direct network effect*.

Network effects, indirect: the increase in a product's economic utility as more customers start using complementary products or as more suppliers start offering complementary products, is referred to as an *indirect network effect*. It is also referred to by others as a *market-mediated network effect* or the *hardware-software paradigm*.

Path dependence means that the early history of market shares, often the consequence of small events or chance circumstances, can determine to a large extent which technology prevails. It is also referred to by others as *irreversibility*, or *non-ergodicity*.

Productivity or labor productivity is defined in this thesis as the ratio between output, measured as a firm's annual added value, and labor input, measured as the annual number of hours worked.

Scale effects occur when there is a positive static relationship between the size of output of a firm and its productivity. This is reflected in a downward slope of the firm's average total cost curve. Scale effects in our definition comprise *economies of scale, scope and sequence*.

Shaper strategy: this means that a firm sponsors its own proprietary technology and strives for dominance of this technology in the market, i.e., the firm wants to *shape* the market.

Social interaction effects occur when an economic agent's preference for a product or technology is dependent upon the opinions or expectations of other economic agents. It is also referred to by others as *social network effects* or *social contagion*.

Sponsor or technology sponsor: a sponsor is a firm that has property rights to a technology and hence is willing to make investments to promote it.

Substitutability means that products or technologies are competitive, so that a consumer will buy either one product or the other. Economically, this means that we may expect a negative cross-elasticity of demand.

Verdoorn law: a long-run linear relationship between the growth of output and the growth of labor productivity (Verdoorn, 1949; Kaldor, 1966). We conceptualize this relationship at the firm level, as a long-run relationship between the firm's growth of output and the firm's growth of labor productivity.

2. INTRODUCTION TO INCREASING RETURNS LITERATURE

The first research question posed in section 1.3 was: *How can market-based and firm-based mechanisms of increasing returns be theoretically specified and defined?* In this chapter, we provide a literature background against which this question can be answered in chapter four and five. We start in section one with an introduction into the history of thought about increasing returns. In the remainder of the chapter, we will further address the economic, complexity and management perspectives on increasing returns. We address the classical economics view in section two, the neoclassical economics view in section three and alternatives and new directions in economics in section four. The complexity science perspective is addressed in section five and the management perspective is addressed in section six. Throughout this chapter we will highlight the contributions of important authors and thereby provide a context to understand the theoretical concepts that will be introduced in chapters four and five.

Note that this chapter is not framed within the limits of the definitions of increasing returns and the research approach as chosen in the first chapter.

2.1 Increasing returns and the history of economic thought

In the field of economics, the study of returns mechanisms has a long history, going back to even before the works of Smith. From the start, the concepts of constant and diminishing returns have been firmly established in economics, being important cornerstones of (general) equilibrium models. By contrast, the concept of increasing returns has received much less attention and has even been looked upon as deviant from mainstream economic theory (Buchanan & Yoon, 1994).

We can only guess at the exact reasons as to why economists in the past have been hesitant to incorporate increasing returns into mainstream theory. Three obvious reasons suggest themselves. The first is that, with the then prevailing state of agriculture and manufacturing, diminishing returns were the rule of the day. While this might have been true for Malthus (1815), Ricardo (1815) or Marx (1867), the argument does not hold for the neo-classical economists and certainly not for modern times. The second reason is the difficulty of incorporating increasing returns in economic models and of bringing it under mathematical control (Arthur, 1994). This reason may well have held for the early neoclassical economists, like Walras (1874) and Marshall (1890), perhaps even for economists until the 1920's, but given the mathematical advance of general equilibrium economics in the 1950's and 1960's, it is hard to believe that increasing returns might have been 'too difficult' for those involved. The third and most likely reason is the disturbing implications of allowing increasing returns in economic models for market efficiency and equilibrium theory. A famous statement in this respect can be found in the work of Hicks (1939). Thinking through the implications of allowing for increasing returns in economic theory, Hicks concludes that "…the threatened wreckage is that of the greater part of general equilibrium theory …" and that the only way to save anything from this wreck is to assume "… that the markets confronting most of the firms with which we shall be dealing do not differ very greatly from perfectly competitive markets." (Hicks, 1939, p.84). In other words, Hicks let the theoretical assumptions of the neo-classical paradigm prevail over the empirical relevance of increasing returns. Corroborative material is provided by Hahn & Matthews (1964, p.833), who state "[…] the reason for the neglect is no doubt the difficulty of fitting increasing returns into the prevailing framework of perfect competition and marginal productivity factor pricing." It is well known from science philosophy (e.g., Kuhn, 1962) and from scientometric studies (Leydesdorff, 1995; Oomes, 2001) that scientific fields can *lock in* to dominant paradigms. As increasing returns was not part of the dominant paradigm, it is no surprise that increasing returns has been effectively locked out of economic theory for a long time.

One of the consequences of this lock-out is that economic theory incorporating increasing returns is less well developed than would perhaps be desirable. Still, throughout the history of economic science, a small but distinct group of economists, starting with Smith, has pointed out the relevance of increasing returns. The interest in increasing returns issues has been discontinuous, with severe ups and downs in the amount of attention it has received (see figure 2.1). We will subsequently discuss this history.[8]

[8] This section builds on economic history as discussed in Ekelund & Hébert (1997), Screpanti & Zamagni (1993) and Buchanan & Yoon (1994). We refer to these works for more in-depth analyses of the economists discussed here.

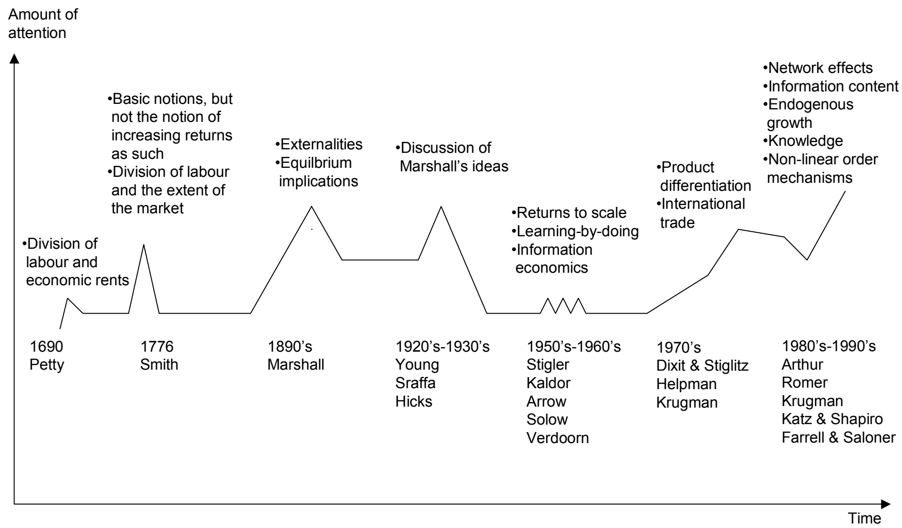

Figure 2-1: Chronology of increasing returns interest in economics (adapted from Commandeur, 1999)

2.2 The classical economic perspective

The concept of increasing returns is not new. As with so many economic concepts, the roots go back to the work of Smith (1776). In fact, Smith's famous story of the pin factory, where one worker could by himself produce a maximum of ten pins a day, but where ten workers who divide the operations between them can produce around *48.000* pins, is a classic example of increasing returns.[9] Even in the era before Adam Smith, in the pre-classical tradition, there is mention of increasing returns mechanisms.

To be complete, the history of increasing returns in economics has to start with the ancient Greeks. Xenophon recognized that the division of labor was the determinant of increases in quantity and quality of goods, more than 2000 years before Adam Smith (Ekelund & Hébert, 1997). Plato also recognized specialization and division of

[9] Buchanan & Yoon (1994) point out that the pin factory example is misleading because it draws attention away from the phenomenon of economy-wide increasing returns and towards increasing returns to scale of operation within a single producing unit. It therefore does not do justice to the broad implications of Smith's analysis. Still, for our purpose, i.e., increasing returns in relation to the firm, it is a suitable example.

labor as a source of efficiency and productivity (Ekelund & Hébert, 1997). Neither Xenophon nor Plato however, developed a theory of division of labor.[10]

While other ancient and medieval 'economists' over the ages delivered contributions to the foundations of economic thought, e.g., on money, value, prices and demand, none of them seem to address issues of increasing returns. An explanation may be that throughout most of the ancient past and the middle ages, economic systems were small and localized, largely self-sufficient, dominated by land and labor as factors of production, and therefore not liable to increasing returns due to trade, economies of scale or the advantages of division of labor.

2.2.1 Before Smith

It is only in the 17th century, during the transition from mercantilism to liberalism, that we encounter early economists who address increasing returns issues. The most prominent of them is Petty (1690), who laid a positivistic basis for economic analysis. He discussed ideas concerning differential returns from different economic activities, anticipating the classical economists' notion that agriculture is a diminishing returns activity whereas production aided by capital goods may well be increasing returns (Petty, 1690). He also anticipated the classical economists with respect to the role played by the division of labor and the relationship between the division of labor and the size of the market (Petty, 1690; Screpanti & Zamagni, 1993).

In a survey of the literature on specialization Yang & Ng (1998) also mention Petty (1690) and his observations and remarks on the productivity implications of an increased division of labor. They state that before Smith the three basic advantages of an increased division of labor, improving the skill of human capital, saving of time and effort in changing tasks and facilitating the invention of machinery, had been mentioned by Maxwell (1721) and Tucker (1755, 1774). Still, however, their contributions remain piecemeal, as they did not systematically study increasing returns or embed in a broader theory.

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[10] For the reasons why *division of labor* is closely connected to increasing returns, see below with the discussion of Adam Smith.

2.2.2 Smith

Despite the contributions of his predecessors, Smith can be regarded as the father of economic science. With him starts what has become known as the classical school of economics. The concept of increasing returns is central to Smith's work, though it is not yet called *increasing returns*. In fact, Smith's book, the *Wealth of Nations*, starts with an analysis of the causes of improvement in the productive powers of labor (Smith, 1776).

Smith's central proposition is that division of labor leads to increased wealth. This is illustrated by his famous analysis of a pin factory. In Smith's time, an experienced craftsman could, with help of the appropriate capital goods, produce about ten pins a day, or, when he did his utmost, certainly not more than twenty. After all, he would have to perform all the production steps himself and it is impossible for him to do more than one thing at a time. During a visit to a pin factory, Smith observed that the ten laborers that worked there could, with help of the same amount of capital goods, produce around *48.000* pins a day, or, that production increases disproportional with the amount of labor. The ten workers achieved this by dividing the tasks among themselves and specializing in performing one task each. Moreover, this specialization of labor leads to increased output through an improvement of skill on behalf of the workmen, time saving in the production process and the ability to use proper and specialized machinery. The implication is that the costs per pin will become lower as more pins are produced. In this way, the division of labor is the basis of increasing returns, in the sense of both *returns to scale* as well as *learning-by-doing*.[11]

While this is clear within the boundaries of the pin factory example, there is a complicating factor involved in that the possibility to capture these increasing returns effects is related to the extent of the market. For example, in a large city it would pay to have an industrial bakery, in which twenty workmen could make thousands of loaves of bread a day. In a small geographically isolated town, however, such an industrial bakery could not exist for lack of demand for bread.[12] Consequently, in this small town one baker will supply the entire need for bread and the principles of labor division cannot be applied. As this also goes for most of the other economic activities in the small town, it causes the whole of the small town's economy to lag behind a large city's economy. Quoting Smith: "As it is the power of exchanging that gives

[11] Smith does not call this *increasing returns* but *improvement of productive powers*.

[12] Bear in mind that in Smith's time for many goods is was not customary or not possible to transport them over long distances.

occasion to the division of labour, so the extent of this division must always be limited by the extent of that power or, in other words, by the extent of the market. When the market is very small, no person can have any encouragement to dedicate himself entirely to one employment […].” (1776, I, III). The implication Smith draws from this is that extended specialization and hence gains in wealth can be accomplished by increasing the extent of the market. In Smith’s liberal tradition, this means opening up internal and external markets, e.g., by the increased buying power of the existing market or by (international) trade.

2.2.3 After Smith: Malthus and Ricardo

Strangely enough, the increasing returns part of Smith’s work did not catch on. Quite the contrary, important classical economic theorists like Malthus (1815) and Ricardo (1815) strongly stress diminishing returns effects. The limited attention for increasing returns phenomena is not surprising when we consider that the classical economists still largely lived in an agrarian society in which the industrial sector was still in its infancy.[13] If a farmer works his land twice as intensively or with twice as many people, it is unlikely that it will yield twice as large a crop.

One of the first to identify the principle of diminishing returns was Anderson (1777). In a short pamphlet, he describes the mechanisms that, when a country consists of land of different quality classes, the land with the highest quality will be cultivated first and the land with the lowest quality will only be cultivated when nothing else is left. In this way, the marginal agricultural production in this country or region will diminish when the population increases and more land is cultivated. Malthus (1815) worked out this principle in more detail.

The essential contribution of Ricardo (1815) to the discussion on diminishing returns is to have shown that diminishing returns existed at the extensive margin, i.e., the same inputs applied to different qualities of land and at the intensive margin, i.e., more inputs applied to the same land. Diminishing returns at the extensive margin is Ricardo’s view of an automatic result of Malthus’ (1798) famous population principle, i.e., that population, when unchecked, increases in geometrical progression whereas the food supply cannot possibly increase faster than in arithmetic progression. This means that it becomes increasingly necessary to start cultivating lesser quality land. This reasoning attributes the principle of diminishing returns to

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13 The principles of Taylor (1911) and Ford’s concept of mass production date from the early 20th century, and were not yet commonplace in the 19th century.

the scale of agricultural production. Diminishing returns at the intensive margin is the result of the absence of technological progress and learning. This reasoning applies the principle of diminishing returns, i.e., descending marginal product, to the increased deployment of a single production factor, in this case labor. It is this relationship that has become known as the *law of diminishing returns*.

2.2.4 The difference between Smith and Ricardo

It is the absence of the possibility of technological progress that makes Ricardo essentially the founding father of diminishing returns, whereas Smith is associated with increasing returns. Arrow (1979) addresses the *division of labor* topic as brought forward by Smith (1776). From the three effects of the division of labor mentioned by Smith, i.e., the effect of practice, minimization of set-up costs and invention of better production methods, Arrow places greatest emphasis on the first. It is closely intertwined with the second however, because specializing in a certain task leads to learning and to the spreading of the learning cost over larger quantities. In this connection, there is a possibility for a positive feedback loop, as a specialization due to large learning cost leads to an increase in experience, thereby reinforcing the reason for specialization. According to Smith, differences in talents are not so much the cause, as the effect of the division of labor. Contrary to this point of view is the Ricardian viewpoint, in which an entity's abilities to produce are given. These *comparative advantages* are seen as the cause for the division of labor through international trade. It is precisely this view that has dominated economic theory.

2.2.5 Mill

Ricardo's work greatly influenced that of Mill (1848). Like Ricardo's, Mill's work is ingrained with the belief that diminishing returns to agriculture is one of the main factors limiting economic growth. Mill also points out that there are diseconomies of scale involved in manufacturing. When a manufacturing firm extends its production, this will yield economies of scale up to a certain point, after which new investments are needed and variable costs will go up; or, where Smith's analysis of the pin factory stops, Mill reasoned further on the consequences of extending production. Eventually, the pin factory will have to buy more machines, put more production halls into use, hire foremen and managers, create an accounting department, all of which will induce average cost to go up after a certain point. Nevertheless, Mill also recognizes the existence of increasing returns to the scale of production in manufacturing industries, either caused by the benefits of the division of labor, analogous to Smith, or caused by the indivisibilities of capital goods needed to set up a manufacturing site. This thinking became the basis for the idea that agriculture was subject to diminishing returns, whereas manufacturing was subject to increasing returns, and because Mill's famous *Principles of Political Economy* (1848) remained for a long time the standard textbook of economics, this idea dominated economic thought at least until the beginning of the 20th century.

2.3 The neoclassical economic perspective

With neoclassical economics interest shifted away from economic growth, which had been so characteristic for the classical economists, toward the formalization of allocation problems and input-output questions. The works of Walras (1874) and Marshall (1890) are seminal in this respect.

2.3.1 Walras and general equilibrium theory

Walras (1874) developed the theory of general economic equilibrium. This theory is an intellectual tour de force, which has had enormous impact on the further developments of economic theory. General equilibrium theory and its extensions are still the dominant paradigm in economic science. The main goal of general equilibrium theory was to specify the axioms leading to a stable economic equilibrium, deviations from which could only be temporary (Kaldor, 1981). The most important of the axioms are:

- all resources and all the preference schedules are taken as given
- all technical processes of production are given and they are moreover linear and homogeneous
- there is perfect competition on both the supply and demand side
- there is no time dimension, decisions to produce and consume are taken simultaneously and there is no carry-over of any goods or information to the future, or from the past
- all transactions take place in an equilibrium system of prices, which is established before any transactions are made

In the course of economic history, most of these axioms have in some way been relaxed. According to Kaldor (1960), however, the model cannot be relaxed with respect to changes in technical knowledge, except when perfectly foreseen, with respect to the occurrence of economies of scale, i.e., increasing returns or non-linearity, with respect to the presence of imperfect competition and with respect to changes in consumer preferences. In other words, the Walrasian model, with all its extensions added over time, is not very useful when trying to understand the economic environment. If the conditions of the model are not met, the economy must be in disequilibrium. The theory, however says nothing about disequilibrium.

2.3.2 Marshall

It was not until Marshall (1890) that neoclassical economists became aware that the postulate of increasing returns did not fit the general equilibrium model. Marshall made it clear that for the neoclassical model to be valid, i.e., for the payment of input factors to equal the value of the output factors, constant returns had to be assumed (Buchanan & Yoon, 1994). This was not compatible with the classical hypothesis that agriculture was subject to diminishing returns and that in manufacturing increasing returns might be present. Therefore, Marshall decided to follow a different path. Rather than striving for explanation of general equilibrium of the economy as a whole, he tried to explain the partial equilibrium of a specific industry. Following the classical economists, Marshall states that the part which nature plays in production shows a tendency to diminishing returns, whereas the part which man plays shows a tendency to increasing returns. Moreover, according to Marshall, industries can be classified as either *diminishing returns industries*, *constant returns industries* or *increasing returns industries*. Marshall: “In the more delicate branches of manufacturing, where the cost of raw material counts for little and in most of the modern transport industries the law of increasing return acts almost unopposed.” (1890, IV, VIII, 2).

Like Smith, Marshall views increasing returns as resulting in the first place from specialization of people and machines. He adds, however, the aspect of increasing returns as related to the cost of physical reproduction. Eventually Marshall arrives at two different definitions of increasing returns (1890, IV, VIII, 2). The first, starting from the notion of division of labor is: “The law of increasing return may be worded thus: an increase of labour and capital leads generally to improved organization, which increases the efficiency of the work of the labour and capital”. This first approach goes back to the work of Smith (1776). Marshall’s second definition, starting from the notion of the scale of production is: “Increasing return is a relation between a quantity of effort and sacrifice on the one hand, and a quantity of product on the other.” (1890, IV, VIII, 2). This second approach contains a number of important notions about increasing returns:

- it concerns the production function, i.e., the supply side

- it is based on scale economies, i.e., increasing returns can only be realized under the condition of larger volumes
- the input-output relation in an industry is the result of a continuous interplay between forces of increasing and diminishing returns

Marshall presents these two definitions in the same section of his book. He does not seem to sense any disharmony between them, nor does he make an attempt to reconcile the two. In other words, while Marshall signals the importance of increasing returns, it is difficult for him to provide theoretical soundness.

Still more difficulties arise, because without the assumption of constant or diminishing returns the competitive process cannot be dynamically stable. According to the theory, increasing returns would automatically result in a monopoly, something that Marshall does not observe from reality. Well aware of the limitations of this theory and of his own contributions to it, Marshall sighs: “The statical theory of equilibrium is only an introduction to economic studies; and it is barely even an introduction to the study of progress and development of industries which show a tendency to increasing return.” (1890, V, XII, 3). In order for increasing returns to remain possible within his neoclassical partial equilibrium model, Marshall invented the distinction between *internal and external economies*. These external economies, e.g., locational or communicational externalities that benefit the entire industry, Marshall reasons, are much more durable than internal economies that benefit only a single firm. Single firms may grow in size and therefore enjoy temporary monopoly benefits, but eventually they will run into the limits of their internal economies and they will die off. Their growth, however, will have contributed to the aggregate volume and therefore to the external economies of the industry that benefit all firms in the industry, independent of size. In this way, an industry will not become completely and definitively monopolized and increasing returns in the form of internal and external economies is compatible with partial equilibrium theory.

Marshall was heavily criticized for his ideas on the classification of industries into diminishing, constant and increasing returns, and for his reconciliation on increasing returns and partial equilibrium. These criticisms will be discussed below.

2.3.3 Bullock, Clapham and the classification of industries

Bullock (1902) questions the universal validity of the distinction between diminishing returns, constant returns and increasing returns industries. He concludes that diminishing returns and increasing returns result from various contending forces and that it is therefore not possible to assign any particular commodity or industry to a fixed place in the classification of the laws of increasing and diminishing returns because this depends on the strength of the contending forces. Before applying these laws to a concrete case, Bullock states, far more serious study has to be made of the actual conditions of the industry in question. He proposed replacing the notion of laws returns with the notion of *the variation of productive forces*. To Marshall's credit, in later editions of his book *Principles of Economics* (1890), he makes reference to Bullock's (1902) article. The discussion started by Bullock was continued some two decades later, by Clapham (1922a; 1922b), Pigou (1922) and Pigou & Robertson (1924). In an article titled *Of empty economic boxes*, Clapham states that the imaginary boxes of *diminishing returns industries*, *constant returns industries* and *increasing returns industries* have no empirical substance and are therefore empty. In this discussion Pigou (1922), being a proponent of the Marshallian stand, takes the opposite position, asserting that if empirical observations did not confirm the theory, this must be due to the bad quality of the statistical evidence (Screpanti & Zamagni, 1993).

2.3.4 Sraffa and the Economic Journal discussion

The problems of reconciling increasing returns and competitive markets that were already sensed but not adequately solved by Marshall, became fully exposed with Sraffa's (1926) article *The laws of returns under competitive conditions* in *The Economic Journal*. Sraffa reasons that to reconcile increasing returns and competitive equilibrium, as Marshall does, it is necessary to postulate that economies of scale are external to the firm, yet internal to the industry. This is not unlike Marshall's concept of external economies. However, Sraffa criticizes Marshall for not being rigorous enough: if there were any economies of scale internal to firms, a firm would be encouraged to expand its activities and would eventually become a monopolist. This is incompatible with Marshall's partial equilibrium theory and therefore any internal economies must be set aside. So what about Marshall's external economies? These, Sraffa reasons, must also be set aside, because most external economies are not limited to a specific industry, but rather apply to multiple industries of the economy as a whole, and if there were such economies external to the industry, Marshall's partial equilibrium analysis would be flawed and it would be necessary to follow a general-equilibrium approach. The only economies that might be relevant are those in between the two extremes of internal and economy-wide economies. Sraffa: "Those economies which are external from the point of view of the individual firm, but internal as regards the industry in its aggregate, constitute precisely the class which is most seldom to be met with." (1926, p.540). In other words, Sraffa's criticism implies that Marshall's theory of competitive equilibrium is either contradictory or irrelevant (Screpanti & Zamagni, 1993).

While Hicks (1939), for example, still considered this argument as a reason to completely set aside the concept increasing returns, Sraffa took the next step. He recognized that increasing returns are de facto important in some industries. His conclusion was that: "It is necessary, therefore, to abandon the path of free competition and turn in the opposite direction, namely towards monopoly." (Sraffa, 1926, p.542). Or, monopolistic structures are not simply *market imperfections or frictions*, but they represent the actual state of things. What is more, it is the theory of perfect competition that is not in accordance with reality in at least two important respects: "… first, the idea that the competing producers cannot deliberately affect market prices and that he may therefore regard it as constant whatever the quality of the goods which he individually may throw on the market; second, the idea that each competing producer necessarily produces normally in circumstances of individual increasing costs." (Sraffa, 1926, p.542-543).

The solution is therefore to abandon the assumption that buyers are indifferent to products from different firms, which means that each firm faces its own, descending, demand curve. In fact, Sraffa introduced the concept of monopolistic competition years before the seminal works of Chamberlin (1933) and Robinson (1933). In monopolistic competition, the firm may operate under decreasing costs of production, while at the same time not being able to extend its production indefinitely, because to sell the increased quantity of production the firm will eventually have to either lower its market prices, or it will run into increased marketing expenses. While in hindsight this can perhaps be regarded as a simple trade-off between increasing returns to the scale of production and diminishing returns to marketing, Sraffa's insights were certainly revolutionary in 1926.

The discussion on the correctness of Marshall's theories and the underlying assumptions about increasing returns in relation to competitive equilibrium went on during the 1920's and 1930's in *The Economic Journal*. In this discussion, Pigou (1927) and Robertson (1930) take the Marshallian stand, while Robbins (1928) and Sraffa (1930) remain critical. Yet in the end no one seems to come up with viable alternative solutions. When the discussion died down at the beginning of the 1930's, increasing returns remained a marginal phenomenon in economic theory.

2.3.5 Hicks

Hicks (1989), in defense of the *constant returns to scale* assumption, demonstrates that while Smith introduces increasing returns in his theory of growth, he implicitly falls back into constant returns in his theory of value. When half-finished goods can be carried over from period to period, Smith's cost of production theory of value only works if prices remain constant from period to period. Therefore, increasing returns, i.e., falling costs and falling prices, become inconceivable.

In the Ricardian view, land is the restrictive factor. This makes for diminishing marginal productivity of the variable production factors, applied to the fixed supply of land. This, in turn, leads to the general marginal productivity doctrine, i.e., production factors are remunerated according to the value of their marginal product. Hicks goes further, describing the theories of Marshall, recognizing both increasing and diminishing returns to scale and Walras, being pure constant returns to scale. This has influenced a major part of what has been done in economic theory to date.

Hicks concludes that there are two persisting traditions in economics: the one so impressed by what has been achieved by constant returns to scale analysis that they have come to live with the assumption and the other one, to which scale economies are so important that they cannot be left aside. These traditions cannot be easily reconciled; rather they seem to be suited to different types of problems. At first sight, micro-problems seem to require scale economies, whereas for macro-problems it might be more convenient to leave them out. According to Hicks, in the field of competition of firms in an industry, i.e., *industrial organization*, the constant returns to scale approach has nothing to offer.

2.4 Alternatives and new directions in economics

The wreckage of economic theory that Hicks (1939) envisioned was avoided, because after the 1930's attention shifted to the analysis of macro-economic relationships, under the influence of the theories of Keynes. For this reason and because of the rigid formalization of economic theory in the post-war decades, resulting in an almost exclusive focus on general equilibrium analysis, the issues regarding increasing returns virtually disappeared from the economic agenda. It was only kept alive by a small number of non-mainstream economists, of whom Young (1928) was the first and Kaldor (1966, 1972, 1985) was the most persistent in his criticisms of orthodox economic theory. Further Verdoorn (1949) and Arrow, at least in his 1962 article on learning-by-doing, must be mentioned, and then there is the

Austrian school, with its emphasis on dynamics and innovation that are difficult to reconcile with constant returns and general equilibrium.

2.4.1 Young and the foundations of endogenous growth theory

During the discussion in *The Economic Journal* mentioned above, a remarkable article by Young (1928) appeared, titled *Increasing returns and economic progress*. The article revives Smith's (1776) central proposition of the division of labor as the source of increasing returns and the relationship of increasing returns with economic growth. This was remarkable because the subjects of division of labor and economic growth, having been central for the classical economists, had virtually disappeared from the stage in the second half of the 19th century. With the article, Young reminded his colleagues that the concepts of the division of labor and economic growth were fundamentally important. Growth in the neoclassical model had been determined by exogenous data, e.g., technical progress, that were outside the scope of economic science. As a result of increasing returns, however, growth could be determined endogenously and might therefore be progressive and cumulative. Young's (1928) paper may therefore be regarded the starting point of what would become known as *endogenous growth theory* in the 1980's.

Young's starting point is Smith's (1776) famous theorem that *the division of labor depends on the extent of the market*. Young deals with two aspects: the growth of indirect or roundabout methods of production and the division of labor among industries. He explains what is, in his eyes, Smith's most important implication: "... with the division of labour a group of complex processes is transformed into a succession of simpler processes, some of which, at least, lend themselves to the use of machinery. In the use of machinery and the adoption of indirect processes there is a further division of labour, the economies of which are again limited by the extent of the market." (Young, 1928, p.530). While this can be read in the work of Smith (1776), Young makes two additional points.

- "The first point is that the principal economies which manifest themselves in increasing returns are the economies of capitalistic or roundabout methods of production." (1928, p.531). These economies are largely identical to the economies of the division of labor between firms or between industries.
- "The second point is that the economies of roundabout methods, even more that the economies of other forms of the division of labour, depend upon the extent of the market ..." (1928, p.531). With this point, Young wants to

make clear that the most important source of realizing these *economics of roundabout methods* is the enlargement of the extent of the market and that not too much should be expected from rational reorganizations of production processes.

Then follows the essence of Young's reasoning: "But just what constitutes a large market? Not area or population alone, but buying power, the capacity to absorb a large annual output of goods." (1928, p.533). This capacity to buy depends, of course, on the capacity to produce: "In an inclusive view, considering the market not as an outlet for the products of a particular industry, but as the outlet for goods in general, the size of the market is determined and defined by the volume of production." (1928, p.533). In this inclusive sense, the concept market means that there must be some sort of balance that the different productive activities must be proportioned to each other, i.e., there is a division of labor. This means in turn that Smith's famous theorem can be rewritten as: *The division of labor depends in large part on the division of labor.* Young explains that this is more than a tautology: "It means, if I read its significance rightly, that the counter forces which are continually defeating the forces that make for economic equilibrium are more pervasive and more deeply rooted in the constitution of the modern economic system than we commonly realize." (1928, p533). It means that every advance in the organization of production alters the conditions of industrial activity and initiates responses elsewhere in the industry. In this way, change may become progressive and propagate itself in a cumulative way.

The process of realizing these increasing returns will be progressive and continuous but will nevertheless take time. There are a number of obstacles working against increasing returns:

- the 'human material' is resistant to change: new trades have to be learnt, new habits to be acquired, labor has to be redistributed geographically, etcetera
- the accumulation of the necessary capital takes time and acceleration of this accumulation will induce increasing costs
- the demand for some products is inelastic or quickly becomes so when supply increases, meaning that the advantages of increasing returns will spread less fast, or will disappear altogether due to increasing problems in selling these products
- there are natural scarcities, limitations and inelasticities in supply, which may block the way to securing economies

- the next important step forward is often initially costly and cannot be taken until a certain quantum of prospective advantages has accumulated, meaning that progress will not be continuous

Yet there are also factors reinforcing increasing returns:

- discovery of new natural resources
- growth of scientific knowledge: “The causal connections between the growth of industry and the progress of science run in both directions, but on which side the preponderant influence lies no one can say.” (1928, p.535)
- growth of the population
- firms’ persisting search for new markets

According to Young this last factor leads in the reinforcement of increasing returns. It should not be understood as the search for a market to dispose of surplus product, i.e., the Marxian point of view, but as finding an outlet for potential products. While the search for new markets, i.e., new potential demand, is a diminishing return activity, the economies of a new and larger industrial plant will also be enormous. Mostly the economies of a new plant to fulfill or serve a new market will be substantially larger than the gradual extension of production in an existing plant.

These are, at least, the effects at firm level. According to Young there will be other effects: “Although the initial displacement may be considerable and the repercussions upon particular industries unfavorable, the enlarging of the market for any one commodity, produced under conditions of increasing returns, generates the net effect, as I have tried to show, of enlarging the market for other commodities.” (1928, p.537). This means that individual firms searching for new markets may increase the *extent of the market* for the whole industry and thereby stimulate further division of labor in this industry.

As to the argument that increasing returns at the firm level would lead to a monopoly at industry level, Young argues: “But the opposed process, industrial differentiation, has been and remains the type of change characteristically associated with the growth of production.” (1928, p.537).

In summary, Young makes three main points (1928, p.539).

- “First, the mechanism of increasing returns is not to be discerned adequately by observing the effects of variations in the size of an individual firm or of a particular industry, for the progressive division and specialization of industries is an essential part of the process by which increasing returns are realized. What is required is that industrial operations be seen as an interrelated whole."

- "Second, the securing of increasing returns depends upon the progressive division of labour and the principal economies of the division of labour, in its modern forms, are the economies which are to be had by using labour in roundabout or indirect ways."
- "Third, the division of labour depends upon the extent of the market, but the extent of the market also depends upon the division of labour. In this circumstance lies the possibility of economic progress, apart from the progress which comes as a result of the new knowledge which men are able to gain, whether in pursuit of their economic or of their non-economic interests."

2.4.2 Verdoorn

In an article in the Italian journal *L'Industria* (1949) the Dutch economist Verdoorn investigated the relationship between the growth of output and the growth of labor productivity. He arrived at an empirical regularity, stating that there is a positive linear relationship between the growth of output and the growth of labor productivity. While the article is not pretentious and seems to have been noticed for the first time by Kaldor (1966), it nevertheless has some important implications: How would productivity grow with growing output, when *exogenous* causes of technological change are left out of the model? The only way this can happen is when the growth of productivity is *endogenous*, meaning that some form of increasing returns, be it division of labor, economies of skills, economies of capital or economies of scale, is present in the system. Regarded in this way, the connection to Young's (1928) article becomes immediately obvious. Verdoorn's (1949) regularity provides, in a way, empirical support for the existence of increasing returns and endogenous economic growth.

2.4.3 The Austrian School

The notion of increasing returns as a characteristic of a firm's cost function is typical for the French (Cournot, 1838; Walras, 1874) and English (Jevons, 1871; Marshall, 1890) traditions of neoclassical theory. As such, we do not find it in the Austrian tradition. The label 'Austrian School' was first used by opponents of the ideas of

Menger. Important representatives of the Austrian school are, besides Menger, Von Wieser, Böhm-Bawerk, Von Mises, Schumpeter and Hayek.

The focus of analysis in the Austrian School is not so much on mathematically tractable economic maximizing or minimizing behavior, but rather on the study of institutions and the conditions of disequilibrum. As such, it has developed into an alternative for the dominant neoclassical paradigm. The reason to discuss it here is that the school's methods provide an alternative basis for the analysis of increasing returns.

The distinguishing features of the Austrian approach are *radical subjectivism* and *methodological individualism*. It means taking the individual economic agent and his unique knowledge, tastes and opportunities, his interpretations of events and other agents' actions, his expectations about future events and behavior and his alertness to new opportunities as the starting point of analysis. Coordination between individuals leads to a collective outcome, or *institution*, e.g. a market or a price. This outcome is not defined as a fixed situation in the way neoclassical economics defines the outcome of the competitive progress as perfect competition. Rather the Austrian approach defines the market as a process. Competition, not in the technical neoclassical sense, but in the classical sense of rivalry drives this market process down the road of coordination of individual plans (Ekelund & Hébert, 1997). This approach is more realistic than the mechanistic neoclassical models. It explicitly addresses coordination issues among individuals that form the basis of market-based forms of increasing returns, i.e., network effects and self-reinforcing expectations.

2.4.4 Kaldor

Since the 1950's, most of non-macro economic science has become locked in to the dominant paradigm of general equilibrium economics, as formalized by Samuelson (1947), Arrow & Debreu (1954) and Debreu (1959). With the acceptance of this paradigm comes the necessary postulate of constant returns to scale (Buchanan & Yoon, 1994). Apart from the Austrian School, which has been a separate tradition in economics, there has been remarkably little criticism on the dominant paradigm. The work of Kaldor (e.g., 1960; 1966; 1972; 1981) is a noteworthy exception.

In a provocative article, titled *The irrelevance of equilibrium economics*, Kaldor (1972) starts explaining that at its purest and most abstract level, the pretences of economic equilibrium theory, as formulated by Debreu (1959), are fairly modest. The theory is logically entirely disconnected from its interpretation. It consists of a set of theories, logically deducible from precisely formulated assumptions. Unlike most scientific theories, where basic assumptions are directly related to observable phenomena, the basic assumptions of economic theory are, according to Kaldor, either unverifiable, e.g., the maximization of profits and the maximization of utility, or directly contradicted by observation, e.g., perfect knowledge and foresight, perfect competition and impersonal market relations.

One of these basic assumptions of general equilibrium theory is constant returns to scale. Marshall (1890) tried to solve this problem through the use of partial equilibrium, i.e., equilibrium in only a part of the economy, and the notion of externalities. In this way he could accommodate increasing and diminishing returns. Sraffa (1926) proved this to be logically wrong. Therefore, general equilibrium economics has always postulated absence of increasing returns, with, as a consequence, the neglect of this concept and it consequences for economic theory. Kaldor (1981, p.330): "The case of increasing returns has never been properly explored in economic theory […] economists in general shied away from exploring the consequences. However, businessmen could never ignore the existence of diminishing costs. It is on account of the economies of large-scale production that a rising market share means success and a falling market share spells trouble."

In other words, increasing returns can empirically be shown to exist: economies of scale are clearly observable, the capital-labor ratio changes with the extent of the market and effects of learning-by-doing, i.e., *dynamic economies of scale*, can be observed. These observations have far-reaching consequences, a first of which is that the notion of general equilibrium is no longer valid. General equilibrium implies that economic forces operate in an environment that is 'imposed' on the system, i.e., a set of 'given' exogenous variables such as Pareto's tastes and obstacles, preferences of individuals and consumers, the production functions and the supply of resources. Change in this equilibrium can only be seen as a *moving equilibrium*, caused by autonomous change in these exogenous variables. According to Kaldor, the question here is whether such an 'equilibrium' is a meaningful notion when increasing returns are assumed.

When increasing returns is introduced, the forces making for change are endogenous. On this Kaldor (1972, p.93) states: "If one takes an all-inclusive view of the economic process, economic activity ultimately consists of the exchange of goods against goods; this means that every increase in the supply of commodities enlarges, at least potentially, the market for other commodities." Thus, the extent of the market depends on the division of labor almost as much as the division of labor depends on the extent of the market. Myrdal (1957) called this *the principle of circular and cumulative causation*. Kaldor argues that Young's (1928) reasoning of combining Say's law with Smith's theorem is not enough in itself to ensure cumulative causation. Young's problem was, according to Kaldor, that he did not have a theory of income generation such as supplied by Keynes eight years later. That is why Young concentrated on reciprocal demand and supply functions, i.e., *roundabout methods of production*.

Kaldor concludes that it is evident that an important feature of economic systems is the coexistence of increasing returns and competition, which is deemed impossible in the Walrasian axioms. Kaldor states that the way in which this competition works is largely uncharted territory.

2.4.5 Arrow

An important contribution was made to the theory of increasing returns and endogenous growth from an unexpected angle in 1962: in an article by Arrow, one of the founding fathers of the mathematical formalization of general equilibrium theory, entitled *The economic implications of learning by doing*.

In the second half of the 1950's, the studies of Abramowitz (1956) and Solow (1956; 1957) clearly indicated that technological change plays a dominant role in economic growth. According to Arrow (1962), their empirical results do not directly contradict the neo-classical production function as the expression of technological knowledge. The only thing that has to be added is the obvious fact that knowledge grows over time. This addition can be made in two ways: either by incorporating knowledge growth as an *exogenous* variable or by assuming that change in knowledge, i.e., *learning*, is *endogenous*. Arrow proceeds on the second path, because: "… a view of economic growth that depends so heavily on an exogenous variable, let alone one so difficult to measure as the quantity of knowledge, is hardly intellectually satisfactory." (1962, p.155).

He therefore assumes the concept of *learning-by-doing*, which states that learning is the product of experience, meaning that learning can only take place during activity. Arrow cites a number of empirical examples of the role of experience in increasing productivity.

- In aeronautical engineering it was found that the number of labor hours per airframe was a decreasing function ($N^{-1/3}$) of the total number of airframes previously produced (*N*). This empirical regularity has become known as the learning curve.
- Verdoorn (see section 2.4.2) applied the principle of the learning curve to national output and showed that the productivity of labor increases with cumulative output. The estimated progress ratio for European countries was measured at about *0.5*.
- The *Horndal effect* shows a similar phenomenon at firm level. The *Horndal iron works* in Sweden made no new investments and no significant change in the production methods for 15 years, yet productivity rose on average by *2%* annually.

Arrow then advances the hypothesis that "… technical change in general can be ascribed to experience, that is the very activity of production which gives rise to problems for which favorable responses are selected over time." (1962, p.156). Arrow then proceeds with the mathematical modeling, taking cumulative gross investment, i.e., the cumulative production of capital goods, as the index of experience. Each new machine is capable of changing the environment, so that learning will take place with continuing new stimuli.

Arrow recognizes that the model can be extended. The existing model only accommodates learning in the capital goods industry, it could be extended to accommodate learning that takes place in the use of a capital good once built. According to Arrow, the model's view of learning as only a by-product of production might be extended to incorporate learning by education or learning by research. Arrow's model is the first theoretical model to incorporate endogenous learning and hence endogenous growth.

2.4.6 Romer and endogenous growth theory

The theory of *endogenous growth* is a body of theoretical and empirical work that emerged in the 1980's. It is macro-oriented and therefore different from, but complementary to, the study of productivity at the firm level. Lucas (1988), Romer (1986; 1990b; 1993; 1994) and Barro & Sala-i-Martin (1992) are important proponents of this theory. It differs from neoclassical growth theories, e.g., those of Abramowitz (1956) or Solow (1957) in that economic growth is not the result of exogenous forces, but rather an endogenous outcome of an economic system (Romer, 1994). This endogeneity requires that at least one of the production factors in the model shows increasing returns. Romer (1986; 1990b) chooses to include the factor knowledge in the production function, because knowledge is non-rival good that may have an increasing marginal product. In other words, knowledge causes increasing returns, which is the basis for endogenous growth.

The models by Romer (1986) and Lucas (1988) are both reconciliations of the competitive equilibrium model with endogenous technological change. Knowledge is regarded as the basic form of capital, in Romer's case knowledge is seen as physical capital, following Arrow (1962) and in Lucas's case knowledge is seen as human capital. In both models, knowledge is regarded as a non-rival good that is not excludable. The non-rivalry implies that the application of knowledge is an increasing returns activity for the firm. The non-excludability implies that firms cannot appropriate the knowledge they develop. Instead, knowledge generates spillover effects. The presence of these spillover effects means that from a social point of view the application of knowledge is also an increasing returns process. The presence of these knowledge spillovers, i.e., externalities, is necessary for the existence of the competitive equilibrium. If knowledge is partly or completely appropriable, a kind of monopoly or monopolistic competition model will be required. To keep the model from 'exploding', the production of new knowledge is assumed to be a diminishing returns activity.

Romer's second (1990b) model takes the next step in abandoning the assumption of perfect competition. It is a three-sector model, in which the first sector, i.e., the research sector, uses human capital and the existing stock of knowledge to produce new knowledge. The second sector, i.e., the intermediate goods sector, uses designs from the research sector to produce producer durables. A third sector, i.e., the final goods sector, uses labor, human capital and producer durables to produce final output. This model thus incorporates knowledge as rival inputs, i.e., in the form of human capital, and as non-rival inputs, i.e., in the form of the stock of knowledge. This non-rivalry again is the source of increasing returns. The stock of knowledge enters into production in two different ways. First, new research designs enable the production of new producer durables in the intermediate good sector. The benefits from this application of knowledge are assumed to be completely excludable, i.e., they provide the basis for firms' market power and monopolistic competition. Second, the new research designs increase the total stock of knowledge. The benefits from this increase are assumed to be completely non-excludable.

Introduction to increasing returns literature

With the appearance of endogenous growth models, economic science has reached a new stage in development, in which increasing returns and imperfect competition are explicitly modeled (Romer, 1994).

2.4.7 New division of labor theory

While economic growth based on increasing returns due to division of labor is one of the oldest ideas in economics, going back to Smith (1776), for a long time there was no fully worked out dynamic model along these lines (Romer, 1987). As Houthakker (1956, p.182) stated: "Most economists have probably regarded the division of labor, in Schumpeter's words, as an 'eternal commonplace', yet there is hardly any part of economics that would not be advanced by a further analysis of specialization."

In recent years, models have been developed that try to explain economic growth from increasing returns due to specialization. Two different paths have been followed. The first is the macro-modeling path, starting from the Dixit-Stiglitz model.[14] Krugman (1979) and Ethier (1982) developed this model into the field of international trade theory and Romer (1987) developed a model for an economy as a whole.

The second path takes the individual as a starting point. Representatives of this path include Yang & Borland (1991), Borland & Yang (1992), Ng (1998) and Yang & Ng (1998). Following Houthakker (1956), they reason that the division of labor starts from the basic indivisibility of the individual. This means that the individual can only perform a few activities simultaneously. The larger this number, the higher the difficulty of coordinating the activities. This means that, when several activities are replaced by a single one, the coordination costs will be lower and there will be larger possibilities for acquiring experience in this activity. In other words, reducing the number of activities gives rise to increasing returns. These will not be realizable however, as long as there is only one individual. In this case, this individual will have to perform by himself all the activities necessary to stay alive. As soon as another individual appears, specialization becomes possible through trade. Through the avoidance of both individuals' internal coordination costs, the post-trade point will be better than either of the pre-trade points. This effect is independent of the relative

[14] While the Dixit-Stiglitz (1977) model is concerned with consumer utility of product diversity, it has been re-interpreted by Ethier (1982) as a production function. In this way, the Dixit-Stiglitz modeling approach has provided a basis for a wide range of models dealing with different forms of diversity.

efficiencies of the individuals, i.e., the Ricardian argument. Under the Ricardian assumptions the benefit of specialization consists wholly in the utilization of comparative advantages, but in the case of Smith's (1776) reasoning the benefit comes mainly from the avoidance of coordination costs by the two individuals. There is also a force working in the other direction. Though specialization will result in avoidance of individual coordination costs, new coordination costs might appear *between* the individuals. These costs narrow the possibilities for improvement through trade and might, in some cases, offset the gains.

In the Yang & Borland (1991) model, every individual chooses his or her level of specialization. The aggregate outcome of these individual decisions is the endogenously determined division of labor for the economy. At any time, individuals make a trade-off: specializing more in the current period generates higher productive capacity in future periods because of learning-by-doing and increasing returns. However, greater specialization implies that more goods have to be bought from others, meaning that a higher level of trade is necessary involving greater transaction costs. The existence of the trade-off, combined with the assumption that economies of specialization are specific to each individual ensures the existence of a dynamic competitive equilibrium. At the macro level, the evolution of the division of labor will enlarge the extent of the market, leading to further accumulation of human capital, increased trade dependence and endogenous comparative advantage. This in turn causes an increasing rate of growth of per capita income, enabling further division of labor.

2.5 Complexity science, sociology and social economics

Complexity science, also known as the study of *complex adaptive systems*, or *CAS*, is a relatively new scientific paradigm. It has become best known through the people working at the *Santa Fe Institute*, a privately financed interdisciplinary research institute entirely devoted to complexity science.[15]

What is complexity? A citation of Langton (in: Waldrop, 1992, p.293) provides insight: "You should look at systems in terms of how they behave instead of how they're made. And when you do, then what you find are the two extremes of order

[15] For a popular record of the first years of the *Santa Fe Institute* and the people working there, see Waldrop's book *Complexity: the Emerging Science at the Edge of Order and Chaos* (1992). This book also provides an accessible introduction to several perspectives on complexity science.

and chaos. It's a lot like the difference between solids, where atoms are locked into place and fluids, where atoms tumble over one another at random. But right in between the two extremes, at a kind of abstract phase transition called 'the edge of chaos', you find complexity: a class of behaviors in which the components of the system never quite lock into place, yet never quite dissolve into turbulence, either. These are the systems that are both stable enough to store information and yet evanescent enough to transmit it. These are the systems that can be organized to perform complex computations, to react to the world, to be spontaneous, adaptive and alive."

This way of looking at the world is becoming increasingly popular in a variety of scientific fields, such as physics, biology, sociology and economics. The complexity approach is especially relevant when studying systems in which complex feedback phenomena play an important role. It can be argued that the behavior of many economic systems, be it firms, industries, or national or global economic systems, is governed by the interplay of positive and negative feedback phenomena. In economic terms, the behavior of markets is governed by the interplay between diminishing and increasing returns. Economic systems therefore seem especially suitable for the complexity approach.

The fundamental differences between the complexity approach and the traditional equilibrium approaches when applied to economic phenomena are the level of *realism* and the extent of *holism* that is built into the models.

With regard to *realism*, the traditional economic perspectives, e.g., the general equilibrium or partial equilibrium models, aim at explaining reality by building models that are a simplification of this reality. This is not unlike the Newtonian principles in physics. The similarity is not accidental, because the early 19th and 20th century economists borrowed heavily from the methods of the natural sciences that were popular at the time. Strangely enough, while the natural sciences have gradually distanced themselves from these methods and moved to other, more realistic explanations of reality, e.g., relativity theory and quantum mechanics in physics or evolutionary theory in biology, economic science has been dominated by the traditional paradigm until late into the 20th century. Gradually however, new methodological paradigms have emerged that include a greater level of realism. The Austrian School of economics, with its approach of radical subjectivism and methodological individualism has been the most noteworthy deviation from the dominant paradigm for a long time. It has greatly influenced evolutionary theories, e.g., Nelson & Winter (1974; 1982), and it may well be argued that the complexity approach is in some ways a logical extension of the 'Austrian' way of thinking.

With regard to *holism*, traditional economics either focuses on macro issues or on micro issues. The aggregation-disaggregation questions are either ignored or assumed to be linearly explicable. For example, in many models, the macro outcomes are assumed to be the linear addition of the separate micro behavior of the economic agents, e.g., firms or consumers. If we drop this assumption[16], the implication is that behavior of the system at the macro level cannot be predicted from the behavior of the agents at the micro level. This is a disturbing conclusion, which leaves economists with severe aggregation-disaggregation problems. With the advance of complexity science this point has been made clear once more. The argument focuses on what is known as *emergence*: simple local interactions between economic agents on the micro level can cause extremely complex behavioral patterns in the economic system at the meso or macro level. Complexity science aims to provide insight into these processes of emergence and connect the unique micro behavior of economic agents to the broad macro patterns of the economic system, e.g., firms, markets, national or global economies.

Within the complexity perspective, the debate is not always so much on increasing returns, but rather on the interplay between positive and negative feedback effects. Since the *Santa Fe Institute's* first proceedings in the field of economics, *The Economy as an Evolving Complex System* (edited by Anderson, Arrow & Pines, 1988), a large number of contributions have been published in this field. The works of Arthur (1989; 1990; 1999), Arthur, Durlauf & Lane (1997), Cowan (1991) and Brock & Durlauf (2001) have been seminal in this field.

In a review of the collection of papers in the second economic proceedings of the *Santa Fe Institute*, *The Economy as an Evolving Complex System II* (edited by Arthur, Durlauf & Lane, 1997), Silverberg (1998) asks the question whether the *Santa Fe Institute* and the complex systems approach has succeeded where others,

[16] Brock (1988, p.82) provides a number of clues as to how we might get complex dynamics from traditional economic models: introduce agents that act as if they discount the future relatively heavy; abandon concavity assumptions in preferences and technology; abandon the assumption of complete markets; abandon the assumption of price-taking agents; impose *complex preferences* or *complex technology*; abandon the assumption that the system is in equilibrium; admit direct effects of some agents' actions upon the tastes or technologies of others. Each of those adjustments, which do not seem to be too unrealistic, fundamentally disrupts the possibility of linear aggregration-disaggregation.

e.g., Simon (1969), Day (1982; 1983; 1984) or Nelson & Winter (1974; 1982), have had only limited success. He provides several answers. In term of popular recognition and the ability to put complexity onto research agendas, the answer is affirmative. In terms of publications in the leading mainstream journals the penetration is still very limited. In terms of solutions to real-world problems, the answer is unclear. Many contributions are computational, i.e., computer simulation models, and are more focused on the method of analysis than the relevance for reality. Finally, Silverberg states that there seems to be a deep problem in the complexity perspective with regard to decision-making reality. On the one hand, there is the risk of sliding into an approach of highly abstract theory that is of little practical relevance. On the other hand, there is the danger of making such specialized predictions under such restrictive, and in practice unverifiable conditions, that it becomes impossible to say when the theory would be applicable.

2.5.1 Arthur

In the 1980's, mainly through the work of Arthur (e.g., 1988, 1989, 1990), increasing returns attracted renewed interest in economics. While the subjects of returns to scale, learning-by-doing and endogenous growth have had a long tradition in economics, the wider field of increasing returns mechanisms in markets had hardly been addressed. Defining increasing returns as *positive feedback effects in economics* (1990) and hence starting from the point of view of complexity science rather then from traditional economics, market-based increasing returns form the core of Arthur's analyses.

Arthur (1988) defines increasing returns as originating from four generic sources:

- *large set-up or fixed costs*, implying falling unit cost as volume increases
- *learning effects*, implying product improvements and or lower costs as prevalence increases
- *coordination effects*, i.e., the benefits of going along with other economic agents
- *adaptive expectations*, meaning that increased prevalence will induce further prevalence

Further, Arthur states that markets in which these increasing returns mechanisms play an important role have four unique properties (Arthur, 1988):

- *multiple equilibria*, meaning that different asymptotic market share solutions are possible

- *possible inefficiencies*, meaning that it is not determined that the eventual solution generates the best possible social benefit
- *lock-in*, meaning that once a solution is reached, it is difficult to exit from it and that it will be difficult to break in for competing solutions
- *path dependence*, meaning that the early history of market share can determine which solution prevails

These are exactly the kind of 'disturbing implications' that economists had for a long time 'shied away from' (Kaldor, 1981, p.330). While Arthur, Ermoliev & Kaniovski (1984) laid down the methodological basis, it took until 1989 before Arthur's seminal paper *Competing technologies, increasing returns, and lock-in by historical small events* was published in a major journal. In his book on the early years of the *Santa Fe Institute*, Waldrop (1992) describes in a vivid manner the difficulties Arthur experienced in getting his theories accepted by the mainstream economic journals.

2.5.2 Sociology

While they are relatively new to economics, mechanisms of direct interaction between agents have been studied for a long time in sociology. It had been known under the label *theory of collective action*, e.g., Granovetter (1978), Oliver, Marwell & Texeira (1985) and Marwell, Oliver & Prahl (1988), *bandwagon effects*, e.g., Granovetter & Soong (1986), *information cascades*, e.g., Bikhchandani, Hirschleifer & Welch (1992) or *network analysis*, e.g., Burt (1987; 1992). Gradually this work has penetrated into the management sciences, e.g., through Granovetter (1985), Gulati (1995; 1998) and Westphal, Gulati & Shortell (1997). The sociological and complexity perspectives seem to be gradually merging, into what is called *social economics*.

2.5.3 Social economics

Social economics is a new emerging field of science that is composed of ideas that have been developed before in economics and sociology. In the words of Durlauf & Young (2001), social economics explicitly aims at providing new insights into social and economic dynamics through the study of the interactions that link individual behavior and group outcomes. Representatives of this new direction are among others Becker & Murphy (2000), Brock & Durlauf (2001), Durlauf & Young (2001), Epstein & Axtell (1996) and Manski (1993). Seminal works in this field are

Thorstein Veblen's *Theory of the Leisure Class* (1899) and Thomas Schelling's *Micromotives and Macrobehavior* (1978).

The starting point of social economics is that individuals are *directly* influenced by the choices of others when they take economic decisions. In economics it is typically assumed that the behavior of individuals is *not directly* influenced by the behavior of others.[17] Of course, in economic terms individuals *do* influence each other, but always *indirectly*, namely through the price mechanism in the market. The social economics approach allows for both *direct* and *indirect* interaction between individuals and it follows the Austrian School of economics in putting methodological individualism at the core of its beliefs. Social economics maintains the individuality and the heterogeneity of the agents in the system, i.e., consumers or firms, at all times. Allowance for random perturbations in the system is an important axiom. Hence, the idea is that agents make their choices individually, either through direct interaction or through interaction by market prices, either parallel or in sequence, either rational and fully informed or irrational and with incomplete information.

The resulting object of study is therefore dynamic, governed by a myriad of positive and negative feedback loops and influenced by stochastic events. Its behavior may therefore be very complex and often far from *steady state* (Durlauf & Young, 2001). One of the consequences of this approach is that it limits the ability to fully characterize the system behavior. Hence, the formal analytical modeling techniques in this field are often complemented by the use of computer simulation techniques. One of the weaker points of the social economics approach as mentioned by Durlauf & Young (2001) is the empirical evidence available as yet. Data often have to be obtained using laborious studies charting social networks. In practice, it proves difficult to distinguish social interaction effects for unobserved individual effects. Most examples supporting social economics models stem from detailed sociological research, e.g., natural experiments.[18] Most econometric approaches to problems in this field suffer from a limited ability to address the heterogeneity of agents and the interactions between them.

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[17] The most noteworthy exception to this generalization is *game theory*, in which direct interaction is one of the axioms.

[18] Natural experiments refer to real-world situations that, with some care, may be studied as scientific experiments by researchers.

2.6 The management sciences

From the historic description we can conclude that increasing returns is basically founded in the economic perspective. The economic perspective mainly focuses on the mechanisms of increasing returns that are *internal* to economic transformation systems, i.e., firms, industry sectors or national or global economies, that is on issues involving the scale of operations or issues involving learning, knowledge and productivity growth. In this perspective, mechanisms of increasing returns that are *external* to economic systems are almost completely ignored. The complexity or social economics perspective, that has recently become more popular, is exactly the opposite, as here the focus is on the *external* increasing returns mechanisms, i.e., direct behavioral interaction or direct information exchange between agents in markets. In turn, in this perspective the *internal* increasing returns mechanisms are largely ignored.

As already quoted above, Kaldor, one of the most prominent critics of the traditional general equilibrium models in economics, stated that: "[…] businessmen could never ignore the existence of diminishing costs." (1981, p.330), and neither of course can management scientists. Different approaches have been taken in studying increasing returns from the management perspective.

2.6.1 Inside-out approaches

In the *resource-based approach*, the firm's resources are assumed to be the most important sources of increasing returns. According to Barney (1997, p.142-143), "In general, firm resources are all assets, capabilities, competencies, organizational processes, firm attributes, information, knowledge and so forth that are controlled by a firm and that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness." In his view, the concepts of *resources, capabilities and competencies* are used interchangeably and often in parallel and that any philosophical hair-splitting over the differences is not of much help to managers and firms. The answers to the questions whether a resource is (1) valuable, (2) rare, (3) costly to imitate and (4) exploited by the organization, determine the strength and sustainability of the competitive advantage that these resources may entail. And with this, the economic performance that the firm is likely to realize compared to its competitors.

For the analysis of increasing returns, resources may be regarded as input factors in a firm's transformation function. Put in this way, the resource-based theories qualitatively extend and refine the economic perspective addressing firm-based increasing return mechanisms. Representative authors who have explored this path are Hill (1997), Hatch & Mowery (1998) and Li & Rajagopalan (1998). Makadok (1999) studies inter-firm difference in scale economies and the effects this has on a firm's market share and the evolution of market shares over time. The authors representative of the resource-based view have barely addressed the market-based increasing returns mechanisms resulting from market interactions.

A relatively recent refinement of the resource-based perspective, that is especially applicable in a dynamic context, is the *dynamic capabilities perspective*.[19] In this perspective the success of a firm's products in the market is viewed as resting on (1) the firm's distinctive processes, e.g., learning and knowledge creation capabilities, (2) the firm's specific asset positions, e.g., knowledge base, installed base of existing adopters, asset investments or sunk costs and (3) the firm's evolution paths that it has adopted or inherited, e.g., path dependencies or technological opportunities. In this approach, the firm's dynamic capabilities are considered to be the most important source of increasing returns. Examples of dynamic capabilities are capabilities to organize, e.g., division of labor, to generate and capture value from knowledge assets, to make use of static and dynamic scale effects, to be able to sense increasing returns opportunities to internalize network effects and social interaction effects and to have adequate market strategies with respect to introduction timing, standardization, network selection, shaping of network and social interaction effects. The dynamic capabilities theory addresses two aspects that are not sufficiently highlighted in the resource-based perspective: (1) the shifting character of the environment and (2) the key role of strategic management in appropriately adapting, integrating and reconfiguring internal and external organizational skills, resources and functional competencies toward a changing environment.

Representative authors following this approach to analyze increasing returns issues are Helfat (1997), Teece (1998) and Dickson, Farris & Verbeke (2001). Williamson (1999) argues that there are still severe problems with the dynamic capabilities view. In his view, the dynamic capabilities theory suffers from tautological definitions of the key terms and a failure of operationalization.

[19] Dynamic capabilities are defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece, Pisano & Shuen, 1997, p.516).

2.6.2 Outside-in approaches

Emphasizing an outside-in approach, we arrive at an *industrial organization theory of the firm*. As mentioned before in chapter one, Sraffa (1926) predicted that the theories of imperfect competition by Robinson (1933) and Chamberlin (1933) would be the logical road to fit increasing returns into economic theory. Eventually, these theories became the basis for what has become known as the industrial organization theory of the firm. In the original, *structuralist approach* to industrial organization theory (e.g., Bain, 1959) market structure was assumed to be so constraining on firm conduct that individual management action could be ignored. Many economic studies of increasing returns fit in this approach, which in itself falls apart in the *Harvard and Chicago traditions* (Tirole, 1988). Whereas the *Harvard tradition* stresses imperfect competition and the possibility of market failure, the *Chicago School* assumes perfect competition and efficient markets (Brouwer, 1991). Representative authors of the *Harvard tradition* are Farrell & Saloner (1985), Katz & Shapiro (1985; 1986), Shapiro & Varian (1998; 1999) and Church & Gandal (1992). Authors representative of increasing returns analysis in the *Chicago tradition*[20] are, e.g., Dixit & Stiglitz (1977) and, more recently, Liebowitz & Margolis (1994; 1995; 1999). A characteristic of this approach is that it virtually ignores the firm-based increasing returns mechanisms.

The same applies to most dynamic inside-out approaches. Whether under the label of *Schumpeterian*, *evolutionary*, or *ecological*, they invariably put emphasis on the primate of market forces at the expense of attention for the strategic intent of the firm. The works of, e.g., Arthur (1989; 1990; 1996; 1999), Rosenberg (1976), David (1985), Granovetter & Soong (1986), Cowan (1991), Redmond (1991), Kirman (1993), Cowan & Gunby (1996), Cowan & Cowan & Swann (1997), Dalle (1997), Arthur, Holland, LeBaron, Palmer & Tayler (1997), Foray (1997), Cowan & Miller (1998) and Clark & Chatterjee (1999) all show the same pattern: they explain only market-based increasing returns mechanisms and to do this they use models in which the firms in the market are considered as passive entities.

Gradually, a *behavioralist approach* to industrial organization theory emerged (Brouwer, 1991). Contrary to the *structuralist* approach, it focuses on firm performance rather than on industry performance, it does not regard industry structure as completely exogenous or stable, but rather as dynamic and partly subject to influences by firm actions and it explicitly recognizes the role of firm conduct in

[20] That is, insofar as 'increasing returns study within the *Chicago tradition*' is not a contradiction in terms.

influencing performance (Spanos & Lioukas, 2001). Representative authors that have followed this approach in the study of increasing returns are Rohlfs (1974), Farrell & Saloner (1986), Matutes & Regibeau (1992), Choi (1994), Katz & Shapiro (1994), Economides (1996), Schilling (1998), Kretschmer, Klimis & Choi (1999), Xie & Sirbu (1995), Cottrell & Koput (1998), Garud & Kumaraswamy (1993) and Gupta, Jain & Sawhney (1999). Analyses of increasing returns based on the behavioralist industrial organization approach have addressed firm-based and market-based mechanisms of increasing returns. However, most studies have addressed either the firm-based mechanisms of increasing returns or the market-based mechanisms of increasing returns and not both in an integrated way.

Compared to the long tradition of increasing returns interest in economics, the implications of increasing returns for management was scarcely researched until the 1980's. Since then, increasing returns has also received wider attention in the management sciences. This increase in attention was not accidental, because, in the same way as the classical economists in the 18th and 19th century observed a shift from a largely agricultural, presumably diminishing returns, economy toward a manufacturing, presumably increasing returns, economy, we experienced a shift from an industrial, capital and physical labor based economy towards a post-industrial information and knowledge based economy.[21] Strikingly, researchers now make similar inferences about the increasing or diminishing returns characteristics of industries as the classical economists did. The only difference is that now the manufacturing industries are deemed *diminishing returns industries* and the IT and knowledge industries are deemed *increasing returns industries* (e.g., Arthur, 1996).

2.6.3 Increasing returns mechanisms in management literature

Though seldom outspokenly identified as increasing returns, there are nevertheless many examples of increasing returns mechanisms described in management literature. Examples of such literature in the field of product and technology adoption-diffusion processes are Bass (1969) and Mahajan, Muller & Bass (1993). Examples in the field of technological standardization processes are Arthur (1990), David (1975; 1985), Rosenberg (1976; 1982; 1994), Farrell & Saloner (1985; 1986) and Katz & Shapiro (1985; 1986). Examples in the field of repeat buying theory are

[21] According to analyses like that of Solow (1957), the larger part of productivity growth cannot be explained by the growth of the classical production factors, but instead by technological improvement that may be interpreted as knowledge (Solow, 1957; Zegveld, 2000).

Ehrenberg (1972) and Fader & Schmittlein (1993). Examples in the field of marketing are Farris, Verbeke, Dickson & Van Nierop (1998) and Dickson, Farris & Verbeke (2001).

2.6.4 Product adoption and diffusion

The diffusion of innovation can be defined as the process by which that innovation is communicated through certain channels over time among the members of a social system (Rogers, 1983). Bass (1969) modeled the diffusion processes of durable products. This model is claimed to describe the empirical adoption curve quite well for a large number of new products and technological innovations (Bass, Krishnan & Jain, 1994).

Gupta, Jain & Sawhney (1999) state that marketing scientists have been slow to respond to the growing importance of this phenomenon in new product adoption. Traditionally, the product introduction and diffusion literature does not take network effects explicitly into account (Bass, 1969; Bass, Krishnan & Jain, 1994; Mahajan, Muller & Bass, 1993). However, the classic *Bass diffusion model* clearly shows demand-side scale effects in the first part of the *S-curve*, reflecting the positive feedback effects of innovative and imitative adoption. The Bass model has been extended to incorporate tactical management decision variables, such as pricing and advertising, e.g., Chatterjee & Eliashberg (1990), Dockner & Jørgenson (1988), Horsky & Simon (1983).

The Bass model is concerned with the timing of initial purchase and provides a rationale for long-term sales forecasting. Mathematically, the model draws upon contagion models from epidemology.[22] Bass distinguishes between individuals who adopt independently of the decisions of other individuals in the social system, i.e., the innovators, and individuals who are influenced in the timing of adoption by the pressures of the social system, i.e., the imitators. As more individuals adopt, social pressure for imitators increases, which will make them more apt to adopt.

The Bass model thus explicitly incorporates the notion of positive feedback, i.e., increasing returns, in the process of innovation diffusion. It is assumed in the model that a large part of the target population, the imitators, adopt a product mainly because of the social pressure of the people who have already adopted. As more

[22] This implies that the Bass model describes the dynamics of the entire population, i.e., *diffusion*, and does not explicitly model the individual's *adoption* decision.

people adopt, the social pressure increases, which constitutes the positive feedback or increasing returns effect, i.e., the part of the *S-curve* where the second derivative is positive. This effect is due to information exchange between adopters and potential adopters. Eventually, as the number of potential adopters left decreases, the effect dies out, which constitutes a negative feedback or diminishing returns effect, i.e., the part of the *S-curve* where the second derivative is negative.

2.6.5 Technology battles

Customer choice between competing technologies also has a positive feedback dimension. Technologies become more valuable to customers as more customers buy and start using products that are based on this technology.[23] The value of a telephone network increases with the number of subscribers, the value of DVD (*Digital Versatile Disc*) technology increases as more people have DVD players and consequently more DVD software becomes available, the value of a game computer increases as more children own the same system, enabling them to exchange games.

The presence of network effects has substantial implications for the dynamics of the market shares of competing technologies (Arthur, 1989; Katz & Shapiro, 1985, 1986, 1994; Redmond, 1991).[24] Examples of such technology battles are widely cited in the literature, e.g., the battle between the QWERTY keyboard layout and alternative keyboard configurations, or the *VHS* versus *Betamax* battle in the home video market. We briefly discuss these below.

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[23] Following John, Weiss & Dutta (1999, p.79), technology can be defined as “scientific knowledge applied to useful purposes”, or “know-how”. They further state that “Positive spillovers exist in know-how creation, dissemination, and use.” (1999, p.80).

[24] Two different types of technology competition can be distinguished: (1) sequential, i.e., a new technology displaces an earlier technology and (2) simultaneous, i.e., two or more equally viable, but incompatible technologies compete for the market (Redmond, 1991).

Example: VHS versus Betamax

The battle of the *VHS* versus *Betamax* competition in the home video market is first mentioned by Katz & Shapiro (1986) and described in detail by Cusumano, Mylonadis & Rosenbloom (1992). This story is also widely quoted as a prime example of increasing returns and inefficiency in the market (e.g., Arthur, 1990; Matutes & Regibeau, 1988; Redmond, 1991; Hill, 1997; Schilling, 1998; Clark & Chatterjee, 1999). The history of the videocassette recorder (VCR) furnishes a simple example of positive feedback. The VCR market started out with two competing formats selling at about the same price: *VHS* and *Betamax*. Each format could realize increasing returns as its market share increased: large numbers of *VHS* recorders would encourage video outlets to stock pre-recorded tapes in *VHS* format, thereby enhancing the value of owning a *VHS* recorder and leading more people to buy one. The same would, of course, be true for *Betamax* format players. In this way, a small gain in market share would improve the competitive position of one system and help it to further increase its lead. Such a market is initially unstable. Both systems were introduced at about the same time and so began with roughly equal market shares; those shares fluctuated early on because of external circumstance, chance and corporate maneuvering. Increasing returns on early gains eventually tilted the competition towards *VHS*: it accumulated enough of an advantage to take virtually the entire VCR market. Yet it would have been impossible at the outset of the competition to say which system would win, which of the two possible equilibria would be selected. Furthermore, if the claim that *Betamax* was technically superior is true, then the market's choice did not represent the best economic outcome. Again, Liebowitz & Margolis (1999) have severely criticized the story, pointing out inaccuracies and questioning the implications for market inefficiency.

Example: QWERTY

The story of the development of the typewriter keyboard into the now common QWERTY configuration was first told by David (1985). It is widely quoted as an example of network externalities and market inefficiency, e.g., by Farrell & Saloner (1985; 1986) and Arthur (1989; 1990). The point of the story is that the QWERTY keyboard configuration was presented more than a century ago to slow typists down, because otherwise the hammers of the typewriters would collide. As more and more typists became trained to use the QWERTY keyboard and as more and more manufacturers of typewriters adopted this standard, the QWERTY keyboard became *locked in*. That is, it was in nobody's advantage to use another type of keyboard, even if this would mean faster typing speeds, because this would require large investments in retraining. David's (1985) conclusion is that, as more efficient keyboard configurations have become available, the industry has prematurely standardized on a basically inefficient system. The QWERTY story as told by David (1985) is criticized heavily and in much detail by Liebowitz & Margolis (1990; 1999), who claim that (1) the story as told is inaccurate and (2) even if were accurate, it does not represent a market inefficiency.

Other well-known examples of technology battles are:

- the *MS-DOS* versus *CP/M* versus *Apple* computer operating system battle in the early personal computer market (e.g., Arthur, 1996)
- the *Netscape Navigator* versus *Microsoft Internet Explorer* battle in the market for web browsers
- the gasoline versus diesel engine competition in the early motorcar market
- the battle between *WordPerfect* and *Microsoft Word* in the word processor market
- the battle for dominance in the game console market between *Sega*, *Nintendo* and *Sony* (Church & Gandal, 1992)
- the direct versus alternating current battle (e.g., David & Bunn, 1988)
- the battle between nuclear reactor technologies in the 1950's, i.e., cooled by gas, light water, heavy water, or liquid sodium (Arthur, 1989)
- the battle between *Microsoft Excel* and *Lotus 1-2-3* (Brynjolfsson & Kemerer, 1996; Shapiro & Varian, 1999)

While the accuracy and the validity of the implications can be debated for all of these stories, as is done, e.g., by Liebowitz & Margolis (1990; 1994; 1995; 1999), they nevertheless provide a body of anecdotal evidence that increasing returns occur in technology battles and that they actually influence market structure.

2.6.6 Double jeopardy

Ehrenberg (1972) observed that brands with higher market shares tend to display market advantages relative to small share brands. Ehrenberg explains this building on the notion of *double jeopardy*. High market share brands have two distinct benefits compared with small share brands: (1) they have more buyers and, (2) these buyers purchase the brand more often than the buyers of the small brand purchase those small brands. In other words: higher market penetration and higher purchase frequency. Fader & Schmittlein (1993) show that there is a third factor: a greater level of repeat purchasing through excess behavioral loyalty for these high share brands. This leads to the prediction that high share brands tend to have even higher repurchase rates than one might predict on the basis of the common repeat purchasing model, used amongst others by Ehrenberg (1972). Fader & Schmittlein (1993) show that this cannot reasonably be explained by differences in the emphasis placed by different brands on advertising, promotion or price, nor by the market responsiveness to these instruments, i.e., increasing or decreasing returns to scale. The notions of non-stationary choices, inertia and variety seeking by customers also do not account for this effect. In other words, the effect of larger brands having a higher repurchase rate is clearly a positive feedback effect.

2.6.7 Positive feedbacks in marketing

Farris, Verbeke, Dickson & Van Nierop (1998) and Dickson, Farris & Verbeke (2001) point out that there are all kinds of positive feedback effects in strategic marketing processes. They mention, e.g., economies of scale in R&D investment positions, in manufacturing cost structures, in brand equity positions and in network asset positions; they mention contagion dynamics, learning-by-doing dynamics and all kinds of routines and rules dynamics. A good example of this last feedback effect arises when firms set their marketing budgets as a percentage of sales. Farris, Verbeke, Dickson & Van Nierop (1998) show that this causes positive feedback loops to appear and that even this simple rule causes quite complex market dynamics. Dickson, Farris & Verbeke (2001, p.219) define market feedback effects as “a recursive relationship between one changing state of nature in a market and another changing state of nature in a market." Their reasoning is that market dynamics are not completely stochastic and exogenous, but rather that there are endogenous regularities to it. In this way they arrive at the similar notion of increasing returns as brought forward by Arthur (1994).

2.7 Conclusions

In this chapter we presented a synopsis of the history of thought on the subject of increasing returns. We have seen that increasing returns thinking has a long tradition in economics, going back to the roots of classical economic theory. In the neoclassical view that was the mainstream of economic theory for most of the 20th century, increasing returns was looked upon as an anomaly; however, on the margins of economic theory building a handful of economists kept an interest in increasing returns going. Nowadays, increasing returns is again getting considerable attention in economics, either through returning to the assumptions of classical economic theory or through fitting it into the neoclassical paradigm.

In the last decades, complexity science has been looked upon as a new and promising perspective from which contributions can be made to increasing returns thinking. Today, however, it is still far from being a generally accepted paradigm and it still has to prove itself in terms of usefulness to real-world problems.

Finally, in the past decades, increasing returns has gradually become incorporated in the management sciences. This increase in attention parallels the increasing information and knowledge intensity of business processes and the increasing volatility in product and technology diffusion that becomes visible in technology battles. There is increasing evidence that increasing returns do exist in markets and firms and that increasing returns influence market structure, firm behavior and product, technology and firm performance.

3. LITERATURE REVIEW

The introduction to increasing returns thinking in the previous chapter is used in this chapter to provide a basis for a more systematic insight into existing increasing returns theory and research. In this chapter, a content analysis is made of 96 publications on increasing returns. The current state of increasing returns research is critically assessed to provide a further justification for the theoretical work and the empirical research reported on in this thesis. In section one we present an overview of the literature on increasing returns. Then we discuss the findings from the literature review. A classification of the literature along the *structure-conduct-performance paradigm* will be discussed in section two, the theoretical perspectives used in literature will be discussed in section three, the mechanisms and definitions of increasing returns addressed in literature will be discussed in section four, the research designs used in literature will be discussed in section five and the results obtained in increasing returns literature will be discussed in section six. We provide conclusions in section seven.

3.1 Systematic literature overview

A systematic overview of increasing returns literature is provided in table 3.1 according to five groups of criteria:

1. classification according to the *structure-conduct-performance paradigm*
2. theoretical perspective and approach
3. mechanisms of increasing returns addressed and definition of increasing returns provided or implied
4. research design used, measurement of increasing returns, level of analysis and time dimension of the study
5. results in terms of influence on market structure and firm performance and in terms of management and policy implications[25]

The *structure-conduct-performance paradigm* adopted in section 1.3 of this thesis was used as the starting point for ordering of the studies presented in table 3.1. Note,

[25] The dimensions chosen for the literature review are unique to this study. Literature reviews as provided by Gaski (1984) and Cannon & Homburg (2001) have served as sources of inspiration. However, since both address empirical studies only, they arrive at different dimensions.

this table is spread over two pages, the left page covering the first seven columns and the right page the last five columns.

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Arrow (1962)	Economics	Neo-classical economics	Basic conditions (technical develop-ment)	Learning effects	Changes in know-ledge (=learning) underlying shifts in the production function	Technical change embodied in new capital goods; learning means that a new capital good requires less labor for producing the same amount of product
Romer (1986)	Economics	Endogenous growth	Basic conditions	Increasing returns and (supply side) externalities to knowledge	Increasing marginal product of knowledge as an input factor in production Positive spillovers of knowledge	Increasing growth rates of productivity
Romer (1990)	Economics	Endogenous growth	Basic conditions	Increasing returns to technology	Increases in the stock of knowledge improve the marginal product of human capital used in producing new knowledge Eventually, this causes non-convexity in the expression for final output (consumer goods) as a function of the primary inputs (human capital, labor, capital, and knowledge)	Increasing economic growth rates
Mill (1848)	Economics	Classical economics	Structure	Scale effects	The diminution of labor needed as the amount of production increases	Not provided
Bullock (1902)	Economics	Neo-classical economics	Structure	Scale effects	Laws of the variation of productive forces: - of a given area of land: law of diminishing returns - of a single plant or establishment: law of economy in organization - of an entire industry, under static conditions: law of varied costs - of an entire industry, under dynamic conditions: laws of increasing or decreasing cost	Depends on the definition: - increasing returns: progressively extra output when quantities of a production factor are added to another production factor that is held constant - the decrease of average cost as the production quantity increases

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Theoretical	Meso (industry)	Dynamic	Technical change can be ascribe to experience	Gross investment is the basic agent of technical change
Conceptual and theoretical (with empirical evidence of productivity growth rates of different countries over extended periods of time)	Macro (economy)	Two-period and infinite-horizon models	Based on the developed model of endogenous technological change: - growth rates can increase over time - the effects of small disturbances can be amplified by the actions of private agents - large countries may always grow faster than small countries	Not provided
Theoretical	Macro (economy)	Infinite-horizon model	1. Growth is driven by technological change that arises from intentional investments made by profit-maximizing agents 2. The stock of human capital determines the rate of growth 3. In equilibrium, too little human capital is devoted to research 4. Integration into world markets will increase national growth rates 5. Having a large population is not sufficient to generate growth	Not provided
Conceptual	Micro and meso	n.a.	1. Agriculture, mining and extractive industries show a tendency to diminishing returns 2. With manufacturing, the case is different: there are many cases is which production is made much more effective by being conducted on a large scale, because of farther division of labor or a better use of indivisibilities of labor and capital 3. The causes tending to increase the productiveness of industry preponderate greatly over the one cause which tends to diminish it 4. The possibilities of extending the size of the system of production depends in the first place on the extent of the market	Not provided
Conceptual	Micro and meso	Static and dynamic	1. We cannot coordinate the law of increasing returns and the law of economy in organization in one single mechanism 2. Diminishing and increasing returns result from various contending forces 3. It is therefore not possible to assign any particular commodity or industry to a fixed place in the classification of the laws of increasing and diminishing returns, because this depends on the strength of the contending forces; before applying these laws to a concrete case far more serious study has to be made of the actual conditions of the industry in question 4. Constant returns would be the result of an accidental equivalence of the various contending forces, and is therefore highly unlikely	Not provided

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Chapman (1908)	Economics	Neo-classical economics	Structure	Increasing returns in production and consumption	The formal law of increasing returns: if factors in production be proportionally increased by successive increments the corresponding marginal outputs will tend to rise	Not provided
Clapham (1922)	Economics	Neo-classical economics	Structure	Scale effects	The increment of product due to the increase by a unit of the quantity of resources occupied in producing	Not provided
Sraffa (1926)	Economics	Neo-classical economics	Structure	Scale effects	Not provided	Not provided
Young (1928)	Economics	Combination of classical and neo-classical economics	Structure	External economies (supply-side)	Economies of division of labor, which take the form of roundabout methods of production, i.e., every firm is a supplier, but also a customer of intermediate inputs	Not provided

Research design	Level of analysis	Time dimension	Influence on market structure and product or business performance	Management and policy implications
Theoretical	Micro and meso	Static	In production: - For production systems of the first order (individual businesses): increasing returns are possible, but ultimately there will be diminishing returns - For production systems of the second order (multiple businesses concerned in the production of one specific commodity): there will be increasing returns due to specialization, but ultimately there will be diminishing returns In consumption: - For consumption systems of the first order (the products a person consumes on his own): there will be decreasing marginal satisfaction, and ultimately decreasing total satisfaction (assuming all products have to be consumed) - For consumption systems of the second order (the products that bring the consumer in touch with other consumers, e.g., public goods): total satisfaction of both the individual consumer as well as of the community as a whole will tend to rise at an increasing rate	Not provided
Theoretical	Meso	n.a.	It is not possible to classify industries unambiguously into classes ('boxes') of diminishing returns, constant returns, or increasing returns	Not provided
Theoretical	Micro	n.a.	1. The laws of diminishing and increasing returns originate from forces of profoundly different nature: - diminishing returns is related to the use of specific factors of production - increasing returns is based on the cost structure of specific commodities 2. Increasing returns - as the concepts of Marshall's internal and external economies - is incompatible with free (perfect) competition 3. Only the exceptional case of economies which are external to the firm but internal to the industry would be compatible with free competition 4. As the theory of free competition differs radically from the actual state of things, it is necessary to turn to the theory of monopoly for the analysis of increasing returns	Not provided
Conceptual	Meso (with links to micro and macro)	Dynamic	1. Increasing returns cannot be discerned adequately by observing difference in size of individual firms or industries 2. The securing of increasing returns depends upon the progressive division of labor, and the principal economies of the division of labor, in its modern forms, are the economies which are to be had by using labor in roundabout or indirect ways 3. The division of labor (between firms, between industries) depends on the extent of the market as much as the extent of the market depends on the division of labor 4. Therefore, the forces that make for economic disequilibrium and growth are more deeply rooted in the economic system than is commonly thought	Not provided

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Leibenstein (1950)	Economics	Neo-classical economics	Structure	Network effects Interaction effects	External effects on utility (as a form on non-functional demand): - bandwagon effect (demand for a commodity is increased due to the fact that others are consuming the same commodity) - snob effect (demand for a commodity is decreased due to the fact that others are consuming the same commodity) - *Veblen effect* (demand for a consumer good is increased because it bears a higher rather than a lower price)	The slope of the demand curve
Stigler (1958)	Economics	Industrial Organization theory	Structure	Scale effects	The downward slope of the long-run average cost curve	Optimum firm size is determined by the survivor technique: firms in an industry are classified by size, and the share of industry output coming from each class over time is calculated; if the share of a given class falls, it is relatively inefficient
Farrell & Fieldhouse (1962)	Economics	Neo-classical economics	Structure	Scale effects	Non-convex production function	Average total cost
Rosenberg (1976)	Economics	Evolutionary	Structure	Interaction effects (technological expectations)	The influence of technological expectations on the pattern of technology adoption	Not provided
Granovetter (1978)	Sociology	Theory of collective action	Structure	Network effects Interaction effects	The costs and/or benefits for an actor of each of two alternatives depends on how many other actors choose which alternative	The threshold: the number or proportion of others who must make a decision before a given actor does so
David (1985)	Economics	Technological development	Structure (techno-logical standar-dization)	System scale economies (= network effects)	Overall user costs of a typewriter system tend to decrease as the system gains acceptance relative to other systems	Not provided
Farrell & Saloner (1985)	Economics	Industrial Organization theory	Structure	Network effects	Customer benefits of product standardization	Increase in customer benefits as the number of customers increases

Research design	Level of analysis	Time dimension	Influence on market structure and product or business performance	Management and policy implications
Theoretical	Meso	Static	1. If the bandwagon effect is the most significant effect, the demand curve is more elastic than it would be if external consumption effects would be absent 2. If the snob effect is the predominant effect, the demand curve is less elastic than otherwise 3. If the *Veblen effect* is the predominant one, the demand curve is less elastic than otherwise, and some portions of it may even be positively inclined 4. When the *Veblen effect* is absent, the demand curve will be negatively inclined, regardless of the importance of the snob effect in the market	Not provided
Analysis of optimum size of firms, both inter-industry on a sample of *48* industries, as well as intra-industry for the petroleum refining industry	Micro and meso	Comparative static	There is customarily a fairly wide range of optimum sizes: the long-run marginal and average cost curves of the firm are customarily horizontal over a long range of sizes	Not provided
Empirical analysis of production functions for *2363* British farms	Micro (firm)	Static	1. Major economies of scale with respect to divisible inputs are exhausted at relatively low output levels (*GBP 5000* per annum, in 1953 terms) 2. When a valid capital measure could be included in the analysis, economies of scale would be found to persist to much higher output levels	Not provided
Conceptual	Micro-meso	Dynamic	Technological expectations may seriously affect the pace of the diffusion process of new and better technologies, in the sense that diffusion may be slower (or sometimes faster) than optimal	Entrepreneurs should make appraisals of the future pay-off of innovations
Theoretical	Micro-meso	Dynamic	1. Groups with similar average preferences may generate very different results, hence it is hazardous to infer individual dispositions from aggregate outcomes or to assume that behavior was directed by ultimately agreed-upon norms 2. The threshold model explains these paradoxical outcomes as the result of aggregation processes: it explains that the 'strangeness' often associated with collective behavior is not in the heads of actors but rather in the dynamics of situations	Not provided
Case study (QWERTY keyboard)	Meso (market)	Dynamic	1. The market outcome is partly governed by historical accidents (chance); there is path dependence 2. Market outcomes (technological standardization) can become locked-in 3. The market outcome is not necessarily efficient (the 'wrong' technology may become locked-in)	Not provided
Theoretical (game theory)	Micro-meso (customer-market)	Two-period game	There can be inefficient inertia when changing from an old technology to a new one, and this problem cannot be entirely resolved by communication between customers	Not provided

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Katz & Shapiro (1985)	Economics	Industrial Organization theory	Structure	Network effects	Positive consumption externalities: the utility that a user derives from the consumption of a good increases with the number of other agents consuming that good	The derivative of a consumer's value function of the network size (which is positive)
Granovetter & Soong (1986)	Sociology / Economics	Evolutionary	Structure	Network & interaction effects	Bandwagon effects: whether a consumer buys is determined in part by how many other consumers have bought	Number of adopters
Katz & Shapiro (1986)	Economics	Industrial Organization theory	Structure	Network effects	The benefit a consumer derives from the use of a good depends on the number of other consumers purchasing compatible items	The derivative of a consumer's value function of the network size (which is positive)
Arthur (1989)	Economics / Complexity science	Ecological	Structure (techno-logical standar-dization)	Network effects in adoption of competing technologies	The more a technology is adopted, the more experience is gained with it, and the more it is improved (which may induce further adoption)	Pay-off of a technology, depending (positively) on the number of previous adopters
Weil (1989)	Economics	Development economics	Structure	External increasing returns	Each agent in the economy may choose to store or not to store knowledge; the more knowledge is stored in society as a whole, the more productive this knowledge becomes	Positive derivative of the return on aggregate amount of knowledge stored
Arthur (1990)	Complexity science	Ecological	Structure	Scale effects Network effects	Positive feedback in the economy	Not provided

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Theoretical	Meso	Static	1. Consumption externalities lead to demand-side economies of scale 2. Multiple equilibria exist for given cost and utility functions	Firms with good reputations or large existing networks tend to be against compatibility Firms with weak reputations or small existing networks will favor compatibility
Theoretical	Meso	Dynamic	For many plausible parameter values in the model, equilibria are asymptotically unstable, and system trajectories consist of cycles that can move, with slight parameter changes, via successive bifurcations into chaotic dynamics	Not provided
Theoretical	Meso	Dynamic	1. Compatibility tends to be under-supplied in the market, but excessive standardization can occur 2. In the absence of sponsors, the technology superior today has a strategic advantage and is likely to dominate the market 3. When one of two rival technologies is sponsored, that technology has a strategic advantage and may be adopted even if it is inferior 4. When two competing technologies both are sponsored, the technology that will be superior tomorrow has a strategic advantage	A technology sponsor will want to ensure that his technology is superior tomorrow to achieve market dominance. To achieve this, he may commit to setting low prices in the future, e.g. by doing investments that lower his marginal costs, by making the product design public, or by advertising that prices will be lower in the future.
Theoretical, case examples (QWERTY keyboard; direct versus alternating current; nuclear reactor technology competition; steam versus petrol car competition)	Meso (market)	Static	Properties of technological adoption/selection regimes: 1. Unpredictability of the technology that will be selected (multiple possible equilibria) 2. Inflexibility of the selected technology (lock-in) 3. Non-ergodicity: small events and chance may determine the outcome 4. Not necessarily path-efficient (a technology with inferior long-run potential may be selected)	1. Firms sponsoring a technology may engage in penetration pricing 2. Laissez faire policy is no guarantee that the superior technology (in the long-run sense) will be the one that survives 3. Effective policy depends on the nature of the market breakdown; alternative policy options are assigning patent rights to early developers, or central-authority guided investments in promising but less popular technological paths
Theoretical	Micro	Two-period game	Given enough complementarity between agents, external increasing returns may generate multiple equilibria	Not provided
Theoretical with case examples	Meso	Dynamic	1. Many possible equilibrium points 2. The market outcome (equilibrium) may become locked in, regardless of the advantages of alternatives 3. Parts of the economy that are resource-based are for the most part subject to diminishing returns, parts of the economy that are knowledge-based are largely subject to increasing returns	Not provided

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Cowan (1991)	Complexity science	Evolutionary	Structure	Network effects	Increasing returns to adoption: for each technology the net benefit to the next adopter increases with the number of previous adopters of that technology	Payoff of adopter *x+1* > payoff of adopter *x*
Redmond (1991)	Manage-ment science	Evolutionary	Structure	Network effects	Self-reinforcement or positive feedback: a system property that tends to amplify or extend a trend or tendency	The division of market shares between two competing technologies
Yang & Borland (1991)	Economics	Combination of classical economics and endogenous growth theory	Structure	Returns to scale Learning-by-doing	Internal and external economies from the division of labor (specialization of agents)	At agent level: gains from specialization in own production against the transaction costs of trading with other agents At market level: the growth of per capita income over time
Church & Gandal (1992)	Economics	Industrial Organization theory	Structure	Indirect network externalities (complementary products, hardware-software)	Consumer utility is dependent on the number of software products available for their hardware	Consumer utility levels
Kirman (1993)	Combi-nation of economics and complexity science	Ecological	Structure	Externalities	Herding or epidemics in ant behavior and in economic markets	The proportion of agents (ants, economic actors) choosing for one of two possible alternatives

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Theoretical / Conceptual	Meso	Dynamic	1. When competing technologies are adopted sequentially, if there is uncertainty about the relative merits of each, the market will under-supply experimentation 2. A central authority can internalize this externality, and raise the expected discount value of a stream of adoptions of what seems at first sight an inferior technology; this approach is severely limited however, because: - the forces driving lock-in and facilitating dominance of an existing technology are very strong - it would take infinite expenditure and infinite amount of time to determine in advance which technology is eventually the best	Not provided
Theoretical model, tested for Video Cassette Recorder case study	Meso	Dynamic	1. It cannot be determined a priori which of the competing technologies will predominate in the market 2. The technology that emerges as dominant is not guaranteed to be the 'best' technological solution 3. Once a technology emerges as dominant, the outcome is difficult, if not impossible, to change 4. Markets may be characterized by extreme instability, in which small causes may have large and lasting effects on market structure and competitive relationships (this is known as a bifurcation point)	Not provided
Theoretical	Micro-meso	Dynamic	Increased division of labor raises labor productivity of the agents, which enlarges the extent of the market, speeds up the accumulation of human capital and raises trade dependence and endogenous comparative advantage. This will yield higher per capita income, which means that potential fur further (endogenous) division of labor emerges.	Not provided
Theoretical	Micro (firm)	Static	1. Multiple equilibria are possible 2. Standardization of technology will be the equilibrium outcome if consumers place a high value on variety relative to preferences over hardware technologies 3. The market outcome will entail sub-optimal standardization in many cases	1. Total welfare will be increased when a standard is imposed 2. A *standards board* could be a useful mechanism for coordinating the expectations of software firms 3. Hardware firms will increase their prices when the number of compatible software products increases
A theoretical model is made explaining ant behavior in food foraging; this model is subsequently applied to economic issues	Meso	Dynamic	1. Depending on the parameter values of imitative behavior and chance behavior, simple interactive behavior of individual agents may result in quite complicated dynamics 2. The choice process is perpetually changing, and not converging into a steady state	Not provided

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Bartelsman, Caballero & Lyons (1994)	Economics	Neo-classical economics	Structure (of the industry)	1. Increasing returns to scale 2. Customer-driven externalities 3. Supplier-driven externalities	Returns to scale: Relationship between growth of industry gross production and growth of industry inputs Externalities: Relationship between growth of industry gross production and other industries' (customers or suppliers) activity level (= their input growth)	1. Coefficient capturing the degree of (internal) returns to scale 2. Coefficient capturing customer external effects 3. Coefficient capturing supplier external effects
Liebowitz & Margolis (1994)	Economics	Industrial Organization theory	Structure	Network effects / network externalities	Network effect: the circumstance in which the net value of an action is affected by the number of other agents taking equivalent actions Network externality: specific kind of network effect in which the equilibrium exhibits unexploited gains from trade regarding network participation (i.e., network externality is an instance of market failure)	Not provided
Cowan & Gunby (1996)	Complexity science	Evolutionary	Structure	Scale effects Learning effects Network effects	Positive feedback or self-reinforcing effects in the economy	Not provided
Oulton (1996)	Economics	Industrial Organization theory	Structure	Scale effects Supply-side externalities	Growth of output as a function of exploitation of scale economies and (supply-side) externalities	The coefficient relating the growth of industry output to: - the growth of industry inputs (scale effects) - the growth of aggregate manufacturing output (externalities)
Abraham-son & Rosenkopf (1997)	Manage-ment science	(Social) network theory	Structure (I.e., structure of the network)	Bandwagon processes (network effects) in innovation adoption	As the number of adopters of an innovation increases, so does its profitability, causing more potential adopters to adopt	Extent of diffusion of the innovation

Research design	Level of analysis	Time dimension	Influence on market structure and product or business performance	Management and policy implications
Empirical analysis of *NBER 4-digit* productivity database for *537* US industries	Meso (industry)	Dynamic	Short-run: 1. Moderate internal increasing returns to scale 2. Positive and significant customer-driven externalities 3. Nonsignificant supplier-driven externalities Long-run: 1. Moderate internal increasing returns to scale 2. Nonsignificant customer-driven externalities 3. Positive and significant supplier-driven externalities	Not provided
Conceptual with case examples	Meso	n.a.	1. Network effects are pervasive in the economy 2. However, most of these network effects mainly work through prices, and carry no special likelihood of market failure 3. Those network effects that have been modeled as transition problems may be valid only in abstract settings, and they are as yet without empirical support 4. There is scant evidence of the existence of network externalities 5. The existing models of network externalities arrive at a variety of conclusions, yet the models do not tell whether these problems are important in the real economy 6. The a priori case for network externalities is treacherous and the empirical case has yet to be presented	Not provided
Case study into Integrated Pest Management (IPM) in agriculture	Meso	Dynamic	1. Economic systems may get trapped away from the least-cost equilibrium (as in the IPM case) 2. This equilibrium is inflexible and the switching process is subject to considerable inertia because: - a switch to the new technology will involve a period of low payoffs - there is uncertainty about the possibilities of the new technology - there is a co-ordination problem with switching, i.e. a single farmer switching will incur significantly higher costs than when all farmers switch - the cost of switching is sufficiently large so that small changes in relative advantage (e.g., through taxes or subsidies) will not be enough to overcome the technological inertia 3. Therefore, only a crisis situation seems to be able to provoke a general switch, and an incremental switching process will be difficult to achieve	A policy maker who wants to promote a technology switch should focus policy interventions to concentrate on resource sin such a way that they are sufficient to overcome inertia in at least a part of the system
Production function estimation for a sample of *124* manufactu-ring industries for *9* years	Meso aggregated to macro	Comparative static	1. There is no evidence for increasing returns internal to the industry; at industry level returns appear to be constant 2. There is evidence for externalities operating at the level of aggregate manufacturing 3. There is no evidence for externalities generated by expansion at the industry sector level	Not provided
Simulation study	Micro-meso (agent-network)	Static	1. Network density influences the extent of innovation diffusion 2. Network structure influences the extent of innovation diffusion and structural idiosyncrasies can have a major effect Both relationships are moderated by the ambiguity of the innovation's pay-off to the adopter	Not provided

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Arthur, Holland, LeBaron, Palmer & Tayler (1997)	Complexity science	Ecological, evolutionary	Structure (agent heterogen-eity and interdepen-dence)	Endogenous (mutually reinforcing) expectations	Complex market patterns (appearance of bubbles and crashes)	1. Price volatility (kurtosis of a population of 25 experiments) 2. Amount of information used by agents for making their forecasts
Choi (1997)	Economics	Industrial Organization theory	Structure	Network effects and Interaction effects	Network externalities create a positive pay-off interdependency: the more people adopt a technology, the more valuable it is Informational externalities: each agent benefits from observational experience, I.e. is able to observe other agents' decisions and is able to learn from their consequences	Number of adopters of the technology
Cowan, Cowan & Swann (1997)	Complexity science	Ecological, evolutionary	Structure (patterns of demand)	Social interactions between consumers	Consumers' preferences are influenced by the consumption behavior of others: peer groups, contrast groups, and aspiration groups	The degree to which consumption by an agent of type s' makes the good attractive to an agent of type s
Dalle (1997)	Complexity science	Evolutionary	Structure	Externalities (local and global)	Network externalities: an agent's utility of adopting a technology is influenced by the number of other agents having adopted this technology	The proportion of agents having adopted one of two possible technologies
Foray (1997)	Manage-ment science	Evolutionary	Structure	Interaction effects	The positive feedback effect of the collective dynamics of localized (technological) learning	Not provided

Research design	Level of analysis	Time dimension	Influence on market structure and product or business performance	Management and policy implications
Computer simulation (artificial stock market)	Micro-meso (agent-network)	Dynamic	If agents are relatively quick in adapting their expectations to new observations of market behavior, the market self-organizes into a complex regime	Not provided
Theoretical	Micro-meso (adopting agent - market)	Static (sequential decisions)	The interaction of network externalities and informational spillovers generates risk aversion and herd behavior in the choice of technologies	Not provided
Theoretical (agent-based equations) + case examples	Micro-meso (consumer-market)	Dynamic	Social interactions influence the patterns of demand emerging in the market, and how these patterns evolve over time	Not provided
Theoretical with computer simulation	Meso	Static	1. Industries have a technological landscape, I.e., they are driven by market forces to different kinds of orderly equilibria, with different properties due to the differences in agent heterogeneity and (local and global) externality parameters 2. Depending on the existence of local and global externalities, three kinds of landscapes are to be encountered: - diversified technological landscapes (both technologies coexisting, non-homogeneously distributed over the market) - structured technological landscapes (both technologies coexisting, distributed in relatively homogeneous groups over the landscape) - homogeneous technological landscape (virtually the whole market has chosen for one technology) 3. Seemingly odd events (e.g. the appearance of technological niches) sometimes obey simple mathematical rules	Public policy implications: - public intervention becomes much more difficult than is usually thought - there are many ways to correct market inefficiencies, which are not substitutable, and which crucially depend on the technological landscape
Case examples (power source for motor cars; QWERTY keyboard; alternating current; nuclear power; ferrous casting; pest control strategies; video cassette recorder)	Meso (market)	Dynamic	1. Path dependence 2. Possible inefficiency: - persistence of obsolete technology - premature standardization of technology - excess diversity	The optimal policy flux would be learning from technology diversity in the early stages, and learning from standardization in the later stages of market evolution

Author (year)	Theoretical perspective	Approach	Position in Structure-Conduct-Performance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Cowan & Miller (1998)	Complexity science	Ecological, evolutionary	Structure (technological standardization)	Local externalities	Positive localized network externalities	Agents' pay-off of a technology, depending on the technology that its neighbors have adopted
Majumdar & Venkataraman (1998)	Management science	Industrial Organization theory	Structure	Network effects	Network effects is a form of increasing returns that arise when there is interdependence between different components or members of an economic system: 1. Conversion effect: there is operations-related increasing returns in moving from an old technology to a new one 2. Consumption effect: there is demand interdependence among adopters 3. Imitative effect: adopters model their behavior after adopters perceived to be similar	Percentage of technology adoption as a result of the technology conversion effect, the firms' interdependence of consumption effect and the firms' imitation effect
Hellofs & Jacobson (1999)	Management science	Industrial Organization theory	Structure	Network effects	Positive network externalities: customers may be (positively) affected by the purchase behavior of other customers when judging product quality	Telephone survey: exclusivity ratio (percentage of respondents preferring that few people use the same brand divided by the percentage of respondents preferring that a large number of people use the same brand) Experiment: *3* items measuring positive and negative externalities on a five-point scale
Morrison Paul & Siegel (1999)	Economics	Neo-classical economics	Structure	Scale economies & agglomeration (network) externalities	Shift of the short-run and long-run cost curves (the relationship between cost and output)	Short-run and long-run cost elasticities with respect to output (internal) and with respect to market activity levels (external). Together these make up a *total scale economy* measure.

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Theoretical	Micro-meso (agent-market)	Static	Decentralized behavior of agents with local network externalities can lead to the emergence of a technical standard, but can also result in a variety of other equilibria	1. Equilibria that exhibit technological diversity (non-standardization) can be eliminated by subsidizing one of the technologies; the height of subsidy needed depends on the strength of agents' preferences 2. The key to understanding standardization is understanding how agents behave when the effects of positive feedback are pulling equally hard in opposite directions
Regression analysis of technology adoption by telecommunications firms on a number of market structure variables	Micro (firm)	Comparative static	1. Operations-related increasing returns to scale for firms provide strong incentives to convert to a new technology from an older one 2. Market-related increasing returns to scale are significant in explaining the differences in adoption levels of technologies 3. The conversion effect is more prominent early in technology adoption, while the consumption effect is prominent throughout	Not provided
Telephone survey and experiment	Meso	Telephone survey: comparative static Experiment: static	1. On average, there is a negative effect of market share on perceived quality. 2. However, market share provides a positive signal about product quality.	Firms could use the positive signal effect of market share on quality to lessen the overall negative of market share expansion created by other mechanisms
Estimation of a cost function model for *two-digit SIC* level U.S. manufactu-ring industries over the period 1959-1989	Meso (*four-digit SIC* level data pooled to *two-digit SIC* level, and aggregated to macro U.S. level)	Dynamic	1. Internal scale economies still prevail in U.S. manufacturing 2. External effects have a (limited) direct effect on total scale economies and a (more extensive) indirect effect on total scale economies 3. When external effects are not taken into account, the measures of internal scale economies become biased by the indirect effect of the external measures	Not provided

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Wilson (2000)	Economics	Neo-classical economics	Structure	Scale effects	The growth rate of output as a function of the cost-share-weighed growth rate of inputs	A parameter representing returns to scale: the ratio of average to marginal cost
Woeckener (2000)	Complexity science	Not determined	Structure	Network effects	The utility from the use of a good depends positively on the total number of users of the good	The surplus for becoming a member of the network depends on a network effect strength coefficient times the network's market share to the power of a coefficient that determines the increase, decrease or constancy of the network effect
Brock & Durlauf (2001)	Complexity science	Social economics	Structure	Interaction effects	The utility or payoff an individual receivers from a given action depends directly on the choices of others in the individual's reference group, i.e., as opposed to dependence that occurs through intermediation of markets	The social utility component of a specific choice
Marshall (1890)	Economics	Neo-classical economics	Structure & conduct	Scale effects, caused by: - internal economies (increase in the scale of the individual firm) - external economies (economies that are the consequence of the aggregate scale of production)	Law of increasing returns: An increase of labor and capital leads generally to an improved organization, which increases the efficiency of the work of labor and capital	Increasing returns is a relation between a quantity of effort and sacrifice on the one hand, and a quantity of product on the other

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Estimation of production functions on the basis of the *NBER* productivity database containing annual data of *450* manufactu-ring industries at *4-digit SIC* level over the period 1958 to 1994	Meso	Dynamic	1. There is essentially no evidence of large increasing returns as needed in many of the current macro models 2. With regard to increasing returns, there is significant heterogeneity among firms 3. The often-found result of decreasing returns at the *2-digit SIC* level holds at the *4-digit SIC* level as well 4. Durable goods industries have higher returns to scale than non-durable goods industries	Not provided
Theoretical	Meso	Dynamic	The authors distinguish four cases: 1. If the systematic basic advantage of a network is relatively high, a unique absorbing state exists, and every stochastic deviation is eventually locked into the network with the systematic advantage 2. If both the systematic basic advantage and the network effect strength are relatively low, the stochastic processes are *ergodic*, i.e., in every situation there is a coexistence of networks 3. if the systematic basic advantage is relatively low and the network effects are considerably strong, each of the networks can become locked in, and there is a strong tendency towards a quick driving out of one of the networks 4. if the systematic basic advantage is relatively low, and the network effects are relatively strong, but not considerably strong, two locked in networks can coexist (when both networks have exceeded sufficiently their critical masses, a relatively long-lasting coexistence becomes probable)	Not provided
Theoretical	Micro-meso	Static	1. Multiple locally stable equilibrium levels of average behavior exist when social utility effects are large enough and decision making is non co-operative 2. A large social multiplier can exist in terms of relating small changes in individual utility to large equilibrium changes in average behavior 3. Introduction of a social planner eliminates multiplicity of average outcomes, but retains the large social multiplier effect 4. The equilibrium is mathematically equivalent to a logistic likelihood function	Not provided
Theoretical	Micro and meso	n.a.	1. Causes which enable firms to rise quickly, often hasten their fall 2. The increase in the scale of business increases rapidly the advantages a firm has over its competitors, and lowers the price at which it can afford to sell 3. This firm enjoying scale advantages and one or two others would divide between them the whole of the branch in which they are engaged 4. While the part which nature plays in production shows a tendency to diminishing return, the part which man plays shows a tendency to increasing return 5. The two tendencies toward increasing and diminishing returns press constantly against each other 6. There is no general rule that industries which yield increasing returns show also rising profits	Not provided

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Verdoorn (1949)	Economics	Neo-classical economics	Structure & conduct	Scale / learning effects	The elasticity of the labor productivity with respect to the production volume	Linear regression of the growth rate of labor productivity on the growth rate of production volume: *d(volume/labor) = constant + elasticity * d(volume)*
Kaldor (1966)	Economics	Combination of classical and neo-classical economics	Structure & conduct	Scale / learning effects	Increase in productivity as a response to, or as a by-product of, the increase in total output This is due to economies of large scale (e.g., indivisibilities of production factors) and/or to learning (e.g., Arrow, 1962)	The Verdoorn (1949) relationship (called *Verdoorn's law* by Kaldor)
Kaldor (1972)	Economics	Combination of classical and neo-classical economics	Structure & conduct	Scale effects Learning effects	1. Decrease of costs per unit of output as plant size increases 2. The breaking up of complex processes into series of simple processes (division of labor) 3. Learning-by-doing: advances in productivity because of accumulated experience	Not provided

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Empirical test of the elasticity for a number of countries over the periods varying from 1869 to 1938 and for a number of industries in different countries over periods varying from 1873 to 1939	Macro and meso	Dynamic / Comparative dynamic (pre and post *World War I*)	1. There is a linear relationship between the growth rate of labor productivity and the growth rate of production volume 2. The elasticity of labor productivity with respect to production volume is over the analyzed periods around *0.45*, with a lower limit of *0.41* and an upper limit of *0.57*	Not provided
Empirical test of *Verdoorn's law* for twelve countries over the period 1963-64 versus 1953-54	Macro	Dynamic	1. The elasticity coefficient of *Verdoorn's law* is around 0.5 over the analyzed period 2. *Verdoorn's law* seems to apply mainly to manufacturing industries, and will be more limited outside the industrial field (it will not apply in agriculture and mining) 3. This supports the classical contention that agriculture and mining are *diminishing returns industries*, whereas manufacturing is an *increasing returns industry* 4. For the services sector, results are more difficult to obtain because of measurement problems	Not provided
Conceptual	Micro and meso	n.a.	1. Allowing for increasing returns means giving up the notion of general equilibrium 2. Allowing for increasing returns, the forces making for continuous change are endogenous 3. Then, every change in the use of resources creates opportunity for further change, meaning that the notion of 'optimum' allocation of resources becomes meaningless; the distinction between resource-creation and resource-allocation, vital to equilibrium economics, loses its validity 4. Given increasing returns, the process of economic development can be looked upon as a continued process of interaction between demand increases which have been induced by increases in supply, and increases in supply which have been evoked by increases in demand 5. We have no clear idea of *how* competition works in circumstances where each producer faces a limited markets as regards *sales* and yet a highly competitive market as regards *price*	Not provided

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Rohlfs (1974)	Economics	Industrial Organization theory	Structure & conduct	Network effects	The utility that a subscriber derives from a communications service increases as others join the system	1. Positive derivative of adopter utility with respect to the number of adopters 2. The slope of the demand curve
Teece (1980)	Manage-ment science	Transaction cost theory	Structure & conduct	Economies of scope	Economies of scope exist when for all outputs *y1* and y*2* the cost of joint production is less than the cost of producing each output separately	*c(y1;y2) < c(y1;0) + c(0;y2)*
Dolan & Jeuland (1981)	Manage-ment science	Evolutionary	Structure (demand functions) & conduct (pricing)	Learning effects	The experience curve	The coefficient of the correlation between the log of accumulated volume and the log of average cost (called experience rate)
McCombie (1985)	Economics	Neo-classical economics	Structure & conduct	Dynamic scale effects (learning effects)	The relationship between the growth of total factor productivity (labor productivity) and that of output (*Verdoorn's law*)	1. The elasticity coefficient of the Verdoorn law 2. The sum of the exponents of a Cobb-Douglas production function

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Theoretical	Micro-meso	Static	1. There are typically multiple equilibria at any given price; which equilibrium is selected depends on: - the conditions of the static model - the initial disequilibrium conditions - the disequilibrium adjustment process 2. The calling pattern between subscribers (uniform of non-uniform) influences the nature of the possible equilibria and how they are selected: - for uniform calling patterns, critical mass is reached only through the creation of a large user population - for highly non-uniform calling patterns (e.g., small groups of people frequently calling each other), critical mass may be reached even with very small user population	1. To create critical mass in fairly uniformly distributed calling patterns, the supplier can: - give the service free for a limited time to a selected group of people, that should be large enough to achieve critical mass - start the service with a low introductory price; this price can then be raised when critical mass is achieved and the number of users increases 2. To create critical mass in non-uniformly distributed calling patterns, the supplier will need to know the communications patterns and try to determine communities of interest groups or self-sufficient user groups; on these groups specific action can be taken, but this requires different pricing schemes than in the uniform case
Conceptual with empirical evidence from the petroleum industry	Micro	Static	1. Economies of scope do not provide a sufficient explanation for multi-product firms 2. There are two important instances in which multi-product firms are needed to capture scope economies: - when the production of two or more products depends upon the same proprietary know-how base and recurrent exchange is called for - when a specialized indivisible asset is a common input to the production of two or more products	If public policy towards the business enterprise has efficiency as the objective, then it is necessary to consider transaction costs as well as technological issues in deriving organizational implications from industry cost functions
Theoretical	Micro-meso (firm-market)	Dynamic	Optimal pricing policy with learning effects leads to higher profitability vis-à-vis myopic pricing policy	For the period of an innovating firm's monopoly: - skim policy of high initial prices followed by lower prices is optimal if the demand curve is stable over time and production costs decrease with accumulated volume - penetration pricing policy is optimal if there is a relatively high repeat purchase rate for non-durables or if a durable's demand is characterized by a diffusion process
Empirical testing of both the Verdoorn law as well as a conventional production function for *20* industries (*2-digit SIC* level) in the US over the period 1963-1972	Meso (used as an approximation for micro-level production function statistics; reason: unavailability of statistics for the individual firm)	Dynamic	1. The estimation of the Verdoorn law suggests that nearly all industries are subject to substantial economies of scale. 2. No evidence was found that these economies of scale primarily arise from greater inter-industry specialization of production 3. The estimation of conventional production functions suggests either constant returns to scale or occasionally very small returns to scale 4. The estimates are sensitive to the exact error structure assumed and provide a warning against the uncritical acceptance of a single model	Not provided

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Oliver, Marwell & Texeira (1985)	Sociology	Theory of collective action	Structure & conduct	Network effects	Accelerating production function relating the contribution of resources to the production level of a collective good	The second derivative of the production function relating resource contributions to the level of a collective good
Farrell & Saloner (1986)	Economics	Industrial Organization theory	Structure & conduct	Network effects	Demand-side economies of scale	The first derivative of customer utility with respect to the size of the network is larger than 0
Burt (1987)	Combi-nation of sociology and manage-ment science	Network analysis	Structure & conduct	Interaction effects	Contagion in the diffusion of a technological innovation (I.e., the evaluation of an innovation by a potential adopter is influenced by others who have already adopted and with whom the potential adopter socially interacts); there are two alternative mechanisms through which this can occur: - cohesion, i.e., influence through direct interaction (conversation) between adopters - structural equivalence, i.e., the potential adopter's perception of which action would be proper for an occupant of his position in the social structure	Measures of the two contagion effects obtained by regressing the actual month of adoption over the normative month of adoption of the innovation by a physician
Marwell, Oliver & Prahl (1988)	Sociology	Theory of collective action	Structure & conduct	Network effects Interaction effects	An individual's net gain from contributing to a collective action is (positively) dependent on the contributions of others	The total payoff from all contributions exceeds the individual's resources/benefits ratio

Research design	Level of analysis	Time dimension	Influence on market structure and product or business performance	Management and policy implications
Theoretical with computer simulations	Micro-meso	Static	1. With an accelerating (increasing returns) production function for the collective good, the start-up costs create severe feasibility problems for collective action 2. With an accelerating production function, once critical mass is reached, this will pay for the start-up costs, which will induce widespread collective action	1. With an accelerating production function for the collective good, a small and resourceful core of agents can begin contributions towards and action that will tend to 'explode' and draw in the other agents 2. With an accelerating production function, contractual solutions (coordinating an communicating the common interest, and making all or none contracts) are most likely to foster mass action
Theoretical	Micro-meso (supplier-market)	Dynamic	When changing from an existing to a new technology, allowing for the presence of an installed base for the existing technology, there can be excess inertia even with complete information. Installed base may therefore be a barrier to entry.	1. Possible strategic action for the entrant: product pre-announcement 2. Possible strategic action for the incumbent: predatory pricing (lowering prices in face of the threat of entry)
Empirical test of theoretical models of the diffusion of a medical drug innovation by interviews among *130* physicians (data by Coleman et al., 1966)	Micro-meso	Static (model of physicians behavior); Dynamic (model of innovation diffusion)	1. Contagion was not the dominant factor driving the medical drug's diffusion 2. Where contagion occurred, its effect was through structural equivalence, not cohesion 3. Regardless of contagion, adoption was strongly determined by a physician's personal preferences 4. There was no evidence of a physician's network position influencing his adoption	Not provided
Theoretical with computer simulations	Micro-meso	Static	1. The overall density of social ties in a group improves the prospects for collective action 2. The centralization of network ties always has a positive effect on collective action 3. The negative effect of costs of using social ties on collective action declines as the groups' resource or interest heterogeneity increases	Selectivity is a key concept in organizing collective action; an organizer operating under resource constraints will approach those agents whose contributions are likely to be the largest

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Matutes & Regibeau (1992)	Economics	Industrial Organization theory	Structure & conduct	Network effects	Network advantages for consumers (i.e., positive network effects) that are not due to network externalities	Consumers value of complementarity between goods (= their reservation price minus the distance between the consumer's ideal specification of the product and the firm's version of that component
Choi (1994)	Economics	Industrial Organization theory	Structure: technology adoption (demand side) & conduct: investment in technology (supply side)	Network externalities	1. Forward externality: early commitment to a technology deprives late consumers of an opportunity to co-ordinate efficiently based on better information 2. Backward externality: early adopters can be stranded inefficiently by later users who do not take their predecessors' preferences into account	Interdependence of adopters' payoffs Interdependence of investors (technology sponsors) payoffs
Katz & Shapiro (1994)	Manage-ment science	Industrial Organization theory	Structure & conduct	Network effects (direct & indirect)	Positive feedback effects	Not provided
Xie & Sirbu (1995)	Manage-ment science	Industrial Organization theory	Structure & conduct	Network externalities	Demand externalities: the benefit to a consumer of a product increases with the number of other users of the same product	Demand for the product is dependent on cumulative sales to date

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Theoretical	Micro-meso (firm-market)	Three-stage game	1. The equilibrium tends to involve socially excessive bundling 2. Mixed bundling strategies tend to increase the range of parameters over which socially excessive standardization occurs	1. Firms will choose to produce compatible components for a wide range of parameters, but will offer discounts to consumers who purchase all components from the same firm. 2. The firm's ability to exploit the demand shift associated with compatibility depends crucially on the range and timing of marketing strategies available to firms
Theoretical (game theory)	Micro-meso (firm/customer -market)	Two-period game	With network externalities and an option to wait with technology adoption the effect of forward externality dominates that of backward externality, resulting in a bias towards too early adoption by users compared to the social optimum	With network externalities and an option to wait with investment, the sponsor of an emerging technology may adopt a less risky strategy than the socially optimum one, because such a strategy may induce current customers to defer their decisions until the uncertainty (of which technology becomes the standard) is resolved
Theoretical & case examples	Micro-meso (firm-market)	n.a.	1. Multiple equilibria may exist 2. Equilibrium may become locked in 3. Equilibrium is not necessarily efficient 4. Firms with established reputations, well-known brand names and ready access to capital have competitive advantage	1. Competitive strategies typical for hardware suppliers in systems markets with network externalities: - dramatic penetration pricing - early and visible sunk expenditures on software - vertical integration to ensure access to software - building up customer beliefs about own system and tearing down customer beliefs about rival systems 2. As for now, there is no general theory of when government intervention is preferable to the unregulated market outcome
Theoretical model with numerical simulation	Micro (firm and duopoly market)	Comparative static	By agreeing on a common standard, both incumbent and entrant may be better off (I.e., compatibility is the preferred choice for both entrants and incumbents)	The optimum pricing strategy in markets with significant positive demand externalities is to price low (even below cost) initially and raise price over time as consumer valuation of product benefit increases with the installed base.

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Desruelle, Gaudet & Richelle (1996)	Economics	Industrial Organization theory	Structure (indirect network effects) & conduct (compati-bility decision)	1. Scale effects 2. Network effects (indirect)	1. Scale effects: fixed costs in production 2. Network effects: customer utility of a good is (positively) influenced by the number of complementary goods available	1. Scale effects: not provided 2. Network effects: the derivative of customer utility with respect to the consumption of complementary goods
Econo-mides (1996)	Economics	Industrial Organization theory	Structure (macro-approach of the problem) & conduct (micro-approach of the problem)	Network effects	The value of a unit of a good increases with the (expected) number of units sold	Consumers' willingness to pay for a good (demand function)
Westphal, Gulati & Shortell (1997)	Sociology / Manage-ment Science	Institutional perspective/ network perspective	Structure & conduct	Network / interaction effects	Increased diffusion of an innovation leads to larger social legitimacy for new adopters, inducing them to adopt	Conformity (of hospitals) to the typical pattern of *TQM* adoption
Fingleton & McCombie (1998)	Economics	Neo-classical economics	Structure & conduct	Dynamic scale effects (learning effects)	The relationship between the growth of total factor productivity (labor productivity) and that of output (*Verdoorn's law*)	The elasticity coefficient of the Verdoorn law
Harris & Lau (1998)	Economics	Neo-classical economics	Structure & conduct	Dynamic scale effects (learning effects)	The relationship between the growth of total factor productivity (labor and capital productivity) and that of output (*Verdoorn's law*)	The elasticity coefficient of the *Verdoorn law*

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Theoretical	Micro-meso (firm-market)	Static	1. The combination of complementarity between components and fixed costs in the production of the components results in (indirect) network effects 2. The presence of fixed cost in the production of complementary components alongside with consumers' desires for variety may result in an equilibrium where complementary goods for one or both systems in the market are not supplied 3. When the indirect network effect is small, a symmetric equilibrium may result, independent of the size of the fixed costs 4. When fixed costs are important, compatibility of systems may be beneficial to consumers and be welfare improving	Not provided
Theoretical (game theory)	Meso (macro-approach, starting with market structure) Micro (micro-approach, starting with firms or consumers)	1. Static 2. Two-period	1. In the presence of network externalities, perfect competition will lead to - multiple equilibria - market inefficiency 2. There is no guarantee that the highest joint profit standard will be adopted 3. Under incompatibility, residual demand facing firms is more elastic than under compatibility 4. Market entry of new firms has two effects: the competition effect and the network effect 5. When firms and consumers interact in more than one period, history matters	1. Network externalities cannot be claimed as a reason in favor of a monopoly market structure 2. Compatibility is a strategic decision 3. Under incompatibility, firms will choose to set lower prices 4. When the network effect is strong enough in relation to the competitive effect, an innovator-monopolist will invite competitors to enter the market and even subsidizes them on the margin to increase production
Empirical study into the timing of adoption of Total quality Management by *2712* hospitals over the period 1985-1993, including the network structure in which they are active	Micro	Static	1. Early adopters are mainly motivated by the organizational efficiency gains of innovation (*TQM*) adoption, and they are therefore more likely to customize *TQM* practices to the organization's unique needs and capabilities 2. Later adopters, experiencing normative pressure to adopt legitimated *TQM* practices are more likely to mimic the normative model or definition of *TQM* adoption implemented in other hospitals 3. More intense network ties decreases conformity to normative *TQM* adoption for early adopters, and increases conformity for late adopters 4. Conformity to normative *TQM* adoption is negatively associated with organizational efficiency benefits, and positively associated with organizational legitimacy benefits from adoption	Not provided
Empirical testing of the Verdoorn law (static as well as dynamic) for *178* regions in *13* European countries over the period 1979 to 1989	Meso	Dynamic (growth rates 1979-1989), Static (cross-section 1979)	1. A highly significant Verdoorn coefficient of *0.575* was found for the dynamic model; this suggests the presence of substantial increasing returns to scale 2. The estimates of the Verdoorn coefficient for the static model were found to be either not significantly different from zero or to be small, with typical values of around 0.10; this implies constant or very small increasing returns to scale	Not provided
Empirical testing of the Verdoorn law for up to *13* industries in *10* UK regions over the period 1968-1991	Meso	Dynamic (model incorporates both short-run, which is an approximation for the static model, and long-run)	1. Overall, the returns to scale are on average greater than one, and thus the Verdoorn coefficient significantly exceeds zero 2. There is considerable variation in the long-run output elasticity coefficients between different regions and between different industries	Not provided

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Schilling (1998)	Manage-ment science	Combination of Resource-based theory and Industrial organization theory	Structure & conduct	Network effects	Increasing returns to adoption, which can be split into two categories: - the more a technology is used, the more it is improved - the benefit a consumer derives from a good depends on the number of other consumers purchasing similar items	Likelihood of technological lock-out
Teece (1998)	Manage-ment science	From Resource-based theory to Dynamic Capabilities theory	Structure & Conduct	Scale effects Learning effects Network effects	Mechanisms of positive feedback that reinforce the winners and challenge the losers	Not provided
Arthur (1999)	Combi-nation of economics and complexity science	Ecological, evolutionary	Structure & conduct	Self-reinforcing expectations	Positive feedback in the economy	Not provided

Research design	Level of analysis	Time dimension	Influence on market structure and product or business performance	Management and policy implications
Conceptual	Micro (firm)	Dynamic	The author provides a number of propositions: 1. Failure to invest in continuous learning will increase the likelihood of technological lock-out 2a. In industries characterized by network externalities, an insufficient installed base will increase the likelihood of technological lock-out 2b. Later entry increases the likelihood of an insufficient installed base, which increases the likelihood of technological lock-out 3a. A lack of complementary goods will increase the likelihood of technological lock-out 3b. The strength of the relationship between the lack of complementary goods and technological lock-out will be increased by the presence of network effects 4a. Timing of entry will have a U-shaped relationship with the likelihood of lock-out: entering very early or very late will increase the likelihood of lock-out 4b. The strength of the relationship between late entry and technological lock-out will be increased by network externalities and low entry barriers 4c. The strength of the relationship between very early entry and technological lock-out will be weakened by the degree of improvement the technology offers over previous technologies 5. Under conditions of an existing dominant design, the likelihood of technological lock-out is positively related to the existence and degree of effectiveness of competitor patents protecting the dominant design 6. Under conditions of an existing dominant design, failure to invest in continuous learning will increase the likelihood of technological lock-out	1. Firms should invest in core capabilities and absorptive capacity to reduce the probability of technological lock-out, i.e., this investment may be a source of sustained competitive advantage 2. The firm needs to employ marketing, distribution, and pricing tactics that will rapidly deploy the technology, even if this means forfeiting returns in the short term, i.e., rapidly building installed base and encourage or sponsor availability of complementary goods 3. If the technology has a clear advantage to consumers, entering the market early gives the entrant a path dependent advantage 4. When the technology is ambiguous or consumer expectations are unclear, it may be in the firm's interest to wait 5. A firm wishing to enter a very new or emerging market can improve its chances of technology acceptance by investing in consumer education 6. The firm must possess core capabilities for producing or quickly developing technology to consumer expectations 7. A firm with a very fast development process can take advantage of both first and second mover advantage
Conceptual	Micro (firm)	n.a.	1. Winner-take-all markets, in which the winner need not be the pioneer and need not have the best product 2. Heightened pay-off associated with getting introduction timing right and with organizing sufficient resources when the opportunity opens up 3. Style of competition is like casino gambling 4. Superior technology alone is not enough 5. Combination with complementary assets is needed 6. There is little pay-off to penny pinching and high pay-off to rapidly sensing and seizing opportunities	Firms need to develop *dynamic capabilities* to sense and seize new opportunities, and to reconfigure and protect knowledge assets, competencies, complementary assets and technologies to achieve sustainable competitive advantage
Conceptual	Micro-meso	Dynamic	Economic patterns seldom fall into the simple homogeneous equilibria of standard economics, but instead are ever changing, showing perpetually novel behavior and emergent phenomena	Not provided

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
John, Weiss & Dutta (1999)	Manage-ment science	Industrial Organization theory	Structure & conduct	Self-regeneration and externalities of know-how	1. Know-how development as a positive feedback process 2. Externalities are spillovers in know-how creations, dissemination, and use	Not provided
Kretschmer, Klimis & Choi (1999)	Manage-ment science / Sociology	Industrial Organization theory	Structure & conduct	Network effects Interaction effects	Self-enforcement effects that transcend their historical cause, either in contradicting it (social contagion) or in escalating it out of proportion (increasing returns)	Not provided
Antinolfi, Kleister & Shell (2001)	Economics	Endogenous growth	Structure & conduct (of economic system)	Returns to scale with respect to technology as an input factor	Degree of homogeneity of the production function	Lambda (= the degree of homogeneity of the production function)
Dickson, Farris & Verbeke (2001)	Manage-ment science	Systems thinking	Structure & conduct	1. Scale effects 2. Learning effects 3. Network effects 4. Self-reinforcing expectations	Positive feedback effects: - asset position advantages (scale effects & network effects) - learning dynamics (learning effects & self-reinforcing expectations)	1. Asset position advantages: average cost consequences of fixed cost investments in distribution, R&D, brand equity, customer service 2. Learning dynamics: not provided

Research design	Level of analysis	Time dimension	Influence on market structure and product or business performance	Management and policy implications
Conceptual	Micro (firm)	n.a.	Authors provide 6 features of technology-intensive markets: 1. Cost structure of products: high fixed, low variable costs 2. Know-how is not easily tradable 3. Diversity of technologies 4. Network compatibility 5. Demand-side increasing returns 6. Importance of technology expectations (pace of development, significance of improvements, uncertainty of advances)	Authors propose four fields in which important marketing decisions have to be taken: 1. Vertical positioning (from upstream, e.g. selling or licensing know-how, to downstream, e.g. operating a service bureau) 2. Product design (platform or product strategy; modular or optimized designs) 3. Transfer right management (selling or licensing know-how; pricing of this transfer) 4. Migration decisions (overlapping of product generation, backward compatibility decisions, setting pace and expectations of change)
Conceptual with some examples	Meso (industry) and micro (firm)	n.a.	1. There is oversupply of potential candidates for goods in the industry, generating a selection problem 2. The quality of goods in the industry is highly uncertain 3. Consumers of goods in the industry form networks 4. Demand for goods in the industry reverses in cyclic ways	Authors provide six management recommendations: 1. Be early 2. Attract suppliers 3. Influence expectations 4. Upgrade customer base 5. Reciprocate trust 6. Create social institutions Authors also provide two broad strategic alternatives: 1. Try to push for increasing returns directly 2. Try to ride the waves as they come
Theoretical + graphic analysis	Macro (economy)	Dynamic	Increasing returns leads to an instable steady state; it causes bifurcation, or multiple possible steady states	Not provided
Theoretical (systems analysis / feedback analysis)	Micro-meso (firm-market)	Dynamic	Positive feedback effects create permanent change and growth: the evolution of economic systems and markets	Understanding feedback effects that dominate market evolution and development is useful for managers in three ways: - it helps them forecast the directions in which markets are likely to evolve - it helps managers appreciate the nature and degree of uncertainty and risk in a particular market's evolution path - it may reveal latent feedback loops that managers can influence and foster

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Thornton & Thompson (2001)	Economics	Neo-classical economics	Structure & conduct	Learning effects	Productivity growth as a consequence of on-the-job learning, internal (within-firm) knowledge spillovers, and external (between firms) knowledge spillovers	The influence of the different forms of experience (I.e., the result of earning effects) on the log of the labor requirements to build a ship
Gandal (1995)	Manage-ment science	Industrial Organization theory	Structure & perfor-mance	Network effects (indirect)	The value of a product or service increases in the number of consumers that use compatible products or services	Price levels
Bryn-jolfsson & Kemerer (1996)	Manage-ment science	Industrial Organization theory	Structure (installed base and product attributes are considered as 'given') & perfor-mance (list price as an indicator)	Network externalities	Relationship between the list price of a software package and its installed base	Coefficient relating the natural log of the inflation-adjusted list price for the product with the percentage of the installed base by this product
Clark & Chatterjee (1999)	Manage-ment science	Evolutionary	Structure (techno-logical standar-dization) & perfor-mance (relative market share of product)	Network effects	The utility a consumer receives from a product is affected by whether other consumers are using the same product (i.e. are members of the same network)	Relative attractiveness of a product for a consumer depending on inherent utility and the value of the network
Smith (1776)	Economics	Classical economics	Conduct	Scale / learning effects	The improvement in the productive powers of labor as an effect of the division of labor	Not provided

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Estimation of production functions for *25* shipyards that built *Liberty Ships* during *World War II*	Micro	Dynamic	1. Learning spillovers across product and across yards were a significant source of growth in productivity, and may well have been more important than conventional learning effects 2. The size of the learning externalities across yards were quite small 3. Authors conclude that learning spillovers help firms grow, but the market failures introduced by learning externalities may be modest 4. Findings also suggest that knowledge spillovers may be determined more by the nature of the technology than by the nature of competition	Not provided
Empirical analysis of the spreadsheet and database management system markets (1989-1991)	Meso (market)	Comparative static	1. The personal computer software market exhibits complementary network externalities 2. Firms whose software products are compatible with the dominant standard will charge a higher price than firms whose products offer compatibility with a smaller set of complementary application programs	Not provided
Empirical: econometric analysis of the spreadsheet market	Meso (industry)	Dynamic	1. Network externalities significantly increased the price of spreadsheet products: *1%* increase in installed base leads to *0.75%* increase in price 2. Products which adhered to the dominant standard, *Lotus* menu tree, commanded prices which were higher by an average of *46%*	1. For vendors, it is advantageous to achieve a significant share of the market quickly, e.g. through penetration pricing 2. Vendors who want to control standards should consider licensing their technology 3. Entry into the software market is likely to be more successful when there is a major change in platform because of inertia from network benefits
Computer simulation	Meso (industry)	Dynamic	The more important network effects are in the market: 1. the more likely it is that a single product will dominate the market 2. the less of an advantage there is to product improvement relative to capturing initial market share 3. the more likely it is that an inferior product can dominate the market if it captures a sufficient number of early buyers	1. Managers have to identify the degree of network effects in their market 2. Capturing initial market share is all-important; first-mover advantages are likely to be particularly strong 3. Penetration style marketing strategies are likely to be useful 4. Focus on fast introduction of 'good enough' products 5. Credible investments in network assets or reputation may convince early adopters 6. Focus on appealing to early adopters, who may act as opinion leaders 7. Managers must analyze the actual decision process customers use in purchasing their product
Conceptual	Micro	n.a.	1. The division of labor is carried furthest in those countries which enjoy the highest degree of industry and improvement 2. The extent of division of labor is limited by the extent of the market	Not provided

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Duchatelet (1982)	Economics	Neo-classical economics	Conduct	Scale effects Learning effects	Increasing returns to scale in production or decreasing cost of production as a consequence of learning from past mistakes	The firm has a *loss function*, and builds a sample of the past differences between its actual decision and reality; the 'loss' therefore decreases with experience
Amit (1986)	Manage-ment science	Industrial Organization theory	Conduct (strategy)	The experience curve and the factors that underlie it: 1. Scale effects 2. Learning effects	1. Increasing returns to scale (scale effect): cost declines that occur as a result of movement along a given long-run average cost curve 2. Learning effect: cost declines that occur over time, reflected by a movement of the long-run average cost curve	The decline of the average total cost with production rate (scale effect) or with cumulative production (learning effect) There is a measurement problem when both effects occur at the same time
Argote, Beckman & Epple (1990)	Manage-ment science	Neo-classical economics	Conduct	Learning effects	Increase in the rate of output when cumulative production grows that are not due to increased inputs of labor and capital, or to increasing exploitation of economies of scale, or to the passage of time	1. Increase in the rate of output due to the rise of cumulative production 2. Increase in the rate of output due to the growth of knowledge stock
Herbig (1991)	Complexity science	Catastrophe theory	Conduct (adoption)	Bandwagon effects	The increase in the pressure for innovation adoption to a firm as a result of the increasing number of adoptions within the firm's industry	The magnitude of the discontinuity of the change between the states *not adopted* to *adopted*
Bikhchan-dani, Hirschleifer & Welch (1992)	Sociology	Ecological, evolutionary	Conduct (agent behavior)	Information cascades (localized conformity; effects of social interaction on aggregate behavior)	The decision of an individual to adopt is positively dependent on previous individuals' adoption decisions, because of sanctions on deviants, positive pay-off externalities, conformity preference, or communication	Number of adopters of behavior (custom, fad, fashion, product, or technology)

Research design	Level of analysis	Time dimension	Influence on market structure and product or business performance	Management and policy implications
Theoretical	Micro (firm)	Dynamic	Even in the presence of a constant returns to scale technology and incomplete information, increasing returns to scale in production can emerge as a sole consequence of learning-by-doing	Not provided
Theoretical	Micro (firm)	Dynamic	1. Competitive advantage through cost leadership can only be obtained in the presence of learning 2. In the presence of decreasing returns to scale, part or all of the cost advantages obtained by riding down the experience curve may be offset by increases in production costs	Firms must carefully identify the sources of cost decline and must use adequate estimation techniques to measure the experience effect
Estimation of production functions for *16* shipyards that built *Liberty Ships* during *World War II*	Micro (aggregated to meso)	Dynamic	1. The conventional measure of learning, cumulative output, significantly overstates the persistence of learning 2. Knowledge stock is a better measure of learning, because it allows both growth of knowledge as well as knowledge depreciation 3. The analysis shows that knowledge acquired through production depreciates rapidly	1. A strategy of adopting high output levels initially, followed by lower levels may be effective to increase productivity if learning is related to cumulative output. It is not necessarily preferable if learning is related to (depreciating) knowledge 2. Failure to allow for depreciation of knowledge may result in production cost forecasts that have systematic errors
Conceptual	Micro	Dynamic	The discontinuity of change of a firm (I.e., the bandwagon pressure) is a function of the number of possible adopters in the firm's industry and the essentiality of innovation adoption to the firm	The model: - provides managers (of an innovation supplier) with a different understanding and prediction of the cumulative adoption curve - enables managers to better segment the market and target potential customers (making a difference between earlier and later adopters)
Theoretical + case examples	Micro-meso (agent-network)	Static	1. Rapid spread of new behaviors (customs, fads, fashions, products, technologies) 2. Mass behavior is systematically fragile and idiosyncratic: small shocks can lead to large shifts in behavior 3. Multiple equilibria may exist 4. The 'wrong' cascade may occur (in the sense that all individuals do not adopt the behavior) 5. The fragility of cascades also means that they can be easily reversed by individuals, opinion leaders, or outsiders	1. When introducing an innovation, one should focus on persuading early leaders, who act as fashion or opinion leaders 2. Release of public information can break incorrect cascades

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Besen & Farrell (1994)	Economics	Industrial Organization theory	Conduct (strategy)	Network effects	Demand-side economies of scale	Standardization of technology
Hill (1997)	Manage-ment science	Resource-based theory	Conduct	Network effects	The value to a customer of owning a product is an increasing function of the availability of compatible products	Not provided
Li & Rajago-palan (1998)	Manage-ment science	Resource-based theory	Conduct	Learning effects	Cumulative knowledge level as a linear combination of cumulative production volume (autonomous learning) and cumulative investment in process improvement efforts (induced learning)	Unit production cost (which is decreasing in cumulative knowledge)
Klette (1999)	Economics	Neo-classical economics	Conduct (scale exploitation)	Scale effects	Increasing returns to scale	The elasticity of scale of production

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Case examples (*MS DOS*; *IBM* mainframes; *VHS* versus *Betamax* video; QWERTY keyboard; Color television, FM stereo, High-definition television)	Micro	Static	1. Markets are 'tippy' (= unstable) 2. A single winning standard will dominate the market 3. Expectations about the ultimate size of the network are crucial 4. History matters (= path dependence) 5. Firms that prevail in the standards battle can expect very large returns	Tactics for fighting a standards battle: 1. Building an early lead 2. Attracting the suppliers of complements 3. Product pre-announcements 4. Price commitments 5. Deciding whether to establish technology as a proprietary standard, join a rival's network, or offer technology to rivals as a proposed industry standard
Case examples	Micro-meso (firm-market)	n.a.	1. Technology standardization 2. Lock-in effects 3. Possible inefficiency	Authors provide a table of benefits, costs, and risks attached to four strategic options for increasing returns markets: licensing, strategic alliances, product diversification, and aggressive positioning Authors also provide a table of main features and contingencies attached to four competitive strategies for increasing returns markets: aggressive sole provider, passive multiple licensing, aggressive multiple licensing, and selective partnering
Theoretical	Micro (firm)	Dynamic	Not provided	Not provided
Econometric analysis of Norwegian manufactu-ring firms from *14* different industry groups (1980-1990)	Meso (*5-digit SIC* code industry level) level aggregated from micro (firm) level data	Comparative static	Increasing returns to scale is not a widespread phenomenon in Norwegian manufacturing. The average firm in most industries seems to face constant or moderately decreasing returns to scale. However, scale coefficients vary substantially within each of the industries analyzed: the differences between scale coefficients within industries are three times as large as the differences between industries.	Not provided

Author (year)	Theoretical perspec-tive	Approach	Position in Structure-Conduct-Perfor-mance model	Mechanisms of increasing returns addressed	Definition of increasing returns	Measurement of increasing returns
Shapiro & Varian (1999)	Economics	Industrial Organization theory	Conduct	Network effects	Network effects: consumers play high value on compatibility	Not provided
Mitchell (2000)	Economics	Evolutionary	Conduct	Scale, scope, and learning effects	Increasing productivity of the firm (learning about technology) and its influence of the scope of the firm's activities	Parameters in the production function: 1. A parameter representing scale economies 2. A learning parameter, representing a better organization of inputs Economies of scope are measured as the increase of output as inputs are spread over a larger set of tasks

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Conceptual with some case examples (Railroad systems, *AC/DC* power, Color television)	Micro (firm)	n.a.	1. Incompatibilities can arise almost by accident, yet persist for many years 2. Network markets tend to tip towards the leading player 3. Consumer expectations can easily become self-fulfilling in standards battles 4. First-mover advantage can be overcome by superior technology if the performance advantage is sufficient and users are not overly entrenched 5. Adoption of a new technology can be painfully slow 6. Victory in standards wars often requires building an alliance 7. A dominant position in one generation of technology does not necessarily translate into dominance in the next generation of technology	1. A firm's ability successfully to wage a standards war depends on 7 key assets: - control over an installed base of users - intellectual property rights - ability to innovate - first-mover advantages - manufacturing capabilities - strength in complements - brand name and reputation 2. Strategy and tactics lessons: - assemble allies (support from consumers, suppliers of complements, competitors) - pre-emption (penetration pricing, rapid design cycles, early deals with pivotal customers) - managing customer expectations (aggressive marketing, making early announcements, make commitments visible) 3. When you have won, do not rest easy: - keep developing the product, even if that means sacrificing backward compatibility) - offer customers a migration path (e.g. by incorporating competitive ideas into updates) - maintain a healthy market for complementary products - compete with your own installed base - protect your position - leverage your installed base into new markets 4. When you fall behind: - do not apply *survival pricing* - connect to the dominant technology (e.g. through adapters or converters)
Theoretical modeling, the predictions of the theoretical model are tested against firm diversification data	Micro	Dynamic	1. The scope of the firm is limited by the increasing difficulty of tasks and the firm's limited ability to focus on a wide variety of disparate production techniques 2. The authors' model explains some facts about the scope of firms: - why there is so much diversification into related fields - why firms that are more diversified tend to be larger, not only overall, but also at every activity they are involved with - why there is a learning curve, in the sense that average costs are non-increasing over the lifetime of a firm - why firm size, growth, and growth rate variability show stochastic properties	Not provided

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
De Liso, Filatrella & Weaver (2001)	Economics	Endogenous growth	Conduct	1. Division of labor 2. Learning-by-doing	The link between returns and output (a result of the sources *division of labor* and *learning-by-doing*	Output-output elasticity
Hatch & Mowery (1998)	Manage-ment science	Capability approach	Conduct & perfor-mance	Learning effects	Improvement in process performance as process-specific knowledge increases, as a consequence of cumulative production volume or cumulative engineering	Density of defects per square centimeter
Garud & Kumara-swamy (1993)	Manage-ment science	Industrial Organization theory	Structure, conduct & perfor-mance	Network effects	The benefits a user derives from a product increase as others use compatible products	Not provided
Arthur (1996)	Economics / Complexity science	Ecological	Structure (of market), conduct (of firms) & perfor-mance (of firms and/or technolo-gies)	1. Scale effects (large up-front costs) 2. Network effects 3. Customer groove-in	1. The tendency for that which is ahead to get further ahead, for that which loses advantage to lose further advantage 2. Mechanisms of positive feedback that operate - within markets, businesses and industries - to reinforce that which gains success or aggravate that which suffers loss	Not provided

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Theoretical	Micro	Dynamic	1. Endogenously created increasing returns can emerge because of: - division of labor - learning-by-doing of individuals - learning-by-doing of the organization 2. Individual learning-by-doing is limited by individual capabilities 3. Division of labor and organizational learning-by-doing is limited by the extent of the market	Not provided
Survey on the manufactu-ring performance of semi-conductor firms	Micro (firm)	Dynamic	1. The learning curve is a product of deliberate activities intended to improve yields and reduce costs, rather than the incidental by-product of production volume 2. Characteristics of learning for new processes differ significantly from those for mature processes 3. The ability of firms to develop, introduce, and expand production with new processes is one of the most important firm-specific capabilities for competition in the semiconductor industry	Reallocation of engineering talent away from problem solving on mature processes to 'debugging' of new manufacturing processes
Case study (*SUN Microsystems* 1982-1989)	Micro-meso (firm-market)	Dynamic	Authors provide a table of the structural facets of competition contingent on: 1. Competitive market or monopoly market 2. Integrated system manufacturers or specialized component manufacturers Authors provide a table of competitive dynamics in network industries, regarding system attributes, firm strategies, and sources of sustainable advantage, contingent on: 1. unconnected closed networks or connected open networks	1. In connected open networks markets an *open systems strategy* with liberal licensing as followed by *SUN* may be very successful 2. Firms competing in these markets must question the conventional wisdom of restricting access to proprietary technologies and discouraging multi-system compatibility
Case examples (PC operating systems *CP/M* versus *MS-DOS* versus *Macintosh*	Micro-meso (firm-market)	n.a.	1. Because of increasing returns in knowledge-based industries, markets tend to become a 'casino of technology' 2. Market instability 3. Multiple potential outcomes 4. Unpredictability 5. Lock-in 6. Possible predominance of an inferior product 7. Fat profits for the winner	For firms: 1. Competition becomes like gambling, the art of competing is primarily a psychological one 2. Superb product or technology, technical expertise, hitting the market first, deep pockets, will, and courage remain important but count for only a limited degree 3. Firms cannot optimize, they can only adapt in a pro-active way 4. Managers have to understand the rules of increasing returns markets For policy makers: 1. Do not penalize success (short-term monopoly is a reward for innovation) 2. Do not allow head starts for the privileged

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Cottrell & Koput (1998)	Manage-ment science	Industrial Organization theory	Structure, conduct & perfor-mance	Indirect network externalities (complementary products, hardware-software)	The effect of software availability on hardware valuation	The value (price) of the hardware to which the software is complementary
Ades & Glaeser (1999)	Economics	Endogenous growth	Structure (extent of the market), conduct (speciali-zation) & perfor-mance (growth)	1. Investment in fixed cost technologies 2. Division of labor 3. Learning-by-doing	Positive connection between initial *GDP* and *GDP growth*	The coefficient of the correlation between initial *GDP* and *GDP growth*

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Case study with statistical estimation	Meso (industry)	Dynamic	1. A single computer platform is likely to dominate the industry 2. Software development decisions influence which hardware design eventually dominates 3. Network externalities (for customers) attach to the software, and the effect on hardware will be to make the platform generic 3. Externalities (for suppliers) in hardware are largely determined by the sunk investments software suppliers have to make in knowledge needed to develop software applications for specific platforms 4. There is a positive relationship between software variety and price, because in the initial stages of adoption, software variety serves as a signal of platform quality 5. Computer software and hardware markets are subject to significant interaction effects	1. Software products must be developed for use on a *computer platform* 2. There are different development strategies: - device-dependent strategies: developing software for a single platform, usually the largest, or expected largest - device-independent strategies: developing software independently of a platform and then generating executable code for the specific platforms
Empirical analysis of 1. cross-country data on population and per capita *GDP* of poorer countries 2. Data on U.S. states in the 19th century	Macro (economy)	1. Static 2. Comparative static	1. The extent of the market determines division of labor, which in turn determines growth 2.The *learning-by-doing* model is rejected	Openness stimulates economic growth, therefore protectionism is doubtful

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Gupta, Jain & Sawhney (1999)	Manage-ment science	Industrial Organization theory	Structure, conduct & perfor-mance	Network effects (indirect)	The usefulness of a technology product for an end-user depends on the availability of complementary software products and services	The probability of choosing a product (hardware) as depending on the levels of software attributes available for this product

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Conjoint study, Delphi procedure and simulation study in the digital television market	Meso	Conjoint study: static Delphi procedure: static Simulation study: dynamic	Industry-specific findings: - division of market shares is asymmetrical, but not *winner-take-all* - niche products may still be attractive in terms of revenue and profitability - assuming full availability of complementary products would dangerously overestimate the sales and extent of transition to digital television - there is a market segment for digital television, also if it does not become a mass market - the initial adoption of digital television is sensitive to the availability of content, rather than to the price level	Industry-specific findings: Complementor firms are likely to: - initially offer movies in digital format - be reluctant to offer other types of content until cumulative adoption exceeds 5% - increase their offer of all kinds of content as cumulative adoption grows - be less willing to offer all types of content beyond 10% cumulative adoption (i.e., they will specialize) General findings: The research framework used in this article may benefit supplier in market where indirect network effects are important. They should: 1. identify directly competing hardware technologies 2. identify the complementary software and the complementors 3. survey customers to identify relevant hardware and software attributes 4. calibrate customer response function and complementor response functions 5. set up a simulation model and conduct sensitivity analysis

Author (year)	**Theoretical perspec-tive**	**Approach**	**Position in Structure-Conduct-Perfor-mance model**	**Mechanisms of increasing returns addressed**	**Definition of increasing returns**	**Measurement of increasing returns**
Makadok (1999)	Manage-ment science	Resource-based theory	Structure, conduct & perfor-mance	Scale effects	Economies of scale is the marginal improvement in efficiency that a firm experiences as it incrementally increases its size	Firms that have higher economies of scale will subsequently gain market share

Research design	**Level of analysis**	**Time dimension**	**Influence on market structure and product or business performance**	**Management and policy implications**
Based on a sample of *1299* different Money Market Mutual Funds in an *87*-month period, a two-step procedure was followed: 1. A test for inter-firm differences in scale economies using *Chow tests* 2. A test for the effect of inter-firm differences in scale economies on subsequent market share and on the evolution of market shares over time	Micro (firm)	Dynamic	1. Scale economies exist industry-wide 2. There are inter-firm differences in scale economies 3. These inter-firm differences have a significant effect on the distribution of market shares (i.e., firms with higher scale economies gain market share) 4. This effect diminishes as firms age, because other firms imitate their capabilities 5. In the Money Market Mutual Funds industry, this erosion of capabilities is gradual process	The relevance of the strategic perspective of either building and defending sustainable competitive advantage (industrial organization, resource-based theory) or focusing on a series of small very temporary advantages (hypercompetition) depends on the rate of imitation of capabilities

Table 3.1: Systematic overview of the increasing returns literature

The *primary key* to the above table is the classification according to the *structure-conduct-performance paradigm* that serves as the basic modeling framework of this thesis. The order of discussion is as follows:

1. basic conditions
2. structure
3. structure-conduct
4. structure-performance
5. conduct
6. conduct-performance
7. structure-conduct-performance

Note that other than for the ordering of the table, the assumptions, definitions and research approach adopted in chapter one have not been imposed ex-ante on this literature review. Rather, the literature review is taken as a means of verifying or falsifying the value of these assumptions, definitions and research approach.

The *secondary key* to the table is the chronological date of publication. Our aim with this table is to provide a representative inventory and review of the existing theory and research on increasing returns. Inevitably there are some limitations to the scope of this review. First, a number of scientific fields in which increasing returns have not received attention were excluded from the analysis, e.g., international trade theory, economic geography and labor market economics. Second, only primary sources were included in the review while secondary sources, e.g., overview articles or comments on the writings of the classical economists, were excluded. Third, the selection is based only on contributions that have appeared in, or were referred to from, the leading economic, complexity and management journals.

3.2 Classification of the literature according to the structure-conduct-performance paradigm

The first criterion according to which the literature was reviewed was the contribution of every study according to the *structure-conduct-performance paradigm* that was chosen as the central framework of this thesis. Every study was classified according to whether it deals with market structure, with firm behavior, or with firm performance, or with any of the relationships between market structure, firm behavior and firm performance.

Almost half *(41)* of the *96* studies assessed deal exclusively with market structure, almost one third *(29)* deal with market structure and firm conduct and only a small minority *(10)* deal with firm performance issues, i.e., with the relationship between structure and performance *(3)*, with the relationship between conduct and performance *(1)* or with the relationships between structure, conduct and performance *(6)*. See table 3.2 below.

Basic conditions	Structure	Structure-Conduct	Structure-Performance	Conduct	Conduct-Performance	Structure-Conduct-Performance
3	41	29	3	13	1	6

Table 3.2: Numbers of studies classified according to the structure-conduct-performance paradigm

3.3 Perspectives on increasing returns in literature

We subsequently assessed and classified the studies on increasing returns by date of appearance and by the theoretical perspective taken, i.e., by the literature stream in which the study is embedded: economics, complexity science, sociology or social economics, or management science. We also classified the studies according to the approach that was taken within this theoretical perspective. See table 3.3 below. Within management this regards the specific *theory of the firm* that is chosen in the study, e.g., resource-based, dynamic capabilities, or industrial organization. Within economics this regards the distinction between, e.g., classical economics, neo-classical economics or endogenous growth theory. Within complexity it regards the distinction between, e.g., social network theory and evolutionary economics.

Period: / Perspective:	< 1899	1900-1949	1950-1979	1980-1989	> 1990	Total
Economic perspective	3	6	8	11	26	54
Complexity science or social economics perspective	-	-	1	5	15	21
Management perspective	-	-	-	4	25	29
Total	3	6	9	17[#]	61[#]	96[#]

[#] NB the numbers of studies for the different perspectives do not always add up to the totals, because some of the studies involve more than one perspective

Table 3.3: Numbers of studies in literature review according to perspective

From the analysis we find the following: first, judged by the increasing numbers of publications over time, increasing returns is receiving increasing attention in general, second, while increasing returns has been an issue in economics for a long time, interest from the complexity science perspective and from the management perspective is relatively recent.

3.4 Mechanisms addressed and definitions provided in literature

We analyzed the studies on increasing returns according to the mechanisms of increasing returns that they addressed and according to the definition of increasing returns they provided. Doing this, we took either the general definition of increasing returns that was provided or the definition of the specific mechanisms of increasing returns that were addressed in the study. A difficulty was that many of the analyzed studies do not explicitly state that they deliver a contribution to the literature on increasing returns and that it was often not specified with which aspect of increasing returns the study deals. Given the definition of increasing returns provided in section 1.5, it became clear that studies that addressed one or more of the four mechanisms of increasing returns: network effects, social interaction effects, scale effects and learning effects had to be included in the literature review.

From this analysis we draw four conclusions. First, most studies focus exclusively on either the firm-based mechanisms of increasing returns *(33)* or on the market-based mechanisms of increasing returns *(53).* Second, only a small minority of the studies *(10)* addresses both the firm-based and the market-based mechanisms of increasing returns. Third, from the review, a clear distinction becomes visible between market-based and firm-based mechanisms of increasing returns. Fourth, a large variety of definitions of increasing returns can be detected. There are two reasons for this variety. The first reason is that different studies address different singular mechanisms of increasing returns. Therefore studies on scale effects define and measure increasing returns in terms of scale effects and studies on network effects define and measure increasing returns in terms of network effects. The second reason is that there are large differences in definition and measurement even within the same aspect. This seems mostly due to researchers studying the same aspect of increasing returns from different perspectives or taking different approaches.

Subsequently, we performed a crosscheck of the mechanisms of increasing returns that were addressed and the perspective that was taken in the study (see section 1.4 and also section 3.3 above). It is noteworthy that studies that take an *economics* *perspective* seem to be primarily concerned with the mechanisms of increasing returns that are *internal* to economic transformation systems, e.g., firms, industry sectors or national or global economies. This involves issues related to the scale and scope of operations or issues related to dynamic scale effects, learning and knowledge and productivity growth. In our terms, this means that they are primarily concerned with the firm-based mechanisms of increasing returns. It is also noteworthy that studies that take a *complexity, sociological or social economics perspective* seem to concentrate on mechanisms of increasing returns that are *external* to economic systems. This involves issues related to behavioral interaction between agents in markets, e.g., network effects or demand-side scale effects, or issues related to information exchange between agents in markets, e.g., social network effects or social interaction effects. In our terms, this involves the market-based mechanisms of increasing returns. Finally, studies that take a management perspective address either the market-based mechanisms of increasing returns or the firm-based mechanisms of increasing returns, but rarely both at the same time.

On this basis we think that the basic assumption we made in section 1.3 is justified, namely that from the management perspective, network effects and social interaction effects may be conceptualized as reflecting market structure and scale effects and learning effects as reflecting firm conduct.

3.5 Research designs used in literature

Next, we analyzed the research design used for the increasing returns studies. Specifically we addressed:

- the way increasing returns was measured in the study
- the way the research was conducted, i.e., whether is was conceptual or empirical or both, which method was used and, when relevant, which sample size was addressed
- the level of analysis of the research model, i.e., micro (firm), meso (industry) or macro (country/international), or any combination of these
- the time dimension of the research model, i.e., static, dynamic, some intermediary form or some combination of these

From this analysis we conclude that there is a large variety in the ways increasing returns is measured. This is, again, due to the fact that different studies address different mechanisms of increasing returns, but it is also due to the fact that the definitions of increasing returns vary widely, even if they relate to the same aspect.

Further, we find that two thirds of the studies *(64)* are either involved with conceptual analysis or with theoretical modeling. Of these *64* studies, *45* are exclusively conceptual or theoretical, *11* also involve *case examples*, but not *case studies* (!), and *8* involve computer or numerical simulation. Finally, of the remaining *32* empirical studies, *7* are case study designs and *25* involve hypothesis testing through econometric estimation.

3.6 Results obtained in literature

We finally analyzed the studies according to the most important *results* presented in terms of (1) the influence of increasing returns on market structure and/or on firm performance and (2) the management and/or policy implications derived.

The conclusions are that:

- more than half of the studies *(53)* do not provide any results in terms of management or policy implications
- the studies that do provide management or policy implications yield a large variety of results regarding the influence of increasing returns on market structure and/or on product and firm performance

3.7 Conclusions

In this chapter we presented a systematic review of the existing literature on increasing returns. From this review we find that integrative approaches to increasing returns, i.e., involving both firm-based and market-based mechanisms of increasing returns, are relatively rare, that empirical research into increasing returns is relatively limited in comparison to the theoretical and conceptual research and that empirical research into the consequences of increasing returns for firm performance is extremely scarce, with any available evidence being mainly anecdotal.

We may therefore conclude that:

- the literature can be classified according to the four main mechanisms of increasing returns that were distinguished (cf., Arthur, 1988), namely: network effects, social interaction effects, scale effects and learning effects
- from a management perspective, network effects and social interaction effects may be considered to be part of market structure and scale effects and learning effects may be considered to be part of firm conduct

- research on increasing returns addressing market structure, firm conduct and firm performance in one study is scarce and this subject is therefore worthy of study
- studies addressing the firm performance implications of increasing returns are scarce and this subject is therefore worthy of study
- different streams of increasing returns literature coexist, based on different basic perspectives taken and we may therefore adhere to the management perspective using the industrial organization approach as chosen in section 1.3
- integrative approaches to increasing returns, i.e., involving both the firm-based and the market-based mechanisms of increasing returns are relatively scarce and this subject is therefore worthy of study
- the number of empirical contributions to increasing returns literature is relatively limited, at about one third of the total, in comparison to the number of theoretical and conceptual contributions, at about two thirds of the total, and this number is therefore worthy of extension

The contribution of our research to the existing body of knowledge will therefore be threefold. First, we will develop an integrative approach to increasing returns, i.e., integrating market-based and firm-based increasing returns. Second, we will measure the mechanisms of increasing returns and empirically test the relations between them. Third, we will systematically investigate the consequences of increasing returns for firm performance. We conclude that our research design, in which the market-based mechanisms of increasing returns, i.e., market structure, influence the firm-based mechanisms of increasing returns, i.e., firm conduct, which in turn influence firm performance, provides a sound basis for such a contribution. In the next chapters we will discuss the market-based mechanisms of increasing returns and the firm-based mechanisms of increasing returns, respectively.

4. MARKET-BASED INCREASING RETURNS

The market structure mechanisms of increasing returns are dealt with in this chapter. Specifically, in this chapter the market-based mechanisms of increasing returns, i.e., network effects and social interaction effects, the conditions influencing these effects and the consequences of the market-based mechanisms for market structure, i.e., how they cause a market potential for scale and learning effects, are discussed.

In addressing the market-based mechanisms of increasing returns in this chapter, we provide the first part of the answer to the first research question: *How can market-based and firm-based mechanisms of increasing returns be theoretically specified and defined?* and we provide a partial content validation for the second research question: *How can market-based and firm-based mechanisms of increasing returns be measured?*

The main thrust of the argument in this chapter is that economic agents do not take their decisions in isolation. Their decisions are mutually dependent, causing positive or negative externalities. From the literature analysis presented in chapter three, we concluded that the two dominant forms of these externalities are network effects and social interactions effects. In sections one and two we provide the definitions and theoretical conceptualizations of these effects. We address the conditions that influence the occurrence and the intensity of these effects in section three. We address the consequences of network effects and social interaction effects for market outcomes in section four. A rationale of how these market outcomes cause a potential for scale and learning effects is provided in section five. Conclusions are given in section six.

4.1 Network effects

4.1.1 Defining network effects

A first mechanism of market-based increasing returns is network effects. The phenomenon of network effects has attracted a lot of attention in recent years, both in economics and in management science, see, e.g., Arthur (1989), Farrell & Saloner (1985; 1986; 1992), Katz & Shapiro (1985; 1986; 1994), Liebowitz & Margolis (1994; 1999), Rosenberg (1982), Shapiro & Varian (1998; 1999). Network effects are sometimes also referred to as network externalities, increasing returns to adoption, or demand-side increasing returns (to scale).[26] Here, we use the term network effects.

Network effects occur when the economic utility of using a product becomes larger as its network grows in size (Farrell & Saloner, 1985; Katz and Shapiro, 1985). Network size is determined by the number of suppliers and users of products based on a common technological standard.[27] Network size appears to be very important in modern information and knowledge intensive markets[28], such as the markets for software programs, cellular phones and internet applications. More classical examples of products where network effects played an important part are the telegraph, telex and telephone. The fax machine also belongs to this category. To cite Kelly (1997, p.142): "Consider the first modern fax machine that rolled off the conveyor belt around 1965. Despite millions of dollars spent on its R&D, it was worth nothing. Zero. The second fax machine to roll off immediately made the first one worth something. There was someone to fax to. Because fax machines are linked into a network, each additional fax machine sliding down the chute increases the value of all the fax machines operating before it."

4.1.2 Direct network effects

When a product's economic utility increases as more customers start using it, this is referred to as direct network effects (Farrell & Saloner, 1985; Katz & Shapiro, 1985). Because the standardized product provides access to the larger network for all customers, both existing and new ones, utility for every customer rises as the network grows in size.

For example, consider a utility function in which the utility *(U)* of a product to a user *(i)* is dependent on the number of other users of this product:

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[26] Formally, there is a distinction between the concepts of *network effects* and *network externalities*, in the sense that *network effects* are a general consequence of network size, and *network externalities* entice the notion of market inefficiency (see Katz & Shapiro, 1994; Liebowitz & Margolis, 1994). See also section 4.4.7.

[27] Two different types of technological networks can be distinguished (Liebowitz & Margolis, 1994; Katz & Shapiro, 1994): (1) *literal networks*, in which participants are literally, i.e., physically, connected to each other, e.g., the telephone network, the cable television network and (2) *metaphorical or virtual networks*, in which there are no physical connections, e.g., the network of *Apple* computers users or the network of *Ford* motorcar owners.

[28] The kind of product and the information and technology intensity of a product are expected conditions for network effects and social interaction effects to emerge. See section 4.3.4 for further discussion.

$$U_i = a + b * (number\ of\ other\ users) \qquad (b>0)$$

The utility of the first user is:

$$U_1 = a + b * (0\ other\ users)$$

The utility of the second user is:

$$U_2 = a + b * (1\ other\ user)$$

Or, in general:

$$U_i = a + b * (i-1)$$

Now, because of the network effect, the total utility after two adopters is not $U_1 + U_2$, but rather $2 * U_2$

Therefore:

$$U_{total} = i * (a + b * (i-1)) = ai + bi2 - bi$$

Here, the i^2 term represents the positive feedback effect. As the utility of every customer in the network continues to rise, it becomes more attractive for prospective customers to join this network. This means that the network grows in size, thereby further increasing the utility for every customer. Therefore, network effects may easily cause positive feedback in the market.

The same mechanism makes it unattractive for customers to leave the network. Apart from financial investments made in the product or the technology and apart from the investments made in learning to use the product or technology, a move to a newer, smaller network would simply mean a reduction of the network benefits.

It can even be shown that customers who have a negative autonomous valuation of the product, in the above example that would mean that $a < 0$, or who have a higher autonomous valuation of a competing product, may eventually be persuaded to buy into the network, simply because the network benefits outweigh the negative autonomous valuation (Arthur, 1989). For example many people complain about the quality of *Microsoft* software, justly or unjustly. Some people even have a negative autonomous valuation of it and would probably be inclined not to buy it if the decision depended purely on their own judgment. However, as the network around *Microsoft* software is very large, the network benefits are also huge and often easily outweigh any negative autonomous valuation.

4.1.3 Indirect network effects

Network effects are also present when products are used in combination with complementary products based on the same technological standard. The increase in a product's economic utility as more customers start using complementary products or as more suppliers start offering complementary products, is referred to as indirect or *market-mediated network effects* (Farrell & Saloner, 1985; Katz & Shapiro, 1985). [29]Sometimes it is called the *hardware-software paradigm* (Katz & Shapiro, 1985), after the markets where the most typical examples of indirect network effects can be found. The market for computer hardware and the software for it or the market for DVD players and the DVD movies available for them (cf., Katz and Shapiro, 1994) provide good examples.

With a growing number of customers who have bought hardware, it becomes more attractive for other customers to do the same, i.e., direct network effects. As the market extends, it therefore becomes more attractive for suppliers to start selling complementary products such as software and peripheral equipment, i.e., indirect network effects, and because they extend the original hardware's functionality, it becomes more appealing for potential customers to buy these complementary products, which in turn increases the demand for the original hardware. Assuming positive network effects, no matter where we step in to this line of reasoning, we always end up with the positive feedback loop of extending markets for hardware and software. This is a reason why, in the market for personal computers, a very large and dominant network emerged around *Microsoft* and *Intel* products, which became known as the *'Wintel'* standard.

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[29] Farrell & Saloner (1985) and Katz & Shapiro (1985) also mention a larger second-hand market and better quality and availability of the post purchase service, respectively, as network effects. In our definition these are included in the indirect network effects.

4.1.4 The double network effect

Until now we have considered the network effect as depending on the number of customers who buy (adopt) products based on a common technological standard. Customers in this case may be consumers or firms that are either the end-user or the trader of the product. However, firms also have another role, namely that of producer of goods and services. In this role, they use product technology[30] as the basis for the goods or services they produce.[31] At the level of adoption of technologies by firms, there is also a network effect.

It can be defined analogously to the product network effect, i.e., the economic utility to a firm of employing a technology becomes larger as its network grows in size. Network size is determined by the number of adopters of a technology. These adopters may be either *sponsors* or *licensees*. According to Katz & Shapiro (1986), a sponsor is a firm that has property rights to a technology and hence is willing to make investments to promote it. Licensees are firms that do not own property rights to the technology, but instead buy the right to use the technology in their products.[32]

Analogously to direct and indirect product network effects, there are direct and indirect technology network effects. The direct technology network refers to the number of sponsors and licensees of a specific technology. The indirect technology network effect refers to the number of sponsors and licensees of complementary technologies. Computer processor technology, e.g., *Intel Pentium* or *AMD Athlon*, and computer operating system technology, e.g., *Windows XP* or *Apple OS X*, are examples of complementary technologies in the computer industry. Optical technology, e.g., lenses, and image registration technology, e.g., CCD sensors, celluloid film or videotape, are examples complementary technologies in the photographic and video imaging industry.

[30] Besides *product technology*, i.e., the technology that goes *into* the product, firms use *process technology*, i.e., the technology determining the way products and services are produced. Here, we limit ourselves to product technology, although analogous reasoning may apply to process technology.

[31] Many service providers seem to have great difficulty thinking in terms of 'technology' when it comes to services. This is one of the reasons for limiting the sample of the first empirical study (see chapter seven) to industrial firms. Nevertheless, it can be argued that producing services also requires product and process technology; although with services it may be more difficult and sometimes even impossible to distinguish *product* and *process*.

[32] We can distinguish between *proprietary technology*, i.e., technology that is owned by some economic entity, that is possibly protected by patents, and of which licenses can be bought and sold and *open source technology*, i.e., technology that is common property, either because patent protection has expired or because the sponsors choose deliberately not to exercise their property rights.

It is important to realize that the product and technology network effects are closely related. The more customers adopt products based on a specific technology, the more suppliers will be inclined to also adopt this technology, e.g., by buying a license from the technology sponsor. This enlarges the network, which means that there is increased competition, driving down prices and increasing product variety. This causes increased attractiveness of the network, thereby stimulating adoption of products by customers and adoption of the technology by suppliers. The technology network effect reinforces the product network effect and vice versa.

The distinction between the product and technology level of network effects is sometimes referred to as *competition within the market* and *competition for the market*, respectively (Besen & Farrell, 1994).

4.2 Social interaction effects

4.2.1 Defining social interaction effects

A second mechanism of market-based increasing returns is social interaction effects, also known as *social network effects* (Abrahamson & Rosenkopf, 1997), or *social contagion* (Burt, 1987; Kretschmer, Klimis & Choi, 1999). Social interaction effects occur when a customer's purchase intention, or a supplier's supply intention, is dependent on the opinions or expectations of other (potential) customers and suppliers. We refer to interdependence of opinions as information exchange and to interdependence of expectations as self-reinforcing expectations.

The essential difference between network effects and social interaction effects is that while the former is associated with the economic utility as a result of actual growth in network size, the latter is associated with perceived network importance as a result of information exchange and formation of expectations (Kretschmer, Klimis & Choi, 1999).

4.2.2 Information exchange

As stated above, we refer to social interdependence of customers' and suppliers' opinions as information exchange. Information exchange effects mainly occur with high-involvement products that are relatively unknown, the quality of which cannot be assessed before purchase and with products of which the purchase entails a large network risk.[33] With the purchase of products such as computers or cellular phones, customers buy into a technological network of compatible products. If the technology life cycle of this network is very short, or if the network does not develop into the market standard, the customer's investment is lost. To assess the risks of investing in such a technological network, customers search for information by consulting opinion leaders and existing product users before they buy the product. This information search behavior generates interaction, i.e., information exchange, between customers. Arthur & Lane (1993) refer to this interaction as *information contagion*. It is more probable that a customer will find favorable information about a product with a large market share than about a product with a small market share. Customers perceive the purchase of the former product to be less risky and will be more inclined to buy it. Consequently the market share of this product increases, increasingly at the expense of the small market share product. In this way information exchange causes positive feedback effects in market shares.

Apart from product-specific information exchange, customers also exchange non-product-related information. Feick & Price (1987) refer to the person who supplies this kind of information to other customers as market mavens (Feick & Price, 1987). Market mavens are defined as "individuals who have information about many kinds of products, places to shop and other facets of markets and initiate discussions with consumers and respond to requests from consumers for market information" (Feick & Price, 1987, p.85). In particular in the case of network technologies, where the complete network of complementary products rather than a single product is at stake, the influence of the market maven on the purchase intentions of other customers can be substantial.

4.2.3 Self-reinforcing expectations

Furthermore, customers have an interest in investing in products that are compatible to a long-living technology network that is widely supported and recognized as a market standard. To assess the risk of investing in a technological network, customers form expectations about the size of competing networks (Katz & Shapiro, 1985). This expected size is dependent on the number of suppliers and customers who have already invested in this network, or will do so in the future. When a substantial number of suppliers and customers expect that a particular network will dominate the market, they will be more inclined to invest in this network. As a result

[33] This may be an *economic network risk*, e.g., the risk of buying into the wrong technology, or a *social network risk*, e.g., the risk of buying into the wrong fashion style or social group.

the size of the network will increase, reinforcing the expectations of customers and thereby attracting even more customers, and because of these self-reinforcing expectations, there is a high probability that eventually this network will indeed dominate the market.

4.2.4 The double social interaction effect

Analogous to the discussion in section 4.1.4, two levels of social interaction effects can be distinguished: the product level and the technology level. At the product level there is information exchange and the formation of expectations between customers and between customers and suppliers regarding the adoption of products based on a common technology standard.

At the technology level, we are dealing with mutual influences between different kinds of suppliers, i.e., technology sponsors, technology licensees and those who have not yet decided[34], regarding the adoption of technologies that form the basis of goods and services produced. When investment in such technologies entails a large network risk, i.e., a risk of investing in a network that does not become the dominant network, suppliers who have not adopted yet will try to assess that risk by looking around to see which other well-known suppliers are sponsoring these technologies and which well-known suppliers have adopted these technologies.[35] On the basis of this information, suppliers may show mimetic behavior. As Westphal, Gulati & Shortell (1997, p.372) state: "[…] communication ties could help disseminate information about legitimate forms of innovative adoption, while also possibly increasing normative pressure to conform to those practices."

Like customers, suppliers also form expectations about the potential size of competing technology networks. On the basis of these expectations they decide to either invest or to announce that they are committed to investing in a technology. They do this by co-sponsoring, by buying licenses, or by announcing or developing new products based on this technology. These commitments reinforce the expectations of other suppliers, increasing the pressure for them to make a choice whether or not to commit themselves to investing. When large enough quantities of

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[34] These strategies are also referred to as, respectively, *shaper*, *follower* and *reserving the right to play* (Hagel, 1996; Coyne & Subramaniam, 1996). See also section 5.5.

[35] Suppliers can adopt a technology either by buying a license or by starting to use an open source technology.

important suppliers have committed themselves, the expectations regarding which network will dominate the market may become self-reinforcing.

Analogous to product and technology level network effects, the product and technology level social interaction effects will be mutually reinforcing.

4.3 Extent of network and social interaction effects

Following the *structure-conduct-performance paradigm* that was adopted as the basic modeling framework of this thesis, an important question is: *Under what circumstances can we expect network effects and social interaction effects to occur, and under what circumstances do network effects and social interaction effects lead to the market outcomes sketched in the previous section?* In other words: *What are the basic conditions affecting the extent of network and social interaction effects?* These basic conditions can be derived from the literature on increasing returns and from the lists of market conditions provided by Scherer & Ross (1990) and Carlton & Perloff (2000). With respect to the market structure mechanisms of increasing returns, the most important influencing conditions are: the marginal gains of network size, the degree of conformity and individuality of customers, the degree and structure of the economic interdependence in the market, the nature of the product and the technology and the characteristics of the product or technology as indicated by complementarity or substitution and compatibility. These will be discussed below.

4.3.1 Marginal gains of network size

The scope of network and social interaction effects is limited by the marginal economic gains of network size. That is the additional economic utility of adding one extra adopter to the network. Usually, these marginal gains are assumed to be positive up to the point where the entire market is satisfied. Liebowitz & Margolis (1994) argue, however that we may very well conceive of a point at which the marginal economic benefits of increasing the number of adopters are exhausted, e.g., by crowding of the network or by customer preferences for more heterogeneity (Katz & Shapiro, 1994; Hellofs & Jacobson, 1999). Further, while many technologies require critical mass, they may not be helped by further participation beyond that level. Where marginal gains of network size are exhaustible at network sizes that are small relative to the market, there is no impediment to the coexistence of multiple networks (Liebowitz & Margolis, 1994, p.141).

4.3.2 Conformity and individuality

Kretschmer, Klimis & Choi (1999) point out that networks are characterized by two competing psychological drives. The first is that of conformity, which means that there are positive marginal social gains of an increase in network size. This is also known as the bandwagon effect (Leibenstein, 1950). The second is that of individuality, which causes negative marginal social gains in response to an increase in network size. This is also known as the snob effect (Leibenstein, 1950).

The characteristics of the customer population may therefore be an important accelerator or limiter of social interaction effects. As most modern consumer markets are characterized by increasing heterogeneity of consumer behavior (Van Asseldonk, 1998), we would expect that customer individuality is a limiting factor to network size. If everybody wants to be different and unique, network size would be close to unity. Still, this is apparently not the case in many technology networks. The caveat lies in the distinction between the product and the technology. At the level of the technology, there is clearly a drive for conformity, i.e., we buy a *'Wintel'* computer because we want to be able to connect easily to others and to the market for complementary products. At the level of the product, however, there is clearly a drive for individuality, i.e., based on the *'Wintel'* standard, the choice of different computer models and features is larger than ever.

4.3.3 Degree and structure of economic and social interdependence

Another important aspect of the network and social interaction effect is the degree and the structure of economic and social interdependence between economic agents, customers as well as suppliers. Abrahamson & Rosenkopf (1997) show that the structure of the social network is an important determinant of the extent of innovation diffusion. They show first that a network with a higher density results in a higher extent of diffusion of an innovation, i.e., more agents within the network eventually adopt this innovation. Second, perhaps even more interesting, they show that network idiosyncrasies, i.e., the location of agents in the network who form a boundary between the fully connected network core and a not fully connected network periphery, can have a large influence on the extent of innovation diffusion.

Different forms of connections between economic agents can be distinguished in markets. First, there is the interaction between suppliers and customers. These interactions involve the buying or selling of products in exchange for money, the after-sales service trajectory and communication in the sense of information provision, advertising, promotions, signaling. Second, there are the mutual interactions between suppliers. These involve interactions between technology sponsors, e.g., head-on competition, coalition forming, R&D alliances or joint ventures, interactions between sponsors and licensees, e.g., buying or selling of licenses, commitments to investing in technology, commitments to develop products or provide services based on this technology and interactions between sponsors and firms that have not decided yet, e.g., signaling or manipulation of expectations. Third, there are the mutual interactions between consumers. These involve direct interactions through the products in the network, e.g., connecting computers, exchanging files, communicating by phone, fax, email, newsgroups, chat sessions or internet search, information exchange behavior, e.g., information search, opinion leadership, role models or word of mouth and, finally, formation of expectations.

An important aspect of the structure of social and economic networks is whether they are local or global (Bikhchandani, Hirschleifer & Welch, 1992; Redmond, 1991). A global network effect means that consumers are influenced in their adoption decision by the behavior of other consumers in the entire market. As an example, they would base a decision to buy a *'Wintel'* or an *Apple* computer system on the proportions of the total world market for *'Wintel'*, respectively *Apple*. Most theoretical models incorporating network effects are limited to the global network effect. They assume that consumers are all identical and that they have perfect information on the size of the network in the market. Most theoretical models incorporating network effects assume that network effects have a global scope and that consumers have information about the size of competing technological networks in the market. This kind of 'perfect information' will not always be present in practice.

While global network effects may have an important influence on a product's utility and on a consumer's decisions to purchase, consumers are also known to be embedded in a social structure that can influence their behavior to a large extent (Redmond, 1991; Abrahamson & Rosenkopf, 1997). Consumers are more heavily influenced by their direct social environment. For example, while the global network effect will make it more efficient to work with a *'Wintel'* computer, a consumer may choose an *Apple* computer if he is heavily embedded in the graphical sector, where the majority uses *Apple* computers. Small pockets or niches in the market may appear or be able to sustain themselves because of localized network and social interaction effects (Redmond, 1991).

4.3.4 Nature of product

The nature of the product and/or technology has a number of dimensions. The first is whether we are dealing with a *consumer product or an industrial product*. A consumer product means that it is used by the end-user, i.e., the consumer, while an industrial product is used by a firm as a means of production. This distinction is quite different from the product-technology level distinction in sections 4.1.4 and 4.2.4. Here we are still at the product level. The implication of the consumer-industrial distinction is not unequivocal. On the one hand it might be suggested that industrial buyers are more rational, which could lead us to expect that in industrial markets network effects might be more important than social interaction effects. On the other hand, when facing uncertain pay-offs in choosing a product, will not industrial customers be inclined to collect more information and be more aware of the market expectations regarding the success of new technologies? Therefore, we might also expect the social interaction effects to be more important than the network effect.

The second dimension is whether it is a *tangible or an intangible product*. The degree of tangibility may be used as an indication of the possibility to assess the quality of the product beforehand. That is, tangibility provides a clue as to whether we are dealing with a search good or an experience good. Of a search good, e.g., a computer, the quality can be determined in advance, of an experience good, e.g., software, this is not the case. Therefore, for intangible goods, the uncertainty is much higher and we would expect social interaction effects to be more important than network effects.

The third dimension, *durability versus non-durability*, tells us something about the probability that a network effect or a social interaction effect will occur. If a product is durable, the customer will likely make a larger investment than if it non-durable, both in terms of the initial buying price as well as in terms of learning to use the product. It is therefore likely that the network of other customers using the same product or compatible products based on the same technology and the network of customers and suppliers of complementary products will become a more important issue in the adoption decision. Likewise, as the investment is higher, the buying risk rises and customers will be more inclined to adopt on the basis of information they have got from others or on the basis of expectations about the value, the extent and the durability of the technology network.

The fourth dimension is *technology intensity of the product*. Technology intensity is related to uncertainty (Arthur & Lane, 1993), because the market outcome, i.e., which technology will be selected and corner the market, is uncertain. Investing in a product based on a technology that will become locked out means an effective loss of the investment.

The fifth dimension involves the *nature of the technology*. According to Arthur (1990; 1996), high-technology products are simply more likely to be compatible to a network of users. Examples of what we normally understand as high-tech are computers, software, portable telephones, fax machines, etc.[36] It is no coincidence that empirical research on increasing returns is mostly focused on computer hardware (Tegarden, Hatfield & Echols, 1999), computer software (Brynjolfsson & Kemerer, 1996; Gandal, 1995), computer software-hardware (Church & Gandal, 1992; Cottrell & Koput, 1998; Garud & Kumaraswamy, 1993), digital television (Gupta, Jain & Sawhney, 1999) or telecommunications (Majumdar & Venkataraman, 1998).

4.3.5 Complementarity

Complementarity means that products are (meant to be) used together and that in this way they have a higher value for customers than when used separately. Formally, complementarity is represented by a positive cross-elasticity of demand, i.e., when products *A* and *B* are compatible, the demand for product *B* will increase with an increase in demand for product *A*. Examples are a computer and a printer, a video recorder and video tapes, a CD player and CD’s. Complementarity can be product-related or technology-related. Examples of complementary technologies are the *Microsoft Windows* computer operating system technology and the *Intel Pentium* computer processor technology for computers, the machine operation technology and a machine’s numerical control technology for industrial machines.

Complementarity of products is a necessary condition for indirect network effects to exist. Technology complementarity will further extend the possibilities for indirect network effects. Product and technological complementarity will lead to more extensive technology networks and therefore more need for, and opportunities for, information exchange between customers.

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[36] The designation *high-tech* does not seem quite appropriate to characterize these technologies. While *high-tech* is common terminology, it means very different things to different people. Most people would characterize computers as *high-tech*, but fax machines by now as *low-tech*. Yet these technologies share a more important characteristic, namely that they can be *connected in networks*. Therefore we would rather talk about *network technologies*.

4.3.6 Substitutability

Substitution means that products are competitive, so that a consumer will have either one product or the other. Formally, this is represented by a negative cross-elasticity of demand. That is, when products *A* and *B* are substitutes, the demand for product *B* will decrease with an increase of demand for product *A*. Examples are a *Hewlett-Packard* computer and a *Dell* computer, a *Philips* CD player and a *Sony* CD player. Substitution can also be product-related or technology-related. Examples of technologies that are substitutes are *Microsoft Windows* and *Apple* or *Linux* computer operating system technology, *Intel Pentium* and *AMD Athlon* computer processor technology.

Technologies that are substitutes will likely cause a technology battle, either parallel or sequential. A technology battle will enhance uncertainty in the market, so that the influence of expectations, i.e., social interaction effects, on behavior, i.e., network effects, will be larger. When products are substitutes, this may generate moderate uncertainty among buyers about which product to adopt. However, the risk for customers of buying a wrong product is much smaller than the risk of buying into the wrong technology. When a customer buys into a losing technology, any product based on this technology may become worthless. When a customer buys into the winning technology, any product based on this technology benefits from the same technology network size.

4.3.7 Compatibility

Compatibility is necessary to allow products to function in harmony with complementary products. It can be ensured by standardization of the technological infrastructure (Farrell & Saloner, 1992). For example, a customer can only benefit from the continuously growing network of Internet-users and content providers if there is a common protocol for communication through the Internet. Therefore, compatibility is one of the most important conditions for a technology network to materialize and therefore one of most important conditions for network effects and social interaction effects to be present.

We may conclude that the strength of network effects and social interaction effects may be higher or lower depending on the marginal gains of the network, the conformity or individuality of the customers, the degree and structure of interdependence in the network, the nature of the product and the complementarity, substitutability and compatibility of the product. In the case of social interaction effects it is even conceivable that a completely negative information cascade will emerge. Bikhchandani, Hirschleifer & Welch (1992) refer to this as a down cascade. This means that negative information about a product or a technology is amplified by the social network, which may ultimately result in the product or technology not being adopted. Such down cascades fall outside the scope of our research, however, and have therefore not been incorporated in the operationalization of social interaction effects in chapters seven and eight.

4.4 Influence of network effects and social interaction effects on market outcomes

We have referred earlier to network effects and social interaction effects as related to the market structure aspect of our research framework. The main reason to do this is because the presence of network effects and social interaction effects may have large consequences for market outcomes, i.e., factors such as the speed of diffusion of products and technologies, the dynamics of the market shares of different competing products or technologies and the predictability of market outcomes (Arthur, 1989; 1996).

4.4.1 Technology battles

In general the market structure will take the form of a competition between different technologies, generally referred to as a ‘technology battle’. Such a technology battle may take different forms that can be distinguished on two dimensions, see figure 4.1. On the first dimension a technology battle may either be parallel, i.e., a competition between two or more equivalent technologies (see Farrell & Saloner, 1985; 1986), or sequential, i.e., a competition between an old, i.e., existing, incumbent, and a new technology, see Arthur (1989), David (1985) or Katz & Shapiro (1985; 1986). On the second dimension, a technology battle may either be evolutionary, i.e., when the new technology is backward compatible, or revolutionary, i.e., when the new technology is not backward compatible, see Shapiro & Varian (1999). Based on these two dimensions, many different kinds of technology battles are possible. Of course, in completely parallel battles there is no old technology and there is nothing for the new technologies to be backward compatible to, hence the blank part in the upper left-hand corner of figure 4.1.

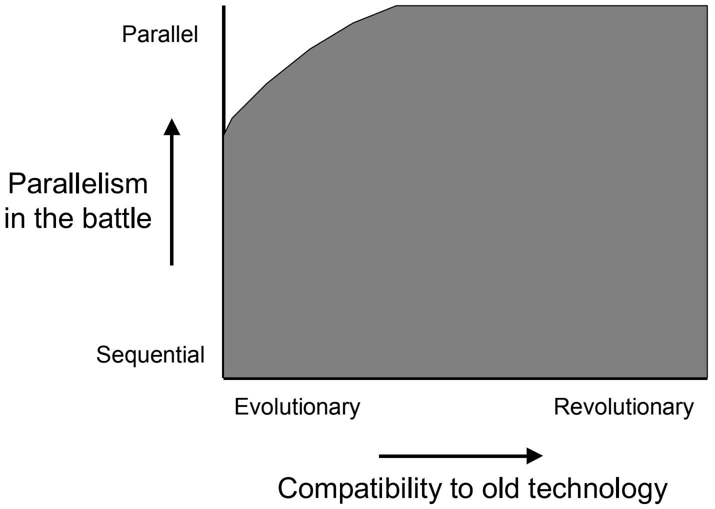

Figure 4-1: Dimensions of technology battles

Arthur (1989) mentions four properties of such technology battles:

1. the market will eventually be dominated by one of the technologies, which means that there are multiple possible equilibria in the market and it is ex ante unpredictable which equilibrium will be selected; this is called *non-predictability* or *winner-take-all*
2. the winning technology will be *locked in*; this is called *inflexibility*
3. it is possible that a sub-optimal technology will be selected; this is called *inefficiency*
4. the end result may be determined by historical small events; this is called *path dependence* or *non-ergodicity*

More properties have been added by others, e.g., *excess inertia* (Farrell & Saloner, 1985; 1986), *excess momentum* (Katz & Shapiro, 1986) and *competition on the network level* (Den Hartigh & Langerak, 2001). These properties will be discussed below. Although many of these issues are still debated (see also section 2.6.5) it has become clear from both the theoretical and the empirical body of research that the presence of network effects and social interactions effects in markets can have severe consequences for adoption and diffusion of technologies and thereby also for the adoption and diffusion of products based on these technologies.

4.4.2 Competition at network level

A first consequence of the occurrence of network and social interaction effects, implicit in most theoretical and empirical literature, but seldom explicitly mentioned, is that competition shifts from the product level to the network level (Den Hartigh & Langerak, 2001). As a result of this shift, features like high product quality, low prices, ownership or patents, or exclusive rights on technology are just an 'entrance fee' for competitive success. The network dimensions of competition, such as the availability of complementary products, compatibility of these products, size of the network or *installed base* and customer expectations with regard to network growth, are more important for competitive dominance (Shapiro & Varian, 1999). In other words, competition takes place on both the product and the network level. However, many firms have not yet incorporated both levels into their competitive strategy. For example, in the battle for the home video standard between *VHS* and *Betamax* that was described in section 2.6.5, *Sony* still competed on technical product quality and exclusive rights on technology.[37] In contrast *JVC*, the first supplier of the *VHS* system, took network effects into account. By providing licenses for *VHS* technology to other suppliers and by strongly stimulating the availability of complementary products, i.e., video movies, *JVC* created a strong network effect around the *VHS* system that still dominates the home video market today.

The network dimension of competition may become so important that any possible market inefficiencies at the product level may hardly matter. Customers might be prepared to accept lower quality on the product level if compensated by advantages on the network level. For example, in the home video market the *VHS* technology's image quality was supposed to be inferior to that of *Betamax*, i.e., at the product level, yet customers favored *VHS* because *VHS-compatible* movies were more widely available at video rental shops, i.e., at the network level. Suppliers often try to win the battle on the network level at the expense of losses on the product level. For example, both *Microsoft* and *Netscape* have been striving to dominate the Internet software market, i.e., at the network level, by offering their Internet browser software free of charge, i.e., at the product level.

Firms participating in the competitive battle between technologies have to take the aspects of network competition explicitly into account, e.g., availability of

[37] Liebowitz & Margolis (1994; 1999) argue that the claims for the technical superiority of the *Betamax* system were unjust, and that in fact *VHS* technology was qualitatively better. The discussion on this point has reached a deadlock. An extensive description of the case is given by Cusumano, Mylonadis & Rosenbloom (1992).

complementary products, compatibility of these products, size of the network or *installed base*, customer expectations with regard to the growth of the network (Shapiro & Varian, 1999). Product dimensions, such as high quality, low prices, or exclusive ownership of patents are just a 'green fee' for participation in this competitive battle.

4.4.3 Multiple possible equilibria

A second consequence of network and social interaction effects is that a battle for the technological standard occurs in the market, of which the outcome is not ex ante predictable (Shapiro & Varian, 1999). Instead of balanced equilibria, we see markets where the winner, be it a technology or the firm that sponsors it, takes the entire market or almost the entire market. Well-known examples are, again, the home video market, i.e., the *VHS-format*, computer operating systems, i.e., *Microsoft Windows*, and web browsers, i.e., *Microsoft Internet Explorer*. Standardization of technology is not only attractive for customers, but is also attractive for the supplier who sets the technological standard. Customers profit from standardization of technology through the compatibility of products. They act in their own interest by choosing products based on the most prevailing technology. Customers who have made their purchase will not easily switch to another technology, because of the investments and learning costs made to adopt this technology. Therefore, the firm that sets the technological standard may expect a rapidly growing group of loyal customers. This *installed base* enables the firm to profit optimally from scale and learning effects in its own development, production and marketing processes.

The mutually reinforcing consequences of network and social interaction often lead to a very asymmetrical distribution of market shares (Arthur, 1996). Often, the *winner takes all* and the loser gets nothing. An example of *winner-take-all* is *Microsoft Windows*, which dominates the market for computer operating systems. An example of *loser gets nothing* was *Sony's Betamax* technology after having lost the *VHS-Betamax* battle in the home video market. Firms losing the battle for the technological standard will either withdraw from the market or become late followers of the winning technological standard. Other well-known examples of battles for the technological standard are the personal computer standard, *Apple* versus *MS-DOS*, the word processor standard, *WordPerfect* versus *Microsoft Word*, Internet browser software, *Microsoft Internet Explorer* versus *Netscape Navigator*, digital cellular communication technology, *GSM* versus *CDMA* and the digital multimedia standard.

4.4.4 Lock-in

Lock-in describes a situation in which the cost of switching to another technology, even though it may be technically superior, is too large for the switch to take place. In the parallel case of technology battle this means that as one of the technologies gains an edge over the other, it may become increasingly popular and therefore eventually corner the market. The higher its pay-off, the more likely it will become *locked in* and the more likely any rival technology will become *locked out*. In the sequential case of technology battle there may also be a lock-in of the existing technology. When a new and better technology comes to the market, it may take a long time for this new technology to gain an edge over the old one. Or it may not happen at all. Arthur (1989) provides the following, simplified, example of a lock-in situation (see also figure 4.2):

U_A = *utility of technology A*
U_B = *utility of technology B*
i_A = *number of adopters of technology A*
i_B = *number of adopters of technology B*

$$U_A = f(i_A) = 10 + 0{,}1 i_A$$
$$U_B = f(i_B) = 4 + 0{,}3 i_B$$

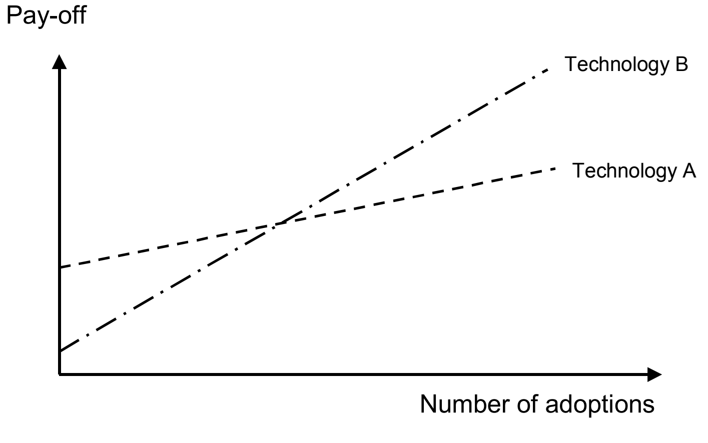

Figure 4-2: Arthur's (1989) example of a lock-in situation

Without foresight and discounting of pay-offs and without one technology being sponsored more than the other, rational agents will adopt technology *A*. In this case technology *A* that is chosen at the outset will become locked in. Of course, this is without counting future pay-offs. Future pay-offs determine the alternative first chosen, depending on height of the pay-off, discount rate, time horizon and degree of uncertainty. It might be conceived that, when alternative *A* has been adopted a number of times, alternative *B* appears to have more future potential. If the difference in future potential between alternatives *A* and *B* is large enough to offset the pay-offs from adoption of alternative *A*, the next adopter *i* might switch to alternative *B*.

Under assumptions of rationality and certainty, the alternative with the highest discounted pay-off will be chosen, of course dependent on time horizon and discount rate. When the discount rate is high, an alternative will be chosen that has a relatively high pay-off in the short term. This alternative may well become locked in as it is most often adopted. Another alternative will only be adopted if its discounted future pay-off more than offsets the sum of the discounted future pay-off of the alternative chosen at the outset and the accumulated pay-off of this alternative due to the number of adoptions to date. This depends on how fast in time a certain alternative is adopted. If adoption is very slow, a changeover to another alternative might well take place. If adoption is very fast, the alternative is more likely to become locked in.

A consequence of this self-reinforcing process is that once a network becomes dominant, customers and suppliers are locked in to it. This means that compared to new alternative technologies the network and the social interaction effects of the dominant technology are so large that customers and suppliers are not prepared to make the necessary investments to switch networks. In other words, the market will be 'frozen' in this particular technological standard and a newer and better technology will find it extremely difficult to break in. Here also, the debate goes whether this represents market failure or inefficiency. From the manager's perspective, this discussion may not be that productive and it may suffice to observe that it may be very difficult to enter the market with a new technology when the existing technology still has the advantage of a large installed base.

Once a solution is reached, it can be extremely difficult to exit from and difficult to break in for competing solutions. Lock-in of a technology therefore becomes a serious barrier to entry for firms that are sponsors of or hold licenses to the locked out technology. This is of course very attractive for firms sponsoring or having licenses to the locked in technology, because it creates a kind of monopoly situation, enabling these firms to appropriate monopoly rents.

4.4.5 Excess inertia and excess momentum

The interplay between network and social interaction effects has important consequences for the development pattern in the market. In the battle for the technological standard the subjective expectations that suppliers and customers have of market outcomes, i.e., which standard will eventually dominate the market, play an important part. Suppliers' and customers' expectations depend on (1) the installed base and, (2) the expected behavior of other customers and suppliers. All these expectations are mutually dependent and adaptive, which means that they constantly change when new information becomes available. The dynamics of customers' and suppliers' expectations can cause extremely complex or even chaotic market patterns (Hommes, 1995). These patterns are difficult to interpret, virtually unpredictable and therefore hard to manage.

The uncertainty about market developments may cause a market stalemate, i.e., excess inertia, in which both suppliers and customers wait for others to decide first (Farrell & Saloner, 1985; 1986). This impedes a collective switch from an existing technological standard to a possibly superior new standard of technology. This may result in none of the competing technologies 'taking off'. Alternatively, it may cause a situation of explosive growth, i.e., excess momentum, in which the investments of some suppliers and customers lead to massive investments on behalf of others. Ultimately, the market may quickly *lock in* to a technological standard, which, at that time, is possibly still inferior (Farrell & Saloner, 1985; 1986).

Here, the concept of *critical mass* is of importance. Critical mass is reached when, for the individual adopting agent, the network effect is so large that it always outweighs a possible negative inherent valuation of a technology. As soon as a technological network reaches critical mass in the perception of customers and suppliers, they expect that this network will dominate or at least maintain itself in the market, causing it to become a relatively safe network to invest in. When a customer or a supplier decides to make this investment by purchasing or introducing a product, the network increases and with it the probability that it will eventually dominate the market. This induces other customers and suppliers to invest in the network, which sets a positive feedback process in motion. Katz & Shapiro (1994) state that, because of the strong positive feedback elements of the network effect, technology competition is prone to 'tipping', which is the tendency for one technology to achieve ever-increasing popularity once it has gained an initial edge.

4.4.6 Path dependence

Path dependence means that the early history of market shares, often the consequence of small events or chance circumstances, can determine to a large extent which solution prevails (Arthur, 1989). It is also referred to as *irreversibility*, or *non-ergodicity*.

The mutual influence of the network effects and social interaction effects leads to irregular movements in the market. Although these movements are unpredictable, they are in retrospect characterized by path dependence (Arthur, 1989). Path dependence means that very small differences in starting conditions may have far-reaching consequences with regard to the final market outcomes; because of path dependence, a small initial competitive advantage may increase continuously. Conversely, firms that incur small early disadvantages may find themselves increasingly disadvantaged with respect to their competitors.

An example of path dependence is Microsoft's position in the market of personal computer operating systems. In the early 1980s Microsoft became the supplier of the operating system for *IBM* PC's, *MS-DOS*, almost by coincidence. Owing to the strong network and social interaction effects in the PC-market, an *IBM* PC with an *MS-DOS* operating system became the market standard. In the rapidly growing PC-market an increasing number of *MS-DOS* copies were sold, which enabled *Microsoft* to realize enormous scale and learning effects. This enabled them continuously to improve existing product versions and to develop new ones. Thus, improved *MS-DOS* versions remained the standard operating system for most PC's, until they were replaced by *Microsoft Windows*. Moreover, because of the complementary nature of the products *Microsoft* has built a dominant position in the markets for word-processing, spreadsheet, database, presentation and internet browsing software. *Microsoft* has become the largest software firm in the world by optimally capitalizing on the different mechanisms of increasing returns, a typical example of how a small initial advantage was continuously reinforced by smart management under conditions of increasing returns.

4.4.7 Market imperfections and inefficiency?

The consequences of network effects and social interaction effects for market behavior and market outcomes are regarded by some as market imperfections or market inefficiencies, e.g., Arthur (1989), Farrell & Saloner (1985; 1986), Katz & Shapiro (1985; 1986). Katz & Shapiro (1986) find the following results:

- compatibility tends to be under-supplied by the market, but excessive standardization can occur
- in the absence of sponsors, the technology superior today has a strategic advantage and is likely to dominate the market
- when one of two rival technologies is sponsored, that technology has a strategic advantage and may be adopted even if it is inferior
- when two competing technologies both are sponsored, the technology that will be superior tomorrow has a strategic advantage

All these consequences are instances of market imperfections. From an economic perspective this is sometimes seen as a problem. The market does not seem to work so perfectly as the general, or even the partial, equilibrium models want us to believe. This is nothing new, it was already recognized by Marshall at the end of the 19th century (1890, book IV, chapter 13 and Appendix H): "If one technology is inherently better than the other (according to measures of economic welfare), but has 'bad luck' in gaining early adherents, the eventual market outcome may not be of maximum possible benefit."

Still, the conclusion that market-based increasing returns may cause market imperfections or inefficiencies is the cause of a fierce debate between proponents and critics of increasing returns. The argument of the proponents is that increasing returns is pervasive in at least an important part of modern economic systems and that this severely impacts the efficiency of the market (e.g., Arthur, 1989).

The critics argue that increasing returns mechanisms, where they do exist, are limited to very special cases and that by implication they do not significantly impact the general equilibrium model, e.g., Liebowitz & Margolis (1994; 1995; 1999). Liebowitz' & Margolis' (1994) approach is to distinguish *network effects* and *network externalities*. They define *network effects* as "The circumstance in which the net value of an action […] is affected by the number of agents taking equivalent actions […]" (1994, p.135). *Network externalities* they define as "[…] a specific kind of network effect in which the equilibrium exhibits unexploited gains from trade regarding network participation." They then proceed to eventually conclude: "Although network effects are pervasive in the economy, we see scant evidence of the existence of network externalities." (1994, p.149).

Liebowitz & Margolis (1995) follow the same kind of approach with respect to path dependence. They distinguish between three degrees of path dependence. The first one is omnipresent, but does not imply inefficiency. The second one occurs because of imperfect information, which leads to decisions that may seem inefficient in retrospect but that were efficient at that time given the available information when they were taken. The third one leads to outcomes that are inefficient but may be remediable. Liebowitz & Margolis (1995) define only this *third degree path dependence* as really inefficient and they conclude that it is extremely rare.

While this discussion has its merits, we will not continue these arguments here. Rather, we adhere to our chosen management perspective, which implies that we deal here with network effects, social interaction effects and path dependence as we defined them, *not with network externalities or third degree path dependence* as Liebowitz & Margolis (1994, 1995, 1999) define them. We conclude that network effects and social interaction effects can have major impact on market behavior and market outcomes and that this creates opportunities for firms to extend their production, realize scale and learning effects and eventually appropriate economic rents. Assuming a managerial point of view, it would indeed be naïve to assume perfect markets. Rather, firms would prefer to have imperfect markets to be able to appropriate economic rents. The question then becomes: How can the firm act strategically in such a way to maximize these rents?

Here also, the opinions diverge, as can be shown in, e.g., the case of *Microsoft*. Some, e.g., Liebowitz & Margolis (1999) argue that the market is efficient and that *Microsoft* has just been smart enough to seize the right opportunities. They argue that new alternatives like *Linux* are becoming available that will endanger *Microsoft's* future position. Thus, the market will do its work and government or courts should not intervene. Others argue that the markets works imperfectly, that *Microsoft* has made misuse of these market imperfections by blocking competition and new entrants and that therefore the government or the courts should intervene.

4.5 The market potential for scale and learning effects

The market outcomes due to the presence of network effects and social interaction effects have important consequences for firms operating in these markets. We may conceptualize these market outcomes as creating a market potential, that individual firms may either exploit or not.

There are multiple ways in which the market outcomes discussed in the previous section can create such a market potential. First, the competition at the network level creates a market potential beyond that of the single product. Firms can offer products in the market that are complementary to the products of other firms, e.g., a firm providing printers that are complementary to another firm's computers. The success of the main product will rub off on the success of the complementary product, thus creating a potential for realizing scale effects. Firms can also offer in the market an entire range of their own complementary products, e.g., a firm providing printers, inkjet cartridges and inkjet paper. This may create a potential for firms to realize economies of scope (see section 5.2.2).

Second, the *winner-take-all* effect means that the potential market for products based on the winning technology may be very large. This creates the possibility to realize the largest scale of production for the products based on this technology, enabling scale effects. Conversely, the potential market for a product based on the loosing technology will be very small.

Third, the lock-in effect makes that a market potential may be very durable, enabling subsequent scale effects and enabling the optimal exploitation of learning effects. Once customers have made their purchase, they will not easily switch to another technology, because of the investments and learning costs related to this specific technology (Arthur, 1989). Therefore the supplier sponsoring this dominant technology *(shaper)* may expect a rapidly growing group of loyal customers *(the installed base)*. The suppliers who acquire licenses *(followers)* may also expect a large group of potential customers for the product they supply on the basis of this technology. Conversely, the potential market for products based on the technology that is locked out may be very small and unlikely to improve.

Fourth, excess inertia means that the market potential for the old technology may remain high while that for the new technology may not come off. Conversely, excess momentum means that not only the scale of production for products based on the technology can be quickly increased, enabling scale effects, but that also the cumulative production of these products increases fast, enabling learning effects.

Fifth, path dependence may influence the market potential in the sense that a very small initial advantage may result in a very large potential for scale and learning effects, or vice versa.

4.6 Conclusions

In this chapter we looked at the market-based mechanisms of increasing returns and their consequences, defining them as determinants of the market structure aspect of the structure-conduct-performance paradigm.

The market-based mechanisms of increasing returns are network effects and social interaction effects. Both network effects and social interaction effects possess the characteristic of generating positive feedbacks in technology and product adoption. We conclude that important influencing conditions of the extent of this positive feedback effect in the market are the degree and structure of economic and social interdependence, i.e., the structure of the network, the nature of the product, complementarity, substitutability and compatibility of the product and the technology.

We also conclude that the presence of network effects and social interaction effects has important consequences for the dynamics and outcomes of the market and will create a potential for scale and learning effects in the market that individual firms may realize. In the market, a technology battle emerges, that has at least five distinct properties: (1) competition takes place on the network level, not on the product level, (2) there are multiple possible equilibrium outcomes of the competitive process, (3) the market can *lock in* to a technology, (4) there can be excess inertia or excess momentum in the market and (5) the market can be *path dependent*. The implication is that a certain degree of market inefficiency may emerge. We conclude that the properties of the technology battle will create a market potential for scale and learning effects that may enable firms to extend the scale of their production, thereby realizing scale and learning effects and eventually appropriate monopoly rents. The scale and learning effects and the ways in which firms can realize these scale and learning effects and boost their performance will be discussed in chapter five.

5. FIRM-BASED INCREASING RETURNS

In this chapter we deal with the firm behavior part of increasing returns. Specifically we address the firm-based mechanisms of increasing returns, i.e., scale effects and learning effects, the conditions influencing these effects, the ways firms can realize the potential for scale and learning effects and the ways firms can exploit scale and learning effects to enhance their performance.

In addressing the firm-based mechanisms of increasing returns in this chapter, we provide the second part of the answer to the first research question: *How can market-based and firm-based mechanisms of increasing returns be theoretically specified and defined?* and we provide a partial content validation for the second research question: *How can market-based and firm-based mechanisms of increasing returns be measured?*

The main thrust of this chapter is that the presence of the market-based mechanisms of increasing returns will cause a market potential for scale and learning effects and that firms can realize this potential in various ways. The way in which firms realize scale effects and learning effects represents the firm conduct aspect of the chosen *structure-conduct-performance paradigm*. Only by realizing the potential for scale and learning effects do firms close the positive feedback loop, and can we speak of increasing returns.

We concluded from the literature analysis (chapter three), that the two dominant mechanisms of firm-based increasing returns are scale effects and learning effects. Before we discuss these, we start this chapter by clarifying the distinction between *increasing returns* and *increasing returns to scale* in section one. We then proceed in sections two and three with the definitions and theoretical conceptualizations of the firm-based mechanisms of increasing returns. The conditions that influence the occurrence and the intensity of these effects are addressed in section four. The way in which firms can realize scale and learning effects, i.e., how they can internalize the market potential for scale and learning effects, is discussed in section five. In section six we address the way in which firms can exploit the realized scale and learning effects to close the positive feedback loop and how firms can increase their product and organizational performance. Conclusions are given in section seven.

5.1 Increasing returns and increasing returns to scale

Before we proceed with the discussion of the *mechanisms* of firm-based increasing returns, i.e. scale effects and learning effects, we address some definition issues about what we mean by *firm-based increasing returns*, relative to the economic conventions of *increasing returns* and *increasing returns to scale*.

An economic system, e.g., a country, a firm or a business unit, may be regarded as a set of transformation processes. Input is everything that is put into the process, e.g., land, labor, capital or data, and output is everything that comes out of the process, e.g., goods, services, information or knowledge. A function can be drawn which relates the input factors to the output factors. This transformation function is typically an *S-shaped* curve (see figure 5.1).[38] To the right of the inflection point[39], output rises less than proportionally with input. Here we talk *in general* about firm-based diminishing returns. To the left of the point of inflection, output rises more than proportionally with input. This is what we refer to *in general* as firm-based increasing returns.

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[38] Mathematically this is a third degree equation of the form $Y = aX + bX^2 - cX^3$, in which Y is the collection of outputs and X is the collection of inputs.

[39] An inflection point is the point at which the derivative function reaches an extreme value (Chiang, 1984). In this case, starting from the origin, the derivative function keeps increasing until the inflection point is reached, after which it decreases. The inflection point is therefore the extreme value of the derivative function. Wolfe (1929) refers to this as the *point of diminishing incremental return*.

Firm-based increasing returns

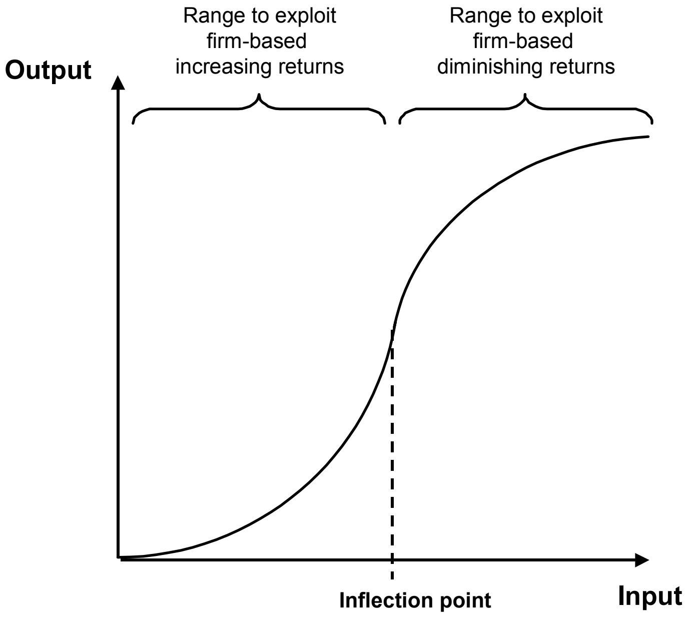

Figure 5-1: Typical transformation function

This terminology may cause confusion though, as in economic literature two forms of increasing returns are distinguished. The first is referred to as *increasing returns to scale*, the second as *increasing returns*. In the economic literature, these terms are quite precisely defined.

5.1.1 Increasing returns to scale

In the economic convention, we speak of *increasing returns to scale* when the outputs rise more than proportionally with an increase of all the input factors to the same amount. See figure 5.2. For example, if output $Y = f\,(L, K)$, i.e., there are two input factors Labor *(L)* and Capital *(K),* we have increasing returns to scale if $Y = f\,(a*L, a*K)$ is larger than $a*Y = f\,(L, K)$, when $a>1$. Increasing returns to scale is therefore a characteristic of the production process.

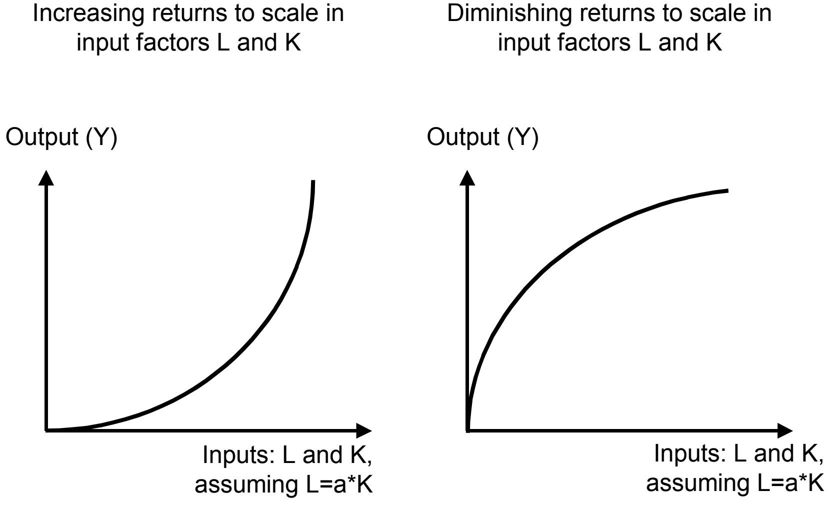

Figure 5-2: Returns to scale

More formally, if the general formulation of a firm's transformation function is $Y = f(L, K)$, then we have increasing returns to scale if the second derivative of this transformation function with respect to the whole bundle of input factors is positive (see table 5.1).

	First derivative of the transformation function	Second derivative of the transformation function
Diminishing returns to scale	$d(Y)/d(L, K) > 0$	$d^2(Y)/d(L, K)^2 < 0$
Constant returns to scale	$d(Y)/d(L, K) > 0$	$d^2(Y)/d(L, K)^2 = 0$
Increasing returns to scale	$d(Y)/d(L, K) > 0$	$d^2(Y)/d(L, K)^2 > 0$

Table 5.1: Returns to scale

It is important to note that the economic definition of *increasing returns to scale* forms the basis of, but is not exactly equal to, our definition of *firm-based mechanisms of increasing returns*, i.e., scale and learning effects, as provided in this thesis; see also sections 5.2 and 5.3.

5.1.2 Increasing returns

If *only one* of the input factors is increased, while the other ones are held constant, we are dealing with the *marginal product* of the varying input factor. The marginal product is the extra output from adding one more unit of this input factor; see figure 5.3. For example, if output $Y = f(L, K)$, the marginal product of factor L is equal to the partial derivative of Y to L: $\partial Y/\partial L$. This is also denoted as $MP_L(L, K)$. The marginal product is increasing if $dMP_L/dL > 0$. Economically, this is called *increasing returns*, *increasing returns to the margin*, or, most correctly, *increasing returns to input factor L*. Increasing returns in this definition is therefore a characteristic of an input factor.

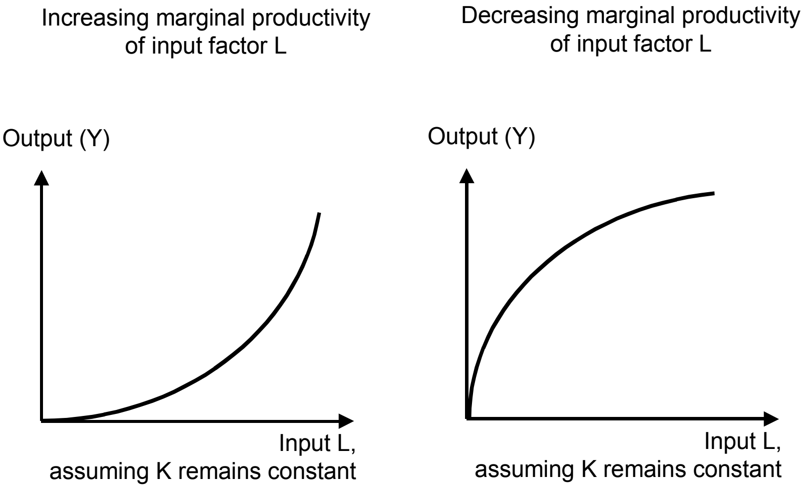

Figure 5-3: Marginal productivity

It is important to note that the definition of increasing returns as *increasing marginal productivity* is *not* the definition of *firm-based increasing returns* that we adopt in this thesis.

We therefore proceed in the next sections with the mechanisms of firm-based increasing returns, i.e., scale effects and learning effects, as they are used in this thesis.

5.2 Scale effects

5.2.1 Defining scale effects

The first and most widely known mechanism of firm-based increasing returns is *scale effects*. Scale effects are closely related to, but more broadly defined than *increasing returns to scale* (see section 5.1.1). Scale effects occur when there is a positive static relationship between the size of output of the firm and its productivity. This is the productivity of the entire bundle of input factors, regardless of any shifts in the composition of this bundle. This productivity can be measured in units and is then reflected in an upward slope of the production function. When this productivity is measured in financial terms it is reflected in the downward slope of the firm's average total cost curve.[40] See figure 5.4.

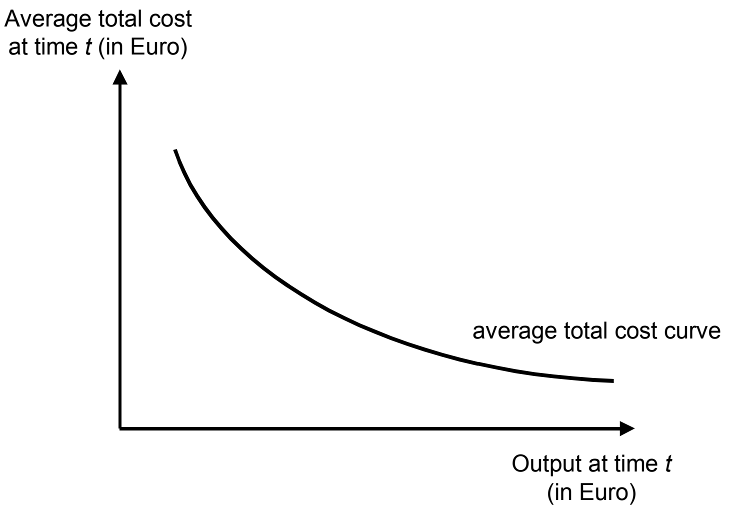

Figure 5-4: Average Total Cost curve

A distinction can be made between scale effects with respect to fixed costs and variable costs. Scale effects with respect to fixed costs mean that the fixed costs of the input factors are spread over as large an output as possible. In other words, the larger the number of products, the smaller the average fixed cost. The realization of scale effects with respect to fixed costs is often considered the most important driver of competitive advantage (Scherer & Ross, 1990). Scale effects with respect to variable costs means that the variable costs will be reduced as a consequence of the

[40] Note that this function has financial terms on the horizontal and the vertical axes.

extended scale of production, e.g., because the input factors embedded in the product may become cheaper when bought in larger quantities.

Note that the scale effect in the transformation process itself is *not* increasing returns *as we defined it in section 1.5*, or, stronger, that it is in fact diminishing returns: the incremental scale advantage becomes smaller as output rises; see also our figure 5.8 and Scherer & Ross (1990). Nevertheless, scale advantages are a powerful mechanism of firm-based increasing returns. The firm can use the cost advantage to lower the market prices of its products, which, under conditions, will lead to higher sales.[41] The firm may also improve the value proposition to its customers, with heterogeneous but substitutable products, which produces similar effects, or it may use a combination of lower prices and improved value proposition. In both cases, the result will be larger sales, which in turn requires larger production volumes, which result in even stronger scale effects. This means that scale effects, when properly exploited may result in positive feedback in the firm.

5.2.2 Economies of scale, scope and sequence

Often a distinction is made between economies of scale[42] and economies of scope. Economies of scale are related to the number of units of the same product produced, i.e., it is cheaper to produce more units of the same product. Economies of scope are related to the variety of different products produced, i.e., it is cheaper to produce different products together in one plant than separately (Scherer & Ross, 1990). Whereas economies of scale refer to lower direct, i.e., product-specific and indirect average costs as the number of units of the same product produced increases, economies of scope refer to lower indirect, i.e., plant-specific or firm-specific overhead costs, average costs as the number of different products increases (Scherer & Ross, 1990).

In economic terms, both economies of scale and economies of scope mean that the cost function is sub-additive (Tirole, 1988), i.e.:

$$C(q_1) + C(q_2) > C(q_1+q_2)$$

[41] These conditions are (1) sufficient market demand, (2) sufficient price elasticity, i.e., the price elasticity of demand has to be smaller than *–1* and (3) improvement of the firm's competitive position, i.e., if it can reduce prices by *5%*, but the competition can reduce prices by *10%*, the firm will likely not gain much.

[42] Note that *economies of scale* is defined differently here than *scale effects* in section 5.2.1.

Here, C stands for cost, q_1 stands for the quantity of product *1* and q_2 stands for the quantity of product *2*.

This means that it is cheaper to produce the products together than separately. The formula holds both when q_1 and q_2 are the same, homogeneous products, i.e., economies of scale, as when q_1 and q_2 are different products, i.e., economies of scope.

Spulber (1993, p.544) adds a third kind of economies, namely economies of sequence. These are related to cost savings from vertical integration. In formal terms:

$$C^U(x) + C^D(q,x) > C(q)$$

Where C^U is the cost of the upstream firm, x is a vector of intermediate inputs, C^D is the cost of the downstream firm, q is the quantity of final product and C is the cost of the vertically integrated firm.

It is clear that in terms of cost functions, economies of scale, economies of scope and economies of sequences can be quite precisely defined. In management practice, however, it may be much more difficult to distinguish between these economies. For example: Does the necessity of appointing another executive manager spring from the increased scale of production, from the increased variety of production, or from the increase of vertical integration? It is plausible that it will be a bit of all three. There are many examples of costs that firms have to make to sustain their operations, but that do not uniquely vary with the scale of production of a single product, neither with the number of different products, nor with the vertical integration, but rather, more holistically, with the firm's entire scale of operations. We will therefore in our further analysis choose to concentrate on *scale effects* as defined in section 5.2.1, which refer exactly to this broad relationship between costs and size of output.

5.3 Learning effects

5.3.1 Defining learning effects

A second mechanism of firm-based increasing returns is learning effects. This means that there is a positive *dynamic relationship* between the growth of output and the growth of productivity (Amit, 1986; Kaldor, 1966).

Firm-based increasing returns

We can distinguish between scale and learning effects by taking the concept of static and dynamic production functions. A change of scale would mean a movement along the static production function. This is what firms routinely do on a day-to-day basis: as output varies they use just a little bit less or a little bit more of their existing input factors.[43] Learning, i.e., a change of knowledge would mean a shift of the static production function. In the long run, a line could be drawn through the static-run production functions, yielding the dynamic production function.

Again, when we measure productivity in financial terms, we are dealing with *cost functions* rather than *production functions*. Learning effects are reflected in the downward shift of the firm's short-term average total cost function or in the downward slope of the firm's long-term average total cost function (Amit, 1986).[44] See figures 5.5 and 5.6.

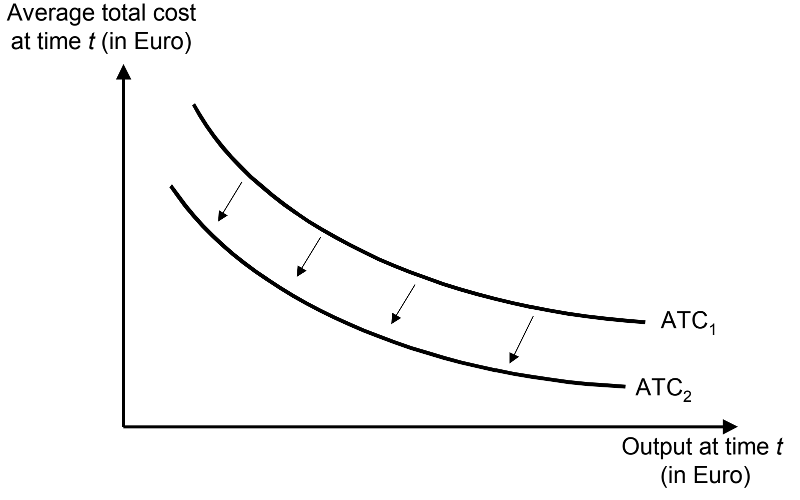

Figure 5-5: Learning effects as the downward shift of the short-run Average Total Cost curve

[43] Note that the time frame is important here: in the longer run, there will always be a combination of scale and learning effects.
[44] Note that both curves have financial terms on the horizontal and the vertical axes.

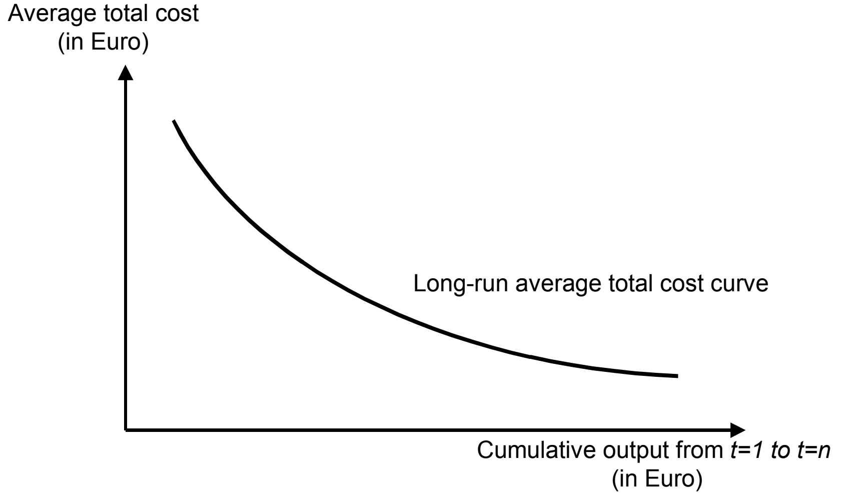

Figure 5-6: Learning effects as the downward slope of the long-run Average Total Cost curve

Learning results in a more efficient use of the input factors.[45] In other words, the same output can be produced with less input, independent of the scale of production at that specific moment, i.e., independent of scale effects. Learning may take place in different forms. According to Levy (1965) it may be the result of conscious managerial action, i.e., *planned or induced learning*, of unexpectedly acquired external information, i.e., *random or exogenous learning*, or it may be the result of automatic improvements as employees become more familiar with their tasks, i.e., *autonomous learning*.

5.3.2 Induced learning effects

Induced learning results from conscious managerial action to improve the productivity of the input factors (Levy, 1965; Li & Rajagopalan, 1998). This can take a number of forms:

- improved process efficiency because of conscious process (re)design or improvement through industrial engineering or process R&D, or because of meticulous process planning

[45] Note that learning does not just affect labor, but that it affects the entire bundle of production factors.

- improved skill, improved efforts or improved intelligence of labor, because of formal training, the hiring of better qualified employees or the selection of the right employees for the jobs that suit them
- changing the mix of input factors used for a specific transformation process, i.e., radical innovation as defined by Zegveld (2000)

5.3.3 Exogenous learning effects

Exogenous learning results from causes that are external to the firm. They include:

- external economies as, e.g., progress in general schooling and education of employees, increased availability of labor potential of the desired quality and size (see, e.g., Verdoorn, 1952).
- externalities that are the consequence of knowledge spillovers (see, e.g., Romer, 1986; Thornton & Thompson, 2001).
- exogenous technological change. Technological change may affect the quality of the product, the methods of organizing production and the quality and/or prices of the capital goods and materials used (see, e.g., Kennedy, 1971). Technological change may be regarded as exogenous or endogenous. Neo-classical growth models usually assume technological change takes place outside the economic system. The technological change is therefore exogenous, but influences the economic system by a stream of innovations that become available 'out of the blue' and that are reflected in better ways of organizing production or in improved quality of capital goods (see, e.g. Solow, 1957).

5.3.4 Autonomous learning effects

Autonomous learning effects involve the automatic improvement in productivity of input factors as accumulated production increases. It is often referred to as *learning-by-doing* (after Arrow, 1962), or as the *experience curve* (Dolan & Jeuland, 1981; Day & Montgomery, 1983; Alberts, 1989).

In Arrow's (1962) view, learning is a product of experience, or learning-by-doing, which means that (1) the level of productivity is a function of cumulative output and (2) productivity grows faster the faster output expands. In other words, learning effects cause productivity to rise in response to, or as a by-product of, the increase in total output. Actually it goes back to an observation made by Smith (1776, I, I) that: "This great increase of the quantity of work, which, in consequence of the division of labour, the same number of people are capable of performing, is owing to three different circumstances; first, to the increase of dexterity in every particular workman; secondly to the saving of time which is commonly lost in passing from one species of work to another; and lastly, to the invention of a great number of machines which facilitate and abridge labour, and enable one man to do the work of many."

The circumstances one and three mentioned by Smith are in fact autonomous learning effects. In dedicating labor to one simple task, the workman learns to perform this task at the highest level of efficiency. In other words, by performing the same task more often, the efficiency of labor itself increases. Moreover, when according to Smith the whole attention of the laborer is directed towards that single task, he is much more likely to discover easier ways, better methods and improved machines.

We see here the two essential effects of autonomous learning: (1) increased efficiency of doing the original task and (2) increased knowledge of how to structure the transformation process.

The first effect relates to the idea of the learning curve, which measures the fall of cost, as employees get more dexterous in their jobs. The *learning curve* is conceptually distinguished for the *experience curve*. Whereas the learning curve usually refers only to labor costs and reflects a kind of short-run learning-by-doing (Hall & Howell, 1985), the experience curve typically involves total cost and also includes technological innovation as a result of experience (Day & Montgomery, 1983; Albert, 1989).

That brings us to the second effect, which is known as endogenous technological change, e.g., Romer (1986, 1990b). Whereas exogenous technological change comes as it were 'out of the blue', endogenous technological change takes place within the economic system. It is reflected in the improvement of either labor or capital due to increasing returns to knowledge application (Romer, 1986, 1990b; Lucas, 1988). The basic thrust is that economic transformation processes generate new information and knowledge as additional output. This additional information and knowledge output may subsequently be used as additional input in the process to develop new products or improve existing ones. A good example is the market for cellular communication networks. The installation of such networks is an activity in which considerable learning effects occur. Each installed network generates new knowledge for improving both the future efficiency, i.e., lower costs, and the future effectiveness, i.e., higher quality, of the network installation process. Consequently firms that have installed large numbers of such networks are creating a growing information and knowledge edge over firms that have installed fewer networks.

5.3.5 The relation between scale effects and learning effects

The contention that learning effects cause productivity to rise in response to, or as a by-product of, the increase in total output is, in fact, nothing else than the famous dictum of Smith (1776) that the returns per unit of labor depend on the extent of specialization and division of labor. In Smith's vision, the larger the extent of the market, the more specialization becomes possible, the higher the productivity. Kaldor (1966) states that Smith (1776) as well as Marshall (1890) and Young (1928) stress the interplay of static and dynamic factors that cause returns to increase. Greater division of labor is not only a scale factor; it also generates improvements of skill and know-how that we refer to as learning effects. Kaldor (1966, p.288): "We cannot isolate the influence of economies of large-scale production due to indivisibilities of various kinds and which are in principle reversible, from such changes in technology associated with a process of expansion which are not reversible." We can therefore conclude that increasing volumes of output cause both scale and learning effects, that these effects are intimately related and that they may therefore be difficult to disentangle.

5.4 Extent of scale and learning effects

Both scale and learning effects are influenced by factors that determine the extent to which they can be realized. We will discuss the most important influencing factors of scale effects and of learning effects below, then we will turn to the influence of information and knowledge intensity on the extent of scale and learning effects.

5.4.1 Extent of scale effects

A proxy often used for cost structure is the ratio between fixed cost and variable cost. With high fixed and low variable cost, the average cost curve runs extremely steep. Even assuming the absence of scale effects with respect to the variable cost, this means that with growing production the firm will realize large scale effects. See figure 5.7.

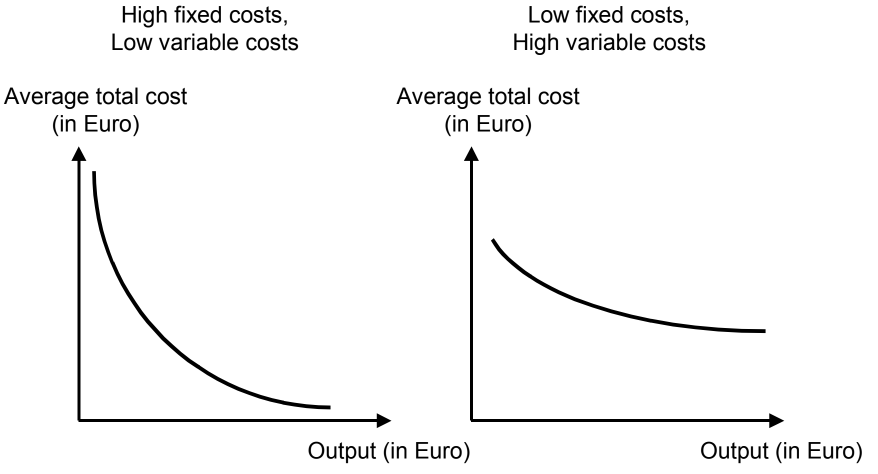

Figure 5-7: Scale effects for different ratios between fixed and variable costs

The cost structure of a product is a reflection of the composition of the bundle of input factors used to produce this product and of the way the firm is able to adapt the cost of those factors. First, different input factors have different cost structures, e.g., information and knowledge intensive products are often characterized by high fixed (development) costs and low variable costs. These variable costs might even decrease with larger production volumes (Shapiro & Varian, 1998).[46] Computer programs are a good example of products that have such a cost structure. These products require high development cost, but very low reproduction and distribution costs, use of the Internet can reduce the costs of reproduction and distribution to almost zero. The consequence of such a cost structure is that the average total cost curve will descend steeply as the production volume increases. Such a cost structure offers large possibilities for gathering scale advantages (see section 5.2.1). Conversely, intermediate inputs such as materials often involve low fixed costs, e.g., maybe only the wages of the purchaser, and high variable costs.

Second, the firm may be able to adapt the cost structure of an input factor. It might e.g. hire employees for longer periods, treating labor as fixed cost, but it might also

[46] Products from capital and physical labor-intensive business processes often exhibit increasing variable cost with increasing production volumes. This causes the familiar *U-shaped* form of the average cost curve.

reward its employees on the basis of hours worked or units produced, treating labor as a variable cost.

There are a number of inherent limitations to scale effects. We mention five of the most important ones; although this enumeration not be exhaustive (see also Scherer & Ross, 1990). First, when output volume becomes very large, the extra cost advantage of extending production by one unit becomes trivial. This holds true for even the most skewed ratio between fixed and variable costs. See figure 5.8.

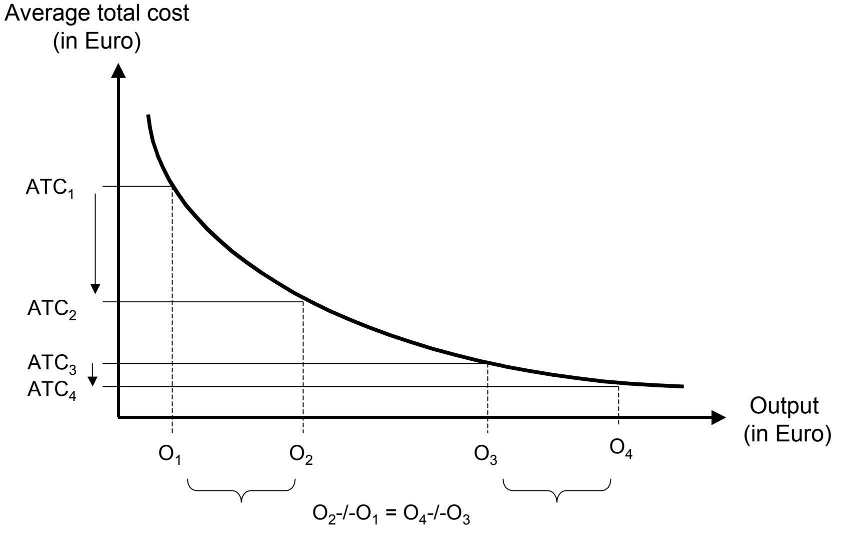

Figure 5-8: Limit of the scale effect

When output volume becomes very large, scale effects on variable costs may no longer hold. While the move from smaller volumes to larger volumes may deliver large rebates with purchasing, effectively reducing the price, the move to still larger volumes may put such a demand strain on the market that it may in effect raise prices instead of lowering them.

Second, new investments will be needed eventually, e.g., when a plant is at maximum capacity, and this imposes a limit on further realization of scale effects on this plant's output. A new plant will have to be built to extend production, which may also realize scale effects up to its maximum capacity, but not any further. We may argue that the second plant may use the same canteen, the same personnel or accounting department, etcetera, and that this may enable further scale effects, but we may also argue the opposite, namely that a two-plant operation may not require less, but more overhead. This brings us to the next point.

Third, as the firm grows bigger, firm coordination costs will rise. Lines of communication become longer and the firm will need more layers of management. This not only increases cost, it also makes the organization less agile, which is a huge problem when the firm operates in unpredictable and volatile environments. Many of the envisaged scale advantages of big mergers do not materialize, exactly because of this effect.

Fourth, firms will run into the limits of the extent of the market, i.e., the maximum number of products that can ultimately be sold profitably in the market. In many markets the cost for delivering products to the customer or for marketing will rise as physical distance increases, e.g., when a firm has a plant in The Netherlands, it will likely focus first on the Dutch market. As it starts to open up new markets that are further away, there may come a point at which the extra gains from opening up a market and selling products no longer outweigh the marketing and distribution cost involved. It will be clear that this is different for different firms and for different products. Firms like, e.g., *Heineken* and *Coca-Cola* seem to be able to market and distribute their products to the most desolate place on earth, because even there the local market for their products is large enough.

The impact of physical distance is strongly diminishing with the spread of the Internet. The Internet makes it possible to market and sell products worldwide through one website, instead of a network of thousands of local stores. The Internet makes distribution of information products, e.g., software or music, more efficient, reducing the variable costs of distribution for these products to almost zero. This significantly increases the *extent of the market*, though there are still limits. Even software that is given away ultimately runs into the limit of the number of possible users, i.e., the number of people who have a computer at their disposal.

Fifth, customers tend to become increasingly heterogeneous in their buying behavior. They demand more product variety, more customization and the suppliers of products are offering this. This individualization and customization of products and services causes a loss of potential economies of scale (Van Asseldonk, 1998). Firms hope to overcome the loss of economies of scale by increasing their economies of scope, i.e., they hope that offering larger variety will enable them to charge higher prices, so that total output in terms of turnover increases. Yet often the extra cost of customizing products, i.e. the *cost of complexity*, or diminishing returns to scope, more than offsets the advantages gained.

Concluding, at some point, diseconomies of scale will arise, overpowering the scale effects. Scherer & Ross (1990, p.104): "… whenever increasing doses of variable inputs (…) are used in combination with some fixed input, sooner or later diminishing marginal returns take hold." This makes that average cost will eventually rise, creating the familiar *U-shaped* cost curve. Scherer & Ross (1990, p.102) observe that "Realisation of scale economies is subject to diminishing returns." This is a very important observation, reflecting the core of our argument that scale effects are actually different from increasing returns. Only if the firm has the capabilities to exploit the scale effects and put them to use may the result become *increasing returns*, or the closing of the positive feedback loop.

5.4.2 Extent of learning effects

The extent of *induced learning effects* is limited by three factors. First, there is an end to better designing and planning of processes. Eventually, the cost and effort of improving the process beyond a certain level will become so high that the marginal benefits will decrease. This is especially visible in the realm of planning. Industrial processes can be optimized for efficient use of input factors by careful process planning. For example, the waiting time for a newly ordered car may easily be two months. The car factory however needs only one day to assemble it and, including subassemblies and transport, the total operation time is less than a week. The operational process is optimized for efficiency. The rest of the time the order for the new car is held until it can be fitted into this optimal production planning. This procedure works fine as long as the competitors cannot do it any faster and as long as the customers are willing to wait for their cars. In a lot of industries however, customers are no longer willing to wait and there may be a competitor who can deliver faster. In such industries, the planning required to meet customer wishes on the one hand and to attain optimal process efficiency at the other, will cost so much and need so much effort, that it nullifies any gain in process efficiency. In this case, the combined efficiency of planning and operations is no better than that of a craft process, where nothing is planned and nothing is optimized for efficiency (see also Van Asseldonk, 1988).

Second, there is a limit to the improvement of skills and intelligence to be gained by training or by hiring of better employees. Here also, the cost and effort spent in training people will eventually cancel out the improvements made possible. This may be because there are limits to the absorptive capacity of people, or because the firm runs into the limits of efficiency improvement. For example, when efficiency is already very high, compared to other firms in the industry, it may not pay to put a lot of effort into training people in order to achieve a further efficiency improvement of *0.1%.* The hiring of better people may also run into limits, either because it takes too much management time and effort to find exactly the right people, or because the concessions that have to be made to these exactly right people, e.g., by paying them high salaries, will cancel out the expected gains.

Third there are limits to shifts that can be made in the mix of input factors used in transformation processes. The substitution of capital for labor is a classical explanation of the increase of labor productivity (see, e.g., Salter, 1960; Kennedy, 1971). The obvious limits to this are, firstly, that this kind of substitution may not always result in productivity improvement. A well-known case is the enormous investments made in information technology in the past decades, that made Solow (1987) remark: “You can see the computer age everywhere but in the productivity statistics”. As second limit is that some activities simply do not lend themselves to execution by a machine, or when they do this machine would be prohibitively expensive. An example is the hype around flexible production automation and robotics in the 1980’s. These super-expensive machines often failed significantly to improve efficiency, because the bottleneck was not in the machine, but in the organization of the production process around it, as became painfully clear from the success of the much simpler Japanese production techniques (see, e.g., Womack, Jones & Roos, 1990).

The limits to the extent of exogenous learning effects are different from those to induced learning. For the pay-offs of external improvement of skills and education of employees much the same argument holds as for the second limit to induced learning effects. The big difference is in the bearing of the cost of these improvements. These costs are to a large part not incurred by the individual firm, but rather by the society of which the firm is a part. Therefore, there will be limits to these effects, but these limits will become visible only at the level of society. Of course, when society has made a choice in this matter, the consequences of that choice automatically provide the limit for the individual firm, e.g., if society chooses for everyone to have theoretical education, rather than learning a craft, a firm will run into limits when it wants to hire craftsmen. The same kind of reasoning applies to the limits of knowledge spillovers and the limits of exogenous technological change.

The limits to the extent of autonomous learning effects can be divided into two groups: the limits to the learning curve and the limits to endogenous technological change. First, analogous to the arguments on the limits of scale effects, the firm may run into the limits of the extent of the market. This may limit the growth of cumulative output, especially for durable goods. When a market is saturated, it may be much more difficult to increase cumulative output than in a market that is growing. Further, an important limit to the learning effect is that it will eventually die out. After a certain level of cumulative output, the marginal gains of learning will become very small. Or even worse, in dedicating all their energy to a single task, employees may eventually become bored with it and productivity might even fall.

The limits to endogenous technological change are more problematic. The concept of knowledge as a by-product of transformation processes, that may be used to improve the efficiency of subsequent processes, is an important point, not only from the management perspective, but also from the economics perspective. The fact that knowledge may be generating a positive feedback loop means that there may be virtually no limits to the growth that is a consequence of the application of this knowledge. While we can easily spot the limits of scale effects, of induced learning, of exogenous learning and of improved efficiency because of autonomous learning, we cannot so easily spot the limits of the positive feedback loop caused by knowledge. It is in this positive feedback loop that we see most clearly the increasing returns potential of learning effects.

5.4.3 Information and knowledge intensity

One of the most important conditions influencing the presence and extent of scale and learning effects is the rising information and knowledge intensity of products and business processes.[47] This is expressed in the rising prevalence of the information

[47] Two points should be made here, that are important but that fall outside the scope of this thesis. The first point regards the definitions of and conceptual distinctions between information and knowledge. Information has been defined by Shapiro & Varian (1999, p.3) as "Anything that can be digitized – encoded as a stream of bits – is information." Glazer (1991, p.2) defines information as "data that have been organized or given structure – that is, placed in a *context* – and thus endowed with *meaning*." (italics Glazer). He adds however "though the definition of 'information' given is familiar within the literature, the notion of exactly what constitutes 'information' is by no means clear." The same problem we encounter when trying to define knowledge. Here we follow Grant (1996, p.110) who states "*What is knowledge?*

services sector, the rising prevalence of information goods, e.g., software and the rising knowledge required to configure and improve business processes.

Information and knowledge have characteristics that differ from those of normal economic goods (Romer, 1986, 1990a, 1990b, 1994; Glazer, 1991; Shapiro & Varian, 1999). A normal economic good is divisible, rival (scarce), excludable (appropriable) and has diminishing returns to use. Information and knowledge differ from the normal economic good on some of these characteristics.

Since this question has intrigued some of the world's greatest thinkers from Plato to Popper without the emergence of a clear consensus, this is not an arena in which I choose to compete." (italics Grant). Nonaka (1994) distinguishes two dimensions of knowledge. The first dimension is codifyability. On this dimension we can distinguish two forms of knowledge, implicit (or tacit) and explicit (see also Polanyi, 1966). Explicit, i.e., codified or codyfiable, knowledge can be transmitted in formal symbols and hence becomes information. Implicit, i.e., tacit, knowledge cannot be formalized and is therefore difficult to communicate. The second dimension is interactivity. Knowledge is first initiated within individuals, but it is organizationally amplified. That is, knowledge is a consequence of interaction and as such it becomes an *emergent property* of a knowledge creating community, e.g., a firm. The consequence of treating knowledge as an interaction factor is that it cannot be treated as a normal factor of production. Unlike information, which is explicit and not dependent on interaction, and hence can be compiled in an 'information good', implicit knowledge cannot be bought or sold completely separate from the entities, e.g., labor, capital or products, in which it is embedded or completely separate from the context, i.e., the interaction pattern within the firm, in which it is embedded. Knowledge may therefore be regarded as a resource, that exists, can be accumulated and can be used at the firm level, but not as a factor of production that can be traded in factor market.

The second point is the issue of information and knowledge intensity. The word 'intensity' implies the ability to measure the extent to which products and processes are based on or consist of information and knowledge. How to measure something that we cannot properly define? Economists have found ways round this problem. One way is to define information goods. Such a good can be either a list of symbolic instructions (Romer, 1990) or a physical medium, e.g., a book, a CD or a video tape, containing this list of symbolic instructions (Romer, 1990; Shapiro & Varian, 1999). Another way round is to consider the information or knowledge to be embedded in the firm's products and services. Glazer (1991, p.5) proposes to calculate information intensity as follows: "a firm is information intensive to the degree that its products and operations are based on the information collected and processed as part of exchanges along the value chain." John, Weiss & Dutta (1999, p.79) phrase it as follows: "Also termed 'know-how' this definition captures the scientific knowledge embodied in a product's functionality, as well as manufacturing and sales knowledge. Products (and services) are therefore manifestations of know-how." The third way round is to calculate the *value* of information or knowledge. Glazer (1991) proposes to calculate the value of information as the sum of (1) the, given the availability of information, larger revenues from subsequent transactions (2) the, given the availability of information, lower costs of subsequent transactions, and (3) the revenues from the marketing and sales of information itself. Based on Zegveld (2000), Zegveld & Den Hartigh (2002) propose to calculate the value of knowledge from the consequences of its productivity, i.e., they measure a firm's knowledge by calculating the Solow (1957) residual at the firm level.

Firm-based increasing returns

Indivisibility: information and knowledge will often, though not always, be indivisible. That means that a certain 'amount' of it is needed before it can be productively applied, e.g., while half of a heap of stones is just half the number of stones, learning half of the alphabet will not enable a person to read half a book. However, while indivisibility may be a common characteristic of information and knowledge, it is not one that distinguishes it uniquely from other commodities, e.g., a car can be considered an economic good, but half a car will not get me to my destination. In production environments it will often be necessary to make large investments in plants and machinery before the firm can even start assembling the first product. These plants and machines also represent indivisibilities. The implication of indivisibilities is important however, because they influence the cost structure of products: high fixed costs, low marginal costs. The unique property of information and knowledge is that these marginal costs will often approach zero (Shapiro & Varian, 1999). This brings us to non-rivalry.

Non-rivalry, or non-scarcity, is *the* essential characteristic of information and knowledge (Romer, 1990a). It is defined as: "A good is non-rival if consumption of additional units of the good involves zero marginal social costs of production" (Nicholson, 1989, p.727). Non-rival goods can be accumulated without bounds (Romer, 1990a). Non-rival goods can be used repeatedly in the process because they are not depleted in the production process, as are labor and capital (Romer, 1990a; Glazer, 1991). Non-rival goods can be used simultaneously by different economic entities. For a normal economic good, if one person possesses it, someone else cannot possess the same good. Two people cannot simultaneously own the same car. If one person has certain information however, another person can possess the same information at the same time. Romer (1990a) shows that if there are non-rival goods that have productive value, output will increase more than proportionally with an increase of all the inputs. Romer (1990a, p.98):

> "If R denotes the set of rival inputs, N the set of non-rival inputs and $F(R, N)$ denotes output, then for integer values of λ,
>
> $$F(\lambda R, \lambda N) > F(\lambda R, N) = \lambda F(R, N)$$
>
> This means that in the large, the elasticity of output with respect to inputs is greater than 1 and that the function $F(\cdot)$ is not concave."

In other words, Romer links non-rivalry directly to the existence of increasing returns. While this non-rivalry is true for existing information and knowledge at a specific moment in time, information and knowledge may in practice be very time-sensitive (Glazer & Weiss, 1993). This means that information and knowledge probably can still be accumulated and replicated at zero marginal costs, but that after some time they will have no productive value.

Excludability, or appropriability, or exclusivity is defined as: “A good is exclusive if it is relatively easy to exclude individuals from benefiting from the good once it is produced” (Nicholson, 1989, p.727). Information and knowledge are often not perfectly excludable. That is, ownership can be exercised, e.g., by patents, copyrights or copy protection, but it cannot be perfectly exercised. Sometimes, information and knowledge are regarded as public goods, i.e. that they are to a large extent non-excludable and exhibit a natural externality. While this may be true for ‘common knowledge’, it cannot be a general property of newly developed knowledge. Romer (1990a) states that because technological advance comes from things that people do, these people must see a benefit somewhere to their actions. These benefits consist of monopoly rents that can only be enjoyed because the information and knowledge developed are at least partially excludable. Still, it is difficult to protect information and knowledge from others. Patents for example give a temporary form of ownership, but also imply complete disclosure of the information, which means that competitors can easily copy it and use it with some minor changes to their own advantage. Knowledge and information are therefore known to generate *spillover effects*.

Information and knowledge are often *self-generative* (Glazer, 1991), which means that new relevant information and knowledge may emerge from the business process as additional output besides the normal output of products and services. The use of information and knowledge may therefore lead to improvement of existing information and knowledge and to the acquisition of new information and knowledge, which Arrow (1962) refers to as learning. The improved or newly generated information and knowledge can be subsequently used as an input factor in the process. This causes information and knowledge accumulation.

The abovementioned economic characteristics of information and knowledge endow them with the possibility of an inherent increasing marginal productivity when used as input factors. Indivisibility and especially non-rivalry make for the unique cost structure of product and processes characterized by high fixed costs and very low marginal costs. As we saw in section 5.4.1 such a cost structure causes large scale effects. The partial excludability aspect makes for two different effects. On the one hand, the excludability can result in large benefits, because the rents will be monopoly rents, but the replication costs of information or knowledge will be close to zero. This means that extending production becomes very lucrative, as can be seen, e.g., in the software market or the market for popular music. On the other hand, the fact that information and knowledge are often not completely excludable causes spillovers that may be regarded as a source of exogenous learning. The self-generating aspect of information and knowledge means that information and knowledge do not exhibit decreasing returns to use, but will often increase in value the more they are used. This means that information and knowledge are the engines that keep autonomous learning effects and endogenous technological change going.

We may conclude that the information and knowledge intensity of products and processes is an important cause of firm-based increasing returns. This does not automatically imply that increasing returns will be realized in the production of goods and service, as information and knowledge will always be used in combination with other input factors that have diminishing marginal productivity, but it certainly enlarges increasing returns opportunities.

Let us return to the general transformation function we showed in figure 5.1. The position of the point of inflection is determined by the characteristics of the input factors. The input factors capital and physical labor are mostly characterized by diminishing marginal productivity. This means that after a certain point deploying extra capital and physical labor will show diminishing returns. Contrary to capital and physical labor, the input factors information and knowledge are mostly characterized by increasing marginal productivity. This means that firm-based increasing returns will be more pervasive than firm-based diminishing returns in information and knowledge intensive processes. This pervasiveness of firm-based increasing returns is a consequence of the economic characteristics of information and knowledge mentioned above. In summary, the ratio between information and knowledge as input factors and capital and physical labor as input factors, determines the extent to which diminishing returns, or increasing returns occur in the business process, i.e., it determines the position of the point of inflection in the transformation function.

Prevailing economic logic considers capital and physical labor to be the most important input factors in the business process. Following this logic the point of inflection in the transformation function is located towards the lower left corner (see the left side of figure 5.9). After a short interval of increasing returns, the diminishing marginal productivity of capital and physical labor will cause diminishing returns, or a less than proportionate output of products and services. This implies that the range within which increasing returns can be exploited is rather small. The logic of increasing returns considers information and knowledge to be the most important input factors of the business process. Consistent with this logic the point of inflection in the transformation function is located to the upper right corner (see the right side of figure 5.9). This means that the range in which increasing returns can be exploited is much larger in these information and knowledge intensive processes than in business processes that are capital and physical labor intensive.

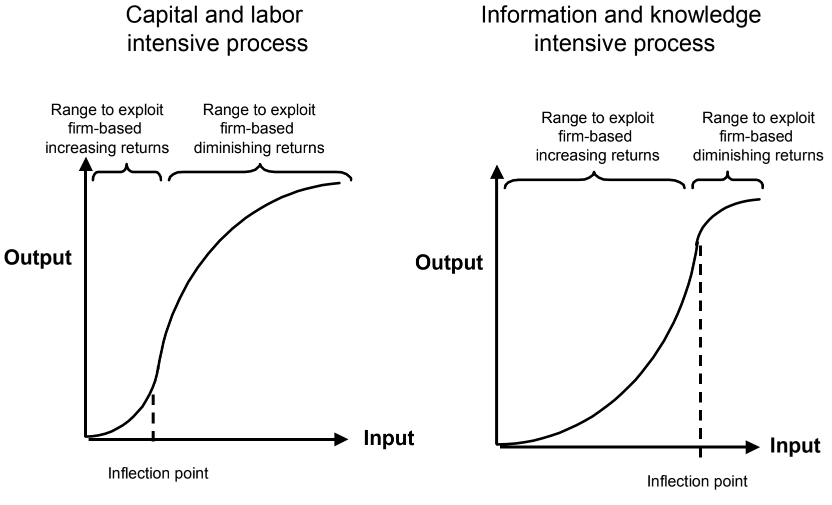

Figure 5-9: The shape of the transformation function for capital and labor intensive processes versus information and knowledge intensive processes

5.5 Firm strategies for internalizing the potential for scale and learning effects

In section 4.5 we argued that the presence of market-based increasing returns determines the potential for scale and learning effects. Individual firms may *internalize this potential* in various ways, i.e., by (1) making the right strategic choices, (2) fighting the battle for the technological standard, (3) influencing customers' and competitors' expectations, (4) avoiding lock-out situations, (5) shaping network competition and (6) exploiting the installed base. These will be discussed below.

5.5.1 *Making the right strategic choices: shaper, follower or reserving the right to play*

A firm can to some extent choose the market in which it wants to operate. This means that the firm can choose a market in which market-based increasing returns are likely to be present. Once the firm operates in such a market, however, it cannot fully determine the market outcomes. As an individual firm, it likely cannot completely control technology battles, because it will be impossible to predict accurately the scope of network effects and social interaction effects and the consequences thereof. Moreover, there will likely be an element of chance playing a role. A firm can also, to a certain extent, determine the firm-based increasing returns intensity of its own products and processes; needless to say that this will not be easy, as it may involve a reconsideration of the core activities and the business concept. In other words, there is a strong element of path dependence in both the markets in which the firm competes and in the firm's core business. Even when it is in theory possible to change these, many firms will choose not to.

Still, to be successful in a market where network and social interaction effects are present and with products and processes that have large potential scale and learning effects play an important role, firms can follow different strategies. While firm strategies are also path dependent, they are much less fixed than markets and core activities and they may change between business cycles. Therefore, choice of strategic approach will in a certain market, and with certain core activities, influence firm performance. Firms may follow three *increasing returns strategies* in such circumstances. The first two, *shaper* and *follower,* are mentioned by Hagel (1996), the third, *reserving the right to play,* is mentioned by Coyne & Subramaniam (1996).

First, firms can choose to follow a *shaper strategy* by sponsoring their own proprietary technology that will generate high returns if it becomes dominant in the market (Besen & Farrell, 1994; Shapiro & Varian, 1999). These firms therefore enjoy the largest potential for scale and learning effects for the products based on this technology. However, such a strategy is both costly and risky, which means that only a few firms can afford to develop and implement such a strategy.

Second, firms can choose to follow an *adapter, or follower, strategy* (Besen & Farrell, 1994; Hagel, 1996). Such a strategy involves joining the dominant technology by acquiring a license for developing products based on this technology. In a situation where the firm is not a sponsor of the dominant technology, it may nevertheless profit from the potential for scale and learning effects created by the dominant technology. Not by competing with the dominant product or technology, i.e., not by focusing on *substitution*, but by:

- offering a product or technology that is *compatible with* the dominant product or technology allows the firm to make a connection to the dominant technology network (Brynjolfsson & Kemerer, 1996; Gandal, 1995). In this way, these firms can capitalize on *direct network effects* and in this way exploit the potential for scale and learning effects created by the dominant technology.
- offering products or technologies that are *complementary to*, i.e., are used together with, the dominant product or technology (Katz and Shapiro, 1986). In this way these firms may capitalize on *indirect network effects*.

For firms following an adapter strategy the asymmetrical division of market shares implies that the potential for scale and learning effects is smaller than for shapers. Moreover, for these firms the decision which group of suppliers to join is essential to avoid a lock-out situation, i.e., a situation in which the technology that the firm has invested in or committed to does not become the market standard.

Third, to avoid such a lock-out situation, firms can choose to postpone the decision to commit themselves to a technology network until it becomes clear which technology network will dominate the market. This strategy of *reserving the right to play* means that firms do all that is necessary to create or keep open opportunities in order to acquire a favorable position at a later stage (Coyne & Subramaniam, 1996). This is not unlike a *real options* approach to strategy, see, e.g., Amram & Kulatilaka (1999).

5.5.2 Fighting the battle for the technological standard

Firms often engage in battles for the technological standards that frequently occur in increasing returns markets (Shapiro & Varian, 1998; 1999). An important question managers have to ask themselves is in what way their firm should participate in the battle for the technological standard. They can do this by sponsoring a technology, either by themselves or by forming a coalition of firms adhering to the same technology. Winning such a battle requires enormous R&D and marketing expenditures to develop the technology and to build *critical mass*. This means that for most firms it will be financially impossible to fight this battle in more than one market. In other words, financial constraints often force firms that want to set a technological standard to adopt a *focus strategy*, i.e., focusing on a limited target market.

It is imperative to build *critical mass* as fast as possible to successfully implement such a focus strategy. This makes customers more confident in the firm's product and technology and it makes the technology more attractive for suppliers of complementary products. It is not necessary to be the first to reach the market, but rather to be the first to reach critical mass through the reduction of market penetration time. The crucial management question is: When to enter the market? On the one hand, being *firs to market* is a high-risk strategy, especially in markets that develop irregularly (Schilling, 1998). The firm might end up making huge investments in what later turns out to be a losing technology. On the other hand, not being *first to market* entails the risk of being too late. A competitor may already have created enough critical mass to set his technology as the market standard. The risk that a competitor has already set a technological standard may be reduced by shortening the *market penetration time*, or *time to critical mass*, of the firm's own technology. Nevertheless, engaging in a battle for a technological standard in a single market remains a high-risk activity. The focus strategy may yield high returns where *winner takes all*, but it may also result in huge losses where *loser gets nothing*.

An alternative strategy is not to engage in the battle for the technological standard, but to become an early follower of the winning technology. In this case, the bulk of the investments in technology development and critical mass building are left to the firm that sets the standard. The follower may enter the market by simply buying a license. This strategy allows the firm to compete in multiple markets simultaneously. Such a strategy reduces the financial risks, but will also yield more modest returns.

5.5.3 Influencing expectations

Whether critical mass is reached is highly dependent on the behavior and expectations of suppliers, both competitors and suppliers of complementary products, and customers in the market due to social interaction effects. Management can take these social interaction effects for granted, but it is also possible to stimulate and steer social interaction effects in the market. This is often referred to as *expectations management* (Shapiro & Varian, 1998). Examples of expectations management are time pacing[48], product pre-announcements, limited product rollouts, working with pre-launch versions of products, e.g., the beta releases in the software industry, and generating free publicity around products.

5.5.4 Avoiding lock-out situations

Information and knowledge intensive markets are often locked in to the technology of the dominant network. This implies that firms that did not invest in this technology are locked out (Schilling, 1998). It is often not possible to predict if and when such a lock-out situation will occur. When a firm stays behind, it will find itself constantly adapting. It is caught up in a back fight. When a firm finds itself in such a situation, the most sensible thing for its management to do is to regard the investments made in the locked-out technology as *sunk costs* and take the loss. This is for example what *Philips* did when its joint venture with *Lucent Technologies* in the cellular phone market turned out to be a failure. In practice however, it is difficult for managers to write off large investments as sunk costs. Often they decide further to develop the locked-out technology, reasoning that in this way at least some of the investment may be recovered. This reasoning is not unlike that of the casino gambler who keeps on gambling just to earn back the money already lost.

Limiting the damage of lock-out situations by timely taking financial losses is of great importance. It saves crucial resources that can be deployed to find a profitable connection with the dominant technological network. The resources saved can also be used to break into a locked-in market with a new technology. However, breaking into a market with a locked-in technology may be very difficult, because the locked-in technology has the advantage of a large installed base, which means that it enjoys strong network and social interaction effects. Breaking into a locked-in market requires a sufficient number of customers, competitors and suppliers of complementary products willing to invest in the new technology to build critical mass. To convince *customers* to switch to the new technology, it must offer them a considerably better value proposition (Farrell & Saloner, 1986). To convince *suppliers* to switch to the new technology, it must offer them a considerably better market potential than the locked-in technology. Building sufficient critical mass for the new technology requires substantial resources. Therefore, firms that try to break into a locked-in market need 'deep pockets'. On balance, the result may be increasing

[48] Time-pacing means setting the rhythm of your market, e.g., the rhythm with new products or new technologies are introduced (see Brown & Eisenhardt, 1998).

returns to adoption of the new technology, but possibly at the cost of a diminishing return to investment.

5.5.5 Competition on the network level

A lock-out situation may occur because managers keep thinking on the product level, while the real competitive battle in the market takes place on the network level. High product quality, attractive design and low prices are just the 'green fee' for competing on the network level, but provide no guarantee for a competitive advantage. Managers may endanger investments on the product level by not explicitly taking the network level into account. An example is the word processing software that was claimed to be superior on the product level, i.e., *WordPerfect*, but which acquired only a small market share because it was not fully compatible with the dominant network of word processing software, i.e., *Microsoft Word*.

5.5.6 Exploiting the installed base

As stated before, network competition is not so much a matter of being *first to market* but rather of being *first to critical mass*. This also means that all costs until critical mass is reached may be regarded as fixed costs, i.e., costs that have to be made in any case to sell successfully the firm's products in the market. As with other fixed costs, once incurred, the name of the game is to sell as many products as possible to recover them. Or, once a technological network has reached critical mass, it becomes important to exploit the *installed base* of customers. This can be realized either by cross-selling complementary products or by offering low-priced upgrades to existing customers. A well-known example of cross selling is the *Acrobat Reader* software, which is offered free of charge by *Adobe* to stimulate the sales of its complementary *Acrobat* software. Offering incomplete *freeware* programs to stimulate sales of the full-specs version is another example of cross selling. *Adobe* for example offers *Adobe Photoshop Elements*, a downgraded version of *Adobe Photoshop*, free of charge with complementary products such as scanners, to stimulate the sales of the full *Adobe Photoshop* program. Managers have to be aware that offering products free of charge helps building critical mass, but does not contribute directly to profits. To apply cross selling effectively, it has to contribute to the sales of complementary products or to the realization of other strategic or tactical goals. An example of the latter is *Microsoft* and *Netscape* offering free Internet browser software with the intention of creating the dominant technological network in this market (Shapiro & Varian, 1998).

5.6 Realizing and exploiting the potential for scale and learning effects

5.6.1 Closing the positive feedback loop

The fact that a firm has internalized (part of) the potential for scale and learning effects does not automatically mean that it will actually be able to exploit scale and learning effects and therefore realize higher firm performance, unless there is a natural monopoly.[49] The capability to exploit the potential for scale and learning effects is therefore an important determinant of firm performance.

As stated before, scale effects and learning effects do not automatically mean that positive feedback in the firm, i.e., increasing returns, is present and certainly do not translate automatically into firm performance. Scale and learning effects only translate into increasing returns when the positive feedback loop is closed, i.e., if the productivity benefits acquired are optimally exploited by management. In this way, scale and learning effects are part of the firm conduct aspect of the *structure-conduct-performance paradigm* (see figure 5.10).

[49] Natural monopolies exist when the minimum effective scale of a firm is very large in relation to the size of the market (Scherer & Ross, 1990), or, in other words, the firm's average total cost curve diminishes over the total range of output of the industry (Nicholson, 1989). In such a situation the presence of scale and learning effects enable one firm to 'naturally' corner the market. The early neoclassical economists (Walras, 1874; Marshall, 1890) thought that the presence of increasing returns to scale would automatically result in a monopoly. While this may be true in the pure economic analytical sense, it is not true from the management perspective. The fact that a firm enjoys larger scale or learning effects does not automatically imply that it will acquire a durable competitive advantage. Rather, other capabilities of firms, such as clever marketing, clever distribution strategies, or clever operating in the technology battle, will play an important role in acquiring competitive advantage. Therefore, natural monopolies may be much scarcer than the neo-classical economists thought. Examples are the electricity industry, the telecom industry, the postal services or the railway operations that have long been thought to be natural monopolies, but in which multiple firms are well able to operate without one of them automatically cornering the market (see also Nicholson, 1989).

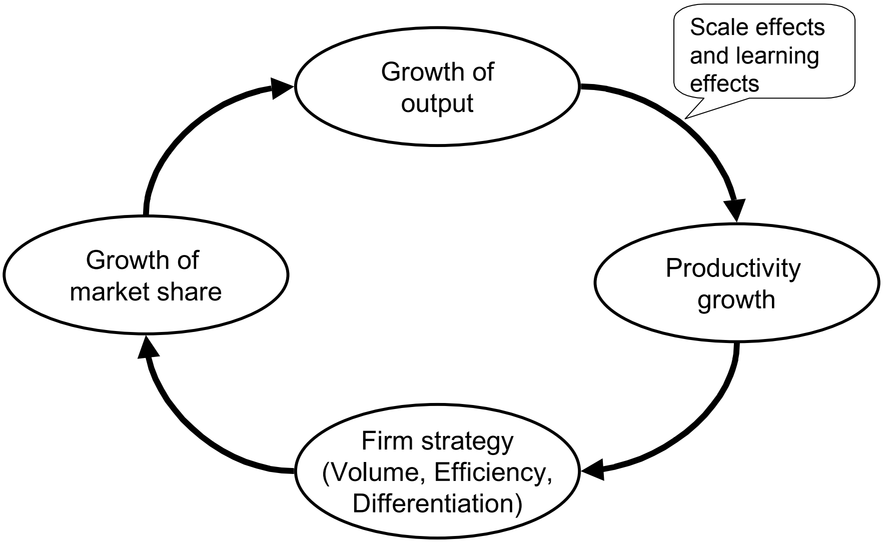

Figure 5-10: The realization of scale and learning effects

The growth of a firms' output over time causes productivity improvements through scale effects and autonomous learning effects. At the same time firms can realize productivity improvements as the result of induced and exogenous learning effects. Firms can use these productivity gains to increase their output by stimulating additional market-demand for their products. This can be done in a number of ways.

The first is to further capitalize on the strategies firms use for internalizing the potential for scale and learning effects. For example, firms can further capitalize on their shaper strategy by selling licenses, protecting their acquired position, leveraging the installed base into new markets and offering customers migration paths to new and updated products (Shapiro & Varian, 1999). Firms can further capitalize on their adapter strategy by exploiting the potential of scale and learning effects through maintaining a healthy market for complementary products or technologies.

The second way for firms to exploit the potential for scale and learning effects is by pursuing a generic competitive strategy as described by, e.g., Porter (1980, 1985) or Van Asseldonk (1998). In such strategies, the productivity gain from scale and learning effects is used to win market share by: (1) offering products at lower prices than competitors for equivalent benefits, i.e., a volume-efficiency strategy or by: (2) providing customers with unique benefits at higher prices than competitors, i.e., a volume-differentiation strategy. Either one of these strategies allows productivity gains and growth of output to cause a positive feedback loop because the additional demand results in a higher market share, higher output growth and hence higher productivity growth.

5.6.2 Generic strategies for value creation

Firms can choose from three dominant value drivers for shaping their generic strategies to create value, i.e., volume, efficiency and differentiation (Van Asseldonk, 1998).

Volume: Some firms choose volume as the dominant driver for value creation. Such firms often focus on strong autonomous growth, often operate in growing markets and strive to grow faster than the market. This strategy is reflected in statements such as: "Our strategy is to grow by *25%* per year." With volume as the dominant driver, such firms manage operational efficiency and product differentiation within the context of their aspired volume growth.

Efficiency: Other firms select efficiency as their dominant driver of value creation. Their strategic objective is to improve productivity by certain percentages every year. Quite often these firms compete in stagnating markets; they compete with other firms on operational excellence by investing in automation and mechanization. These firms try to maintain or increase their market share by offering lower prices than competitors. These firms create their value for the larger part by improving their cost structure.

Differentiation: Lastly there are firms that select differentiation as their dominant driver of value creation. These firms emphasize product development and branding. They introduce new products with a higher added value either by improving product quality or by investing in a brand image and brand leadership. Such firms often try to build a broad assortment of products to serve various segments in the markets in which they operate.

It is possible to combine the different value drivers into multiple strategies for value creation. When producing high volumes *(volume)* of standardized products *(efficiency)* a firm hopes to take advantage of economies of scale and of experience curve effects. When producing high volumes *(volume)* of differentiated products *(differentiation)* a firm hopes to provide superior value for multiple market segments or even for individual customers. Combinations of efficiency with differentiation or volume with efficiency and differentiation are difficult to implement due to the potential for conflict between cost minimization and the additional cost of value-added differentiation.

The most dominant generic strategies according to Porter (1980) are the cost-leadership strategy *(volume-efficiency)*, the differentiation strategy *(volume-differentiation)* and the focus strategy (*efficiency* or *differentiation* focused on niche markets). Firms may pursue a cost-leadership strategy with low-priced products or they may pursue a differentiation strategy by using the cost advantage to offset the cost required to improve their product proposition.

A *volume-efficiency* or *focus-efficiency* strategy requires a no-frills product that is produced at a relatively low cost and made available to a very large customer base. The cost advantage is used to win market share by pricing the product lower than competing products. By winning market share and producing higher volumes of products firms hope to take even more advantage of economies of scale and experience curve effects. The cost advantage may also be used to invest in organization-wide process improvements, thereby reducing cost even further. Maintaining an efficiency strategy hence requires a continuous search for cost reductions in all aspects of the business. The associated distribution strategy is to obtain the most extensive distribution possible. Promotional strategies often involve trying to make a virtue out of low cost product features. To be successful a volume-efficiency strategy requires building up a considerable market share advantage and preferential access to raw materials, components, labor, or some other important input. Without these advantages competitors can easily mimic an efficiency strategy. Successful implementation also benefits from process engineering skills, products designed for ease of manufacture, sustained access to inexpensive capital, close supervision of labor, tight cost control and incentives based on quantitative targets

A *volume-differentiation* or *focus-differentiation* strategy uses productivity gains to create a product that is perceived to be unique. The unique features or benefits should provide superior value for customers. It is through this creation of superior value for customers that firms win market share. By winning market share and producing higher volumes of products firms take even more advantage of economies of scale and learning effects, and because customers see the product as unrivalled and unequalled, the price elasticity of demand tends to be reduced and customers tend to be more loyal. This enables firms to adopt a premium pricing strategy. Besides, learning-by-doing may result in product improvements, thereby better tailoring products to specific customer needs and realizing superior customer value relative to other firms. To maintain this strategy firms should also have strong research and development skills, strong product engineering skills, strong creativity skills, good cooperation with distribution channels, strong marketing skills, incentives based largely on subjective measures, be able to communicate the importance of the differentiating product characteristics, stress continuous improvement and innovation and attract highly skilled and creative people.

The strategies of volume-efficiency and volume-differentiation will be rewarded with a rise of market share, provided of course that the competition is unable to do the same. This is important because market share is a major determinant of net profit (Szymanski, Bharadway & Varadarajan, 1993). The exact size and duration of superior performance depends on whether the price reduction is smaller than the cost advantage that creates efficiency and whether the price premium offsets the additional costs associated with the differentiating product features. Implementation of either strategy will nevertheless strengthen the positive relationship between productivity growth and performance growth.

5.6.3 Relationship of the exploitation of the potential with firm performance

The exploitation of scale and learning effects will become manifest in firm performance because output, prices and costs are known determinants of firm performance. By realizing scale and learning effects, the volume-efficient firm achieves a higher output with a better unit margin and prices lower than those of competitors and the volume-differentiated firm achieves a higher output with a better unit margin and prices higher than those of its competitors. Thus both strategies improve firm performance versus the performance of competing firms that do not realize scale and learning effects to the same extent.

Firms can realize product performance from the realization of scale and learning effects by embedding the realized economies of scale and learning effects in their product strategy. Managers can improve customer satisfaction and acceptance by improving on product quality and innovativeness and/or by lowering product prices. This will raise sales and extend the firm’s market share.

Firms can realize organizational performance through the realization of scale and learning effects. The realization of scale effects is not necessarily restricted to specific products but may enable a firm to realize economies of scope (Teece, 1980). The realization of learning effects allows firms to realize product and process improvements and spread best practices throughout the organization.

5.7 Conclusions

In this chapter we looked at the firm-based mechanisms of increasing returns and the way the firm uses these mechanisms to improve its performance as the firm conduct aspect of the *structure-conduct-performance paradigm*.

The firm-based mechanisms of increasing returns are scale effects and learning effects. Scale effects are defined broadly, to incorporate economies of scale, scope and sequence and to be clearly distinguished from the *economic conventions of increasing returns and increasing returns to scale*. Learning effects are also defined broadly to incorporate induced, exogenous and autonomous learning effects, the last being divided into learning-by-doing and endogenous technological change. Scale and learning effects only become *increasing returns* in our definition when they are specifically used by the firm to generate even larger scale and learning effects, in other words, when the firm is able to close the positive feedback loop. Without intentional action by the firm, scale and learning effects will eventually die out and hence will not cause increasing returns. Besides intentional firm action, the information and knowledge intensity of products and processes are the most important conditions influencing the extent of scale and learning effects.

Following the *structure-conduct-performance paradigm*, firm-based increasing returns are the result of the firm's internalization of market potential for scale and learning effects and the subsequent realization of this potential. The extent to which firms are able to do so is influenced by the strategic choices they make, e.g., whether they choose a *shaper strategy*, a *follower strategy* or a *reserving the right to play strategy*. Firm performance is the result of the firm's *exploitation* of scale and learning effects. Firms can do this by using the well-known generic competitive strategies.

6. FRAMEWORK & HYPOTHESES

This chapter is the linch-pin between the theoretical part of the thesis, consisting of chapters two, three, four and five and the reports of the research projects in chapters seven, eight and nine. In section one of this chapter we present a research framework that is based on the chosen structure-conduct-performance paradigm adopted in chapter one, on the justification provided by the literature study of chapters two and three and on the conceptualizations of market-based and firm-based increasing returns derived from chapters four and five. On the basis of this research framework, the research hypotheses will be formulated in section two. These hypotheses will be empirically tested in three empirical studies, the research designs of which are discussed in section three. Measurement issues are addressed in section four and conclusions are provided in section five.

6.1.1 Conceptual framework

The analytical framework chosen for this thesis is the *structure-conduct-performance paradigm*. According to this paradigm, market structure influences firm performance through the mediating effect of firm conduct (Bain, 1959).

The *structure-conduct-performance paradigm* has been used in chapter four and five to classify the market-based and firm-based mechanisms of increasing returns. We consider market-based mechanisms of increasing returns, i.e., network effects and social interaction effects, as indicators of market structure and firm-based mechanisms of increasing returns, i.e., scale effects and learning effects, as indicators of firm conduct. This implies that the market-based mechanisms of increasing returns are hypothesized to influence firm performance through the firm-based mechanisms of increasing returns. The hypothesized relationships resulting from this reasoning are shown in figure 6.1.

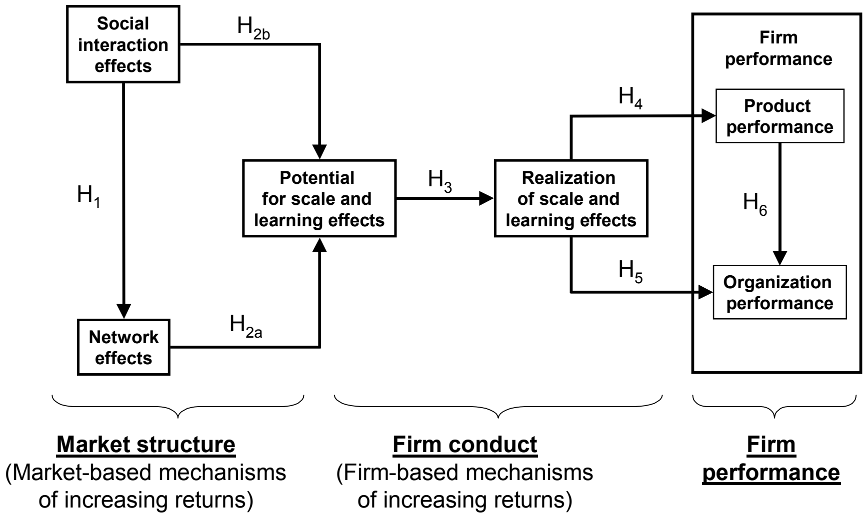

Figure 6-1: General research framework and hypotheses

This conceptual framework reveals several relationships. First, social interaction effects are hypothesized to have a positive effect on network effects. Second, network effects and social interaction effects are hypothesized to have a positive effect on the firm's potential for scale and learning effects. Third, the firm's potential for scale and learning effects is hypothesized to have a positive impact on its realization of these effects. Fourth, realization of scale and learning effects is hypothesized to have a positive effect on product performance. Fifth, the realization of scale and learning effects is hypothesized to have a positive influence on organizational performance. Sixth, product performance is hypothesized to affect positively organizational performance. We will subsequently discuss these hypotheses.

6.2 Research hypotheses

6.2.1 The effect of social interaction effects on network effects

Social interaction effects were defined in terms of information exchange and the formation of expectations that occur when customers and suppliers face social and economic network risks. Through social interactions customers and suppliers try to reduce these risks, by interpreting other customers' and suppliers' opinions and preferences. For individual customers, the formation of opinions and preferences will likely precede their actual behavior (Katz & Shapiro, 1986; Rosenberg, 1976). The actual behavior of customers subsequently causes the network effect, because the economic value of the network increases as more customers adopt a product based on the same technology. Therefore we hypothesize that:

(H_1) the larger the social interaction effects, the larger the network effects

Note that the assumption underlying this hypothesis is that social interaction effects are defined as the social aspect of network effects, i.e., a larger social network will have a positive influence on the willingness to adopt a product. Therefore the hypothesis is that the influence of social interaction effects on network effects will be positive. This is in accordance with the way social interaction effects are operationalized in chapters seven and eight. The hypothesis does not account for social interaction effects that take the form of *vicious circles*. In the terminology of Bikhchandani, Hirschleifer & Welch (1992, p.998) our social interaction effects therefore reflect an *up cascade*, but not a *down cascade*.

6.2.2 The effect of network effects and social interaction effects on the potential for scale and learning effects

The presence of network effects and social interaction effects make it more attractive for customers to buy products based on a particular technological standard. It also makes it more attractive for suppliers to adopt this technology and to offer compatible products. The presence of network effects and social interaction effects will therefore cause a technology standards battle with an a priori uncertain outcome.

This standards battle is likely to be won by only one of the competing technologies, i.e., there are multiple possible equilibria (Farrell & Saloner, 1985; 1986; Katz & Shapiro, 1985; 1986; Arthur, 1989; Besen & Farrell, 1994). The winning technology will dominate the market, which means that the potential market for products based on this technology is very large. In other words, there will be a large potential for scale and learning effects in the market due to the expected scale of production for the products based on the winning technology.

The standards battle also means that competition will take place at the level of the technology network. This enables firms to offer products or technologies that are compatible with and complementary to the dominant technology, resulting in a potential for scale and learning effects for those firms.

A further consequence of network effects and social interaction effects is the possibility for a technology to gain popularity very fast once it has gained an initial edge in the market (Abrahamson & Rosenkopf, 1997; Katz & Shapiro, 1994; Besen & Farrell, 1994). This is due to excess momentum and path dependence. The fast-increasing popularity means that not only the scale of production for products based on the technology can be quickly increased, enabling scale effects, but also that the cumulative production of these products increases fast, enabling learning effects.

Once customers have made their purchase, they will not easily switch to another technology, because of the investments and learning costs related to this specific technology (Arthur, 1989). This is due to lock-in and excess inertia. These effects may benefit a dominant incumbent technology by creating entry barriers in the market. Firms may therefore expect a stable group of customers that will remain loyal to the dominant technology. In other words, there is a market potential for scale and learning effects for the product based on the dominant technology. Therefore we hypothesize:

> ***(H_2) the larger the (a) network effects and (b) social interaction effects, the larger the potential for scale and learning effects***

6.2.3 The effect of the potential for scale and learning effects on the realization of scale and learning effects

The fact that there are multiple equilibria in the market and that there is a very asymmetric distribution of market shares, creating a potential for scale and learning effects, does not automatically mean that all individual firms will be able to internalize this potential. On the contrary, in a *winner-take-all* market there is only one winner and many losers. To be successful in increasing returns markets, firms can follow different strategies. They can choose to follow a *shaper strategy* by developing an own proprietary technology to appropriate all the returns (Besen & Farrell, 1994; Hagel, 1996; Shapiro & Varian, 1999). However, such a strategy is both costly and risky, which means that only a few firms can afford to develop and implement it. An alternative, known as an *adapter, or follower, strategy*, is to join the winning technology by acquiring a license for developing products based on this technology (Hagel, 1996).

By choosing either a shaper or a follower strategy firms are able to internalize the potential for scale and learning effects. Furthering our argument, presented in section 6.2.2, they can make use of the different market outcomes.

- As a *shaper* they are the main sponsor of a technology and when their technology becomes dominant they will internalize a large part of the potential for scale and learning effects in the market. Conversely, the potential for scale and learning effects for *shaper* firms that sponsor a loosing technology will be very small.
- Due to the competition at network level (see above), even firms that are not *shapers* may enjoy a potential for scale and learning effects. By choosing a *follower strategy*, such firms are able to internalize part of the potential for scale and learning effects from the dominant technology network by selling compatible and complementary products or technologies.
- Due to *excess momentum* and *path dependence* both a *shaper* firm sponsoring a dominant technology and a *follower* firm acquiring a license for this technology may expect a rapidly growing group of customers. In this way, they internalize part of the market potential for scale and leaning effects.
- Due to *excess inertia* and *lock-in* both a *shaper* firm sponsoring a dominant technology and a *follower* firm acquiring a license for this technology may expect a *stable* group of customers *loyal* to the dominant technology. In this way, they internalize part of the market potential for scale and leaning effects.

Therefore we hypothesize:

> ***(H_3) the larger the potential for scale and learning effects, the higher the realization of scale and learning effects***

6.2.4 The effect of the realization of scale and learning effects on product and organizational performance

As previously explained, scale and learning effects only become positive feedback mechanisms, i.e., increasing returns, when they are embedded in the firm's competitive strategy aimed at making optimal use of the acquired efficiency gain (Amit, 1986; Day & Montgomery, 1983). Firms may use the realized efficiency gain in different ways, for example for the pursuit of a cost-leadership strategy with low-priced products, or for the pursuit of a differentiation strategy with products that deliver superior customer value. Either way, such a strategy will improve product performance versus the performance of products of competitors that do not realize scale and learning effects to the same extent. Besides, learning-by-doing may result in product improvements, thereby better tailoring products to specific customer needs and realizing superior customer value relative to other firms. Thus we hypothesize that:

> ***(H_4) the higher the realization of scale and learning effects, the higher the level of product performance***

Analogous to the effect on product performance, realizing scale and learning effects may cause positive feedback in the firm when used for achieving organization-wide process improvements (Hatch & Mowery, 1998). Through better efficiency and higher effectiveness, these improvements result in better market outcomes in terms of sales growth, market share (Makadok, 1999) and new products. This in turn causes higher operational cash flows, higher profits and better returns on investment. Hence we hypothesize that:

> ***(H_5) the higher the realization of scale and learning effects, the higher the level of organizational performance***

For many firms organizational performance is, to a large extent, determined by the performance of a few primary products, i.e., products with a high market share. The rationale is that there is a positive relationship between the market shares of the firm's primary products and organizational performance. Market share as an antecedent of organizational performance is consistent with the profitability models proposed in numerous empirical studies; see Capon, Farley & Hoenig (1990) for an overview. The relationship is grounded in: (1) efficiency theory, i.e., the cost efficiencies for firms with higher market shares through a downward sloping cost experience curve, (2) market power theory, i.e., firms with higher market shares exercising market power to set prices, obtain inputs at lower costs and extract concessions from channel members and (3) product assessment theory, i.e., customers use market share as a signal for product quality and a product's widespread acceptance as an indicator of superior quality. Although the organizational performance impact of primary products may not hold universally, a meta-analysis performed by Szymanski, Bharadwaj & Varadarajan (1993) reveals that on average market share has a significant and positive effect on organizational performance. That primary products with high market shares are typically more profitable than those with lower market shares is also one of the more robust findings from the *PIMS-project* (Buzzell & Gale, 1987). Accordingly, we hypothesize:

> ***(H_6) the higher the level of product performance, the higher the level of organizational performance***

An indication of which hypothesis is tested in which empirical study, is provided in section 6.3, table 6.2.

6.3 Research design

According to Churchill & Iacobucci (2002) we can distinguish four types of research design: exploratory, descriptive, explanatory and predictive. These can be looked upon as stages in a continuous process (Churchill & Iacobucci, 2002) in which exploratory studies are often seen as the initial step. This step generates tentative explanations or hypotheses that serve as specific guides to descriptive, explanatory or predictive studies.

Descriptive and explanatory research designs have been used in this thesis. First the concepts to be studied have been described using literature study. A research model and hypotheses have been formulated on the basis of these preliminary ideas. Subsequently, the relationships between the concepts, i.e., the testing of hypotheses, have been explained by means of three empirical studies.

6.3.1 First empirical study

In the first empirical study, a cross-sectional management survey among *257* Dutch industrial firms was conducted to collect primary data. The survey method is especially appropriate to address 'what' type research questions (Yin, 1994). As this type of question is put forward in the central problem of this thesis and in the research questions, it is appropriate to use the survey method in the testing phase of this thesis. A possible drawback of the cross-sectional survey method is that cause and effect are measured at the same time, which means that we should be careful in drawing conclusions about causal relationships. This can be overcome by a firm theoretical grounding of the hypothesized relationships. The main argument for applying the cross-sectional survey method is that it enables the detection of differences between industries. This is especially important because information and knowledge intensive industries and industries with high economic and social interdependence are expected to be more increasing returns sensitive than industries with low information and knowledge intensity and low economic and social interdependence. The first empirical study will address the complete conceptual framework. See figure 6.2.

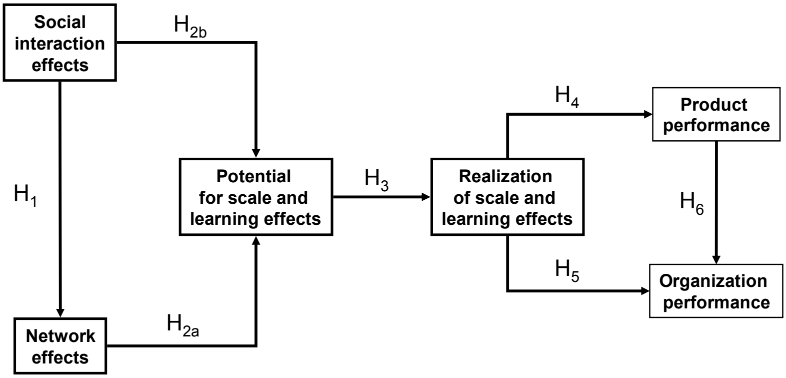

Figure 6-2: Research framework first empirical study

6.3.2 Second empirical study

The second empirical study was another cross-sectional management survey, this time among *36* large Dutch based firms listed on the *Amsterdam Stock Exchange*, combined with objective measurement of these firms' financial data. The sample for this study was a subset of the sample that was used for the third empirical study. This study focused on collecting subjective data on the market-based mechanisms of increasing returns through the survey and on measuring the firm-based mechanisms of increasing returns and firm performance by objective financial data. Analogous to the first empirical study, the second one also addressed the market structure, the firm conduct and the firm performance parts of the generic research framework, all measured over a period of five years. This makes for a comparative static research design, which enables us to draw causal inferences about the hypothesized relationships, albeit still with some care. This empirical study was focused on the relationship between network and social interaction effects, between network effects and the potential for scale and learning effects, between the potential and the realization of scale and learning effects and between the realization of scale and learning effects and firm performance. See figure 6.3.

Framework & hypotheses

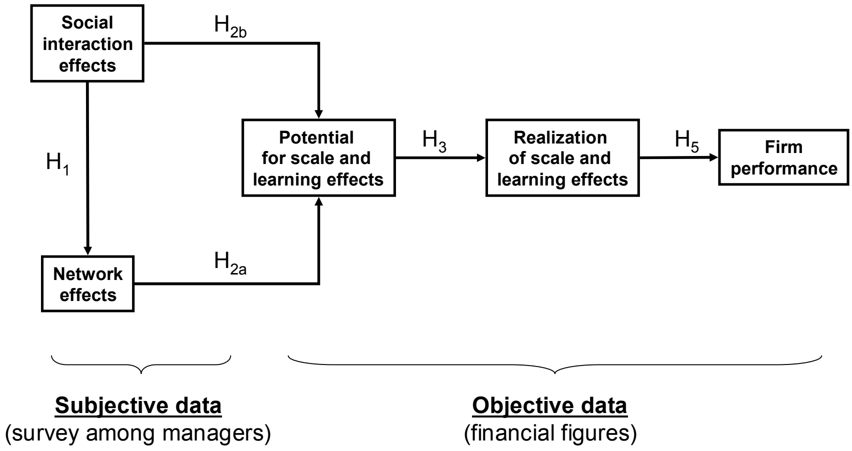

Figure 6-3: Research framework second empirical study

6.3.3 Third empirical study

In the third study, an analysis of the *Verdoorn law* and of the productivity-performance relationship was conducted for *118* large Dutch-based firms listed on the *Amsterdam Stock Exchange*. The data of the firm-based mechanisms of increasing returns and firm performance were based on existing objective data sources, i.e., financial data derived from annual reports. This study specifically addressed the firm conduct and firm performance parts of the generic research framework. It focused on the relationship between the potential and the realization of scale and learning effects and on the consequences of the realization of scale and learning effects for firm performance. The analysis was dynamic, enabling causal inferences about the hypothesized relationships of the research model. See figure 6.4.

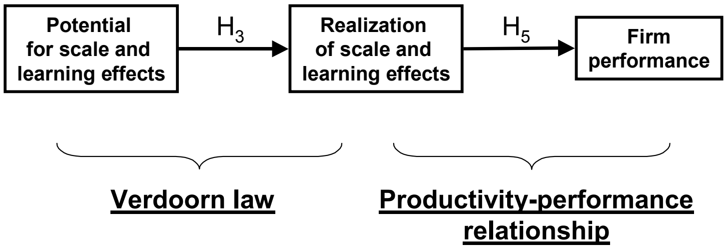

Figure 6-4: Research framework third empirical study

6.3.4 Relations between the studies

To discuss how these three studies are related, we will use the concept of *triangulation*, which is defined by Jick (1979)[50] as the combination of multiple methodologies in the study of the same phenomenon. There are generally two kinds of triangulation: between-methods and within-method. *Between-methods triangulation* is used for cross-validation when two or more distinct methods are found to be congruent and yield comparable data. *Within-method triangulation* uses multiple techniques within a given method to collect and interpret data. As Jick (1979, p.603) states: "[…] 'within-method' triangulation essentially involves cross-checking for internal consistency or reliability while 'between-method' triangulation tests the degree of external validity."

Both within-method and between-method triangulation are present in this thesis. The within-method triangulation becomes clear by comparing the first and second empirical studies. In the survey part of both studies, the scales used to measure market-based forms or increasing returns are essentially the same, though in the second survey study they are converted to comparative static measures. The two survey studies addressed different, independent samples. The sample for the first study was a random selection of Dutch firms in industrial and information technology industries. The sample for the second study consisted of Dutch firms listed on the *Amsterdam Stock Exchange* and comprised a broader array of industries than the first survey study. In this way, the two studies could be used to crosscheck

[50] Jick (1979) quotes this definition from Norman K. Denzin (1978, p.291), *The Research Act – 2nd edition*, New York, McGraw-Hill.

for internal consistency of the scales and reliability of the measurement of the market-based increasing returns mechanisms.

The between-method aspects become clear by comparing the first empirical study with the third empirical study. While starting from the same basic research model, there are some marked differences in the collection and analysis of the data:

- in the first study the research design was static, whereas that of the third was dynamic
- in the first study we used subjective scales for the measures of the firm-based forms of increasing returns and firm performance, whereas in the third study we used publicly available financial data to do so
- for the analysis of the response on the first survey study, the research model was estimated using structural equation modeling; regression analysis was used for estimating the relationships in the third study

Thus, the first and the third study can be used to crosscheck for the firm-based increasing returns mechanisms and for the implications on firm performance. Together, the second and third empirical studies can be used to cross-validate the results of the first empirical study.

We may conclude that on a continuum of triangulation design from primitive and simple to complex and holistic (Jick, 1979) our thesis is somewhere in the middle. In this thesis we try to strike a balance between on the one hand testing the reliability of the measures and the hypothesized model relationships and on the other searching for external validation of these measures and relationships.

6.3.5 Summary research design and hypotheses addressed

The tables 6.1 and 6.2 below summarize the research designs of the different studies and the hypotheses addressed in each.

Study:	First empirical study: cross-sectional management survey (chapter 7)	Second empirical study: management survey and financial measurements (chapter 8)	Third empirical study: Verdoorn law and productivity-performance analysis (chapter 9)
Aspects of research model addressed	- Market-based mechanisms - Firm-based mechanisms - Product performance - Organizational performance)	- Market-based mechanisms - Firm-based mechanisms - Firm performance	- Firm-based mechanisms - Firm performance
Data collected	Primary data (telephone survey)	Primary data (mail survey) and secondary data (publicly available financial data)	Secondary data (publicly available financial data)
Measurement	Subjective, perceptional data	Subjective perceptional data and objective financial data	Objective financial data
Level of analysis	Micro (firm)	Micro (firm)	Micro (firm) and meso (collection of firms)
Time dimension	Static	Comparative static	Dynamic

Table 6.1: Overview of the research designs of the empirical studies

Research hypotheses:	Study:	First empirical study (chapter 7)	Second empirical study (chapter 8)	Third empirical study (chapter9)
H_1	The larger the social interaction effects, the larger the network effects	X	X	
H_{2a}	The larger the network effects, the larger the potential for scale and learning effects	X	X	
H_{2b}	The larger the social interaction effects, the larger the potential for scale and learning effects	X	X	
H_3	The larger the potential for scale and learning effects, the higher the realization of scale and learning effects	X	X	X
H_4	The higher the realization of scale and learning effects, the higher the level of product performance	X		
H_5	The higher the realization of scale and learning effects, the higher the level of organizational performance	X	X	X
H_6	The higher the level of product performance, the higher the level of organizational performance	X		

Table 6.2: Overview of which of the research hypotheses are addressed in which empirical studies

6.4 Measurement

6.4.1 Measurement of network and social interaction effects

Our conceptualization of network effects and social interaction effects in chapter four was based on individual customers' or firms' assessments of technology network pay-offs, information exchange behavior and expectations formation behavior. This implies that network and social interaction effects should preferably be directly measured from the perspective of these agents, i.e., from the perspective of customers and suppliers. Measuring perceptions involves asking suppliers and customers directly about their product and technology adoption decisions. This can be done in different ways.

The first possibility is to conduct a field survey, e.g., by mail, by telephone, through the internet or by face-to-face interviews. The field survey is the approach we chose for the first and second empirical studies. For the first study we chose to conduct a telephone survey, for the second study we chose to conduct a mail survey. The survey provided us with data on managers' perceptions of the situation in a specific market. As the empirical research on increasing returns is relatively limited however, we found that only in two existing empirical studies was the survey method used to obtain a direct measurement of network and/or social interaction effects. The first one is the study of Hellofs & Jacobson (1999, p.21), who asked respondents by telephone to indicate that "When purchasing [*product category name*] would you (1) prefer that a large number of people used the same brand as you, (2) prefer that a very few other people purchased the same brand as you, or (3) be indifferent to the number of people purchasing the same brand as you?" Because this study focused on specific product categories, we concluded that its measurements could not be used to fit our survey. The second study is that of Schilling (2002); it provides items on availability of complementary products, i.e., indirect network effects in our definition. This study appeared only when our survey was already in the data gathering stage; therefore the measures developed in this study could not be incorporated in our survey.

The second possibility is to conduct an experiment, e.g., a laboratory or field experiment or a conjoint measurement. We did not follow this approach, but we did conduct a literature analysis to see whether measurements that were used in studies following such an approach could be adapted for use in our survey. We know currently of three studies where direct measurement of network effects was done using an experimental research design. The first is again the study of Hellofs &

Jacobson (1999), where subjects in the experiment had to answer to three items on a five-point scale that intend to measure positive or negative externalities. The experiment in their study is used as a validation/replication of results obtained by a model based on indirect measurement of network effects. The study focuses on externalities generated by brand. The second study is that of Gupta, Jain & Sawhney (1999), who performed a *conjoint analysis* to validate their proposed consumer response model. The conjoint analysis measured consumers' valuation of different product attributes, both hardware and software related, but limited to the market for digital television. The consumer response model measures indirect network effects only. The model thus generated provides a basis for doing a computer simulation. The specific focus of these first two studies prevented us from using the developed measurements for our purpose. The third is a study of Srinivasan, Lilien & Rangaswamy (2004), who used academic experts and *MBA* students to rate the degree of direct and indirect network externalities for different categories of products on a scale of *(1) no network externalities, to (7) very high network externalities*. This way of measurement presupposes knowledge of the concept of network externalities on behalf of respondents, something we could not expect in our sample of respondents. We therefore concluded that we could not use these measurements for our study.

We concluded that, for our purpose, no scales were available for measuring the constructs of network effects, social interaction effects and market consequences and we therefore had to develop new scales. Srinivasan, Lilien & Rangaswamy (2004) confirm this conclusion. The development and validation of our newly developed scales will be discussed in chapters seven and eight.

6.4.2 Measurement of scale and learning effects

In chapter five we conceptualized scale effects and learning effects. We now turn to the question of how to measure scale and learning effects. Measurement of scale and learning effects can follow objective or subjective approaches.

First, we can use a subjective approach to the measurement of scale and learning effects. This can be done by conducting a field survey asking representatives of the firm to give their opinion on the potential and the realization of scale and learning effects within their firm. This is the approach followed in the first empirical study. The development and validation of these measures is discussed in chapter seven.

Second, we can measure objectively the immediate consequences of scale and learning effects, i.e., the rise or fall of firm productivity, conforming to our definitions of scale and learning effects in sections 5.2 and 5.3, respectively. This is the approach that we use in the second and third empirical study. The realization of scale and learning effects means that a firm needs fewer inputs with respect to outputs. In economic terms, this means a rise in the marginal productivity of the combination of input factors. The main advantage of this approach is that scale and learning effects can be measured by objective and publicly available data. The development and validation of these measures is discussed in chapters eight and nine.

Third, we can chart objectively firms' average total cost curves. As we saw in sections 5.2 and 5.3, charting the firm's average total cost curve at any specific moment allows us to measure potential scale effects and charting the shifts of the firm's average total cost curve allows us to measure potential learning effects. Charting firms' average total cost curves causes a measurement problem, as we have to know the ratio between a firm's fixed costs and a firm's variable costs. These data are generally not publicly available. Of course we could ask representatives of firms to provide such data. This runs into the limitation, however, that firms' representatives are generally unwilling to share detailed information on their costs structures and, even it they would be willing to do so, it might be a practical impossibility for them to provide it. While the distinction between fixed and variable cost is conceptually straightforward and may even be calculated for a simple and clearly defined business process, it is unclear at the aggregate firm level which portion of costs should be regarded as 'fixed' and which as 'variable'. The limitations might be overcome by conducting research on a small scale, diving deeply into the peculiarities of the individual firm, e.g., by conducting a case study. This approach does not fit with the aimed contributions of this thesis however.[51]

Fourth, we can chart objectively firms' experience curves to measure learning effects or, optionally, we can chart firms' learning curves to measure the specific part of learning effect that has to do with increasing the efficiency of doing the original task. Charting firms' experience curves or learning curves causes fewer problems, as the only thing we have to do is measure the development of average total cost over time. This has been done many times, since Wright (1936) first observed that the number of labor hours needed for the production of an airframe was a decreasing function of

[51] Furthermore, applying methods that make us enter the 'black box' only makes sense when first the input-output relation has been validly demonstrated, i.e., by *not* entering the black box. This means creating large cross-sectional data sets.

the total number of airframes of the same type produced (see also Arrow, 1962) and since the appearance of the *Boston Consulting Group* report *Perspectives on experience* in 1972 (Day & Montgomery, 1983). The way of measuring the experience curve has usually been to test whether the *log* of average cost *(AC)* at time *t* is a linear downward sloping function of the *log* of cumulative volume units *(V)* at time *t* (Dolan & Jeuland, 1981; Day & Montgomery, 1983):

$$Log\ AC(t) = a - b * log\ V(t)$$

The difference between the experience curve and the learning curve is that while the latter reflects only the increasing efficiency of labor with respect to the original task, the former reflects all cost components and also includes all innovations, i.e., endogenous technological change, of the task. Therefore, the experience curve reflects our concept of learning effects much better than the learning curve. The experience curve, when applied at the firm level, i.e., not at the process or at the product level, incorporates induced and exogenous learning effects, autonomous learning effects and scale effects (see also Day & Montgomery, 1983; Hall & Howell, 1985). Induced and exogenous learning effects are reflected in the parameter *a*, whereas autonomous learning effects and scale effects are reflected in the parameter *b*. Without diving deeply into the 'black box', however, it is virtually impossible to distinguish between the cost savings caused by autonomous learning effects and those caused by scale effects. Therefore we did not follow this approach.

6.4.3 Measurement of firm performance

In view of our conceptualization of scale effects and learning effects, it is useful to distinguish between product performance and organizational performance. There are three reasons to measure product performance as well as organizational performance. The first is to measure the consequences of market-based increasing returns. While these effects are mainly about the dominance of product technologies, we have to bear in mind that customers buy *products*, not *technologies*. In other words, the success of the firm in either sponsoring a product technology or getting the most out of a license to this product technology is measured through the success or failure of the firm's products based on this product technology.

The second reason is that firm-based increasing returns are partly related to the number of products and/or the value of the output of specific products. This is especially true for the *economies of scale* part of scale effects and for the *learning* *curve* part of autonomous learning effects. As previously explained, scale and learning effects only cause positive feedback loops when they are embedded in the firm's competitive strategy aimed at making optimal use of the acquired efficiency gain (Alberts, 1989). Firms may use the realized efficiency gain in different ways. First, they may pursue a cost-leadership strategy with low-priced products. Second, they may decide to use the cost advantage to offset the cost required to improve product quality to pursue a differentiation strategy. Either way, such a strategy will improve product performance versus the performance of products of competitors that do not realize scale and learning effects to the same extent. Besides, learning-by-doing may result in product improvements, thereby better tailoring products to specific customer needs and realizing superior customer value relative to other firms.

Third, for many firms organizational performance is, to a large extent, determined by the performance of a few primary products, as described in section 6.2.4.

Measuring organizational performance alongside product performance is important because organizational performance directly measures the *economies of scope* and *economies of sequence* parts of scale effects and all but the *learning curve* parts of learning effects. Apart from the effects on product performance, the realization of scale and learning effects may cause positive feedback loops when they are used for pursuing economies of scope (Teece, 1980) and sequence (Spulber, 1993) and for organization-wide product and process improvements (Hatch & Mowery, 1998). Achieving economies of scope and sequence and organization-wide product and process improvements will result in better organizational performance in terms of sales growth, market share, new products, operational cash flows, profits and return on investment.

Organizational and product performance can be measured in different ways, either by measurement of objective performance data that are publicly available or supplied by representatives of the firm, or by measurement of the subjective opinions of knowledgeable persons. Subjective measures of organizational performance are frequently used in strategy research and have been shown to be reliable and valid (Dess & Robinson, 1994).

Product performance and organizational performance were measured using the subjective opinions of representatives of the firm in the first empirical study. The development and validation of these measures is described in chapter seven. In the second and third empirical studies, organizational performance was measured using publicly available objective performance data. The development and validation of these measures is described in chapters eight and nine.

6.5 Conclusions

In this chapter we presented the general research framework used in this thesis based on the *structure-conduct-performance paradigm* and the conceptualizations of the market-based and firm-based mechanisms of increasing returns from chapters four and five. On the basis of this research framework, hypotheses have been derived that will be tested in three empirical studies, described in chapters seven, eight and nine. The research hypotheses are shown in table 6.3, along with which hypotheses are tested in which empirical study.

Research hypotheses:	Study:	First empirical study (chapter 7)	Second empirical study (chapter 8)	Third empirical study (chapter9)
H_1	The larger the social interaction effects, the larger the network effects	X	X	
H_{2a}	The larger the network effects, the larger the potential for scale and learning effects	X	X	
H_{2b}	The larger the social interaction effects, the larger the potential for scale and learning effects	X	X	
H_3	The larger the potential for scale and learning effects, the higher the realization of scale and learning effects	X	X	X
H_4	The higher the realization of scale and learning effects, the higher the level of product performance	X		
H_5	The higher the realization of scale and learning effects, the higher the level of organizational performance	X	X	X
H_6	The higher the level of product performance, the higher the level of organizational performance	X		

Table 6.3: Overview of the research hypotheses

7. REPORT FIRST EMPIRICAL STUDY

The research process and the results of the first empirical study of this thesis, a cross-sectional management survey among managers of *257* Dutch manufacturing firms, are reported on in this chapter.

The development of the measures for this survey will be described along the steps 'for developing better measures of marketing constructs' as suggested by Churchill (1979), namely (1) specify the domain of the construct, (2) generate a sample of items, (3) collect data, (4) purify the measure, (5) collect data, (6) assess the reliability of the measure, (7) assess the validity of the measure and (8) develop a norm. Steps 1 through 4 are addressed in section one. Step 5 is addressed in section two. Steps 6 through 8 are addressed in section three.

The research hypotheses formulated in section 6.2 are tested in section four. We report on additional tests of the model in section five. Conclusions are provided in section six.

7.1 Development of the measures

7.1.1 Specifying the domain of the constructs

The first step, specifying the domain of each of the constructs was done in the theoretical part of the thesis. In chapter four it was determined that there are two market-based increasing returns mechanisms, namely network effects and social interaction effects We initially regarded these two mechanisms as separate constructs. According to the theoretical specification of network effects provided in chapter four, the measurement of network effects should at least address the following aspects:

- measurements of direct and of indirect network effects
- measurements at the product level and at the technology level
- measurements of the demand side effect, i.e., customers, and of the supply side effect, i.e., suppliers

Similarly, the measurement of social interaction effects should at least address the following items:

- measurements of information contagion and of self-reinforcing expectations

- measurements at the product level and at the technology level
- measurements of the demand side effect, i.e., customers, and of the supply side effect, i.e., suppliers

In chapter five it was determined that there are two firm-based mechanisms of increasing returns, namely scale effects and learning effects. We initially regarded these two mechanisms as separate constructs. According to the theoretical specification of scale and learning effects provided in chapter five, an explicit distinction should be made between the *potential* for scale and learning effects and the *realization* of scale and learning effects.

It was further determined, see chapters four and five, that there are a number of elements that could possibly influence the market-based mechanisms of increasing returns, the firm-based mechanisms of increasing returns, or the relationships between these. These elements are: complementarity, compatibility, substitution, path dependence, lock-in, market predictability, i.e., excess momentum or excess inertia, and knowledge intensity. The measurements of complementarity, compatibility and substitution should at least address the product and the technology level.

Finally, to research the implications of increasing returns for performance, measures have to be developed for the constructs of product performance and organizational performance.

7.1.2 Generating a sample of items

Step two in Churchill's (1979) procedure is generating a sample of items. As the amount of systematic empirical research into increasing returns is relatively limited, we found that for our purpose no existing measurement scales were available to measure the constructs of network effects, social interaction effects, scale effects and learning effects as we conceptualized them in chapters four and five. Consequently, these scales had to be newly developed. The same was true for the constructs of complementarity, compatibility, substitution, path dependence, lock-in, market predictability and knowledge intensity. Consequently, an initial pool of items was generated for each of these constructs, based on a literature search and on the theoretical specification of chapters four and five.

Regarding the construct of product performance, we adapted ten items from Griffin & Page (1996). These items comprise and extend the product performance measures that have been suggested in the increasing returns literature, e.g., price, quality and the price-quality ratio (Garud & Kumaraswamy, 1993; Gandal, 1995; Brynjolfsson & Kemerer, 1996; Cottrell & Koput, 1998; Hatch & Mowery, 1998), margins (Garud & Kumaraswamy, 1993), volume growth (Garud & Kumaraswamy, 1993; Gupta, Jain & Sawhney, 1999) and customer utility (Gupta, Jain & Sawhney, 1999).

Regarding the construct of organizational performance we adapted seven items from Naman & Slevin (1993) and Slater & Narver (1994). These items comprise and extend the organizational performance measures that have been suggested in the increasing returns literature, e.g., market share (Redmond, 1991; Garud & Kumaraswamy, 1993; Clark & Chatterjee, 1999; Makadok, 1999), profits and revenues (Garud & Kumaraswamy, 1993; Arthur, 1996).

7.1.3 Collecting data and purifying the measures

Step three in the Churchill (1979) procedure is collecting initial data to pre-test and purify the measures. We pre-tested the questionnaire in three phases: (1) face-to-face interviews with five academics and ten managers, (2) a test survey among *21* managers enabling the testing of substantive validity of the constructs (Gerbing & Anderson, 1991) and (3) face-to-face interviews with five academics and five managers. In each stage, participants identified items that were confusing, tasks that were difficult to respond to and any other problems they encountered when filling out the questionnaire. During and after each stage, as step four in the Churchill (1979) procedure, we revised or eliminated problematic items and developed new ones.

The major adjustments during and after the first stage focused on the elimination of problematic items and on the development of new items. The most noteworthy adjustment took place within the constructs of scale effects and learning effects. Initially, we had generated a pool of *13* items for measuring scale effects and an equal number of items for measuring learning effects, each item reflecting a specific cost aspect. From the interviews with managers it turned out that they were unable to differentiate between the different cost aspects of scale effects and learning effects. Moreover, they found it to be very difficult to differentiate between scale effects and learning effects.[52] It was therefore decided to reduce the measurement of scale effects

[52] This should not come as a surprise, because, as argued in section 6.4, it is very difficult in practice to disentangle scale effects and learning effects.

to two items, reflecting scale effects on fixed and variable costs and to reduce the measurement of learning effects to a single item. At this stage we envisaged making a single three-item construct reflecting scale and learning effects. The participating managers reported no problems in distinguishing between the *potential* for scale and learning effects and the *realization* of scale and learning effects. Hence, this distinction was kept.

The test survey in the second stage used a sampling frame of 2936 Dutch manufacturing firms with more than *20* employees in the specified industry sectors (see table 7.1). Through a telephone pre-survey of *185* randomly selected firms, *60* firms were identified with a knowledgeable marketing manager in a position to generalize about patterns of behavior related to the content of inquiry. These *60* marketing managers were sent a standardized questionnaire by mail. In answering the questions we asked the respondents to focus on their primary product in their principal served market segment. Our efforts yielded *21* usable responses, or a usable response rate of *35.0%.*

After the analysis of the test survey results, a number of important adjustments were made. First, we decided to use *seven-point Likert scales* instead of *five-point scales* for all major constructs to improve variance in answers. Second, we carefully examined whether the order in which questions were put had any effect on the answering patters. Where this was the case, the order was adjusted. Third, a number of control questions requiring respondents to provide detailed market share data on products and technologies were deleted because of high non-response. Fourth, the number of items to measure network effects and social interaction effects were reduced from *16* to *8* items each as respondents reported that these questions were tedious and they resorted to repeating answering patterns. We achieved this reduction by not longer asking respondents to answer questions on network effects and social interaction effects from their own *and* from the customer's perspective, but only from their own perspective. A test for unidimensionality (Steenkamp & Van Trijp, 1991) using principal axis factoring with an *eigenvalue* of *1.0* and factor loadings of *0.40* as the cut-off points showed that respondents had indeed perceived the questions from their own perspective and from the customer's perspective as being quite similar.

During the third stage the adjustments were much smaller, indicating the improvement made after the previous stages. The instructions for filling out the questionnaire were improved, the formulations of the questions were fine-tuned to prevent possible misunderstandings and the questionnaire layout was optimized. By the end of the third phase of pre-testing the participants reported no concerns. The questionnaire was therefore ready for final administration.

In the final version of the questionnaire all constructs, except for knowledge intensity, were measured using multiple items and using *seven-point Likert scales* anchored by *(1) strongly disagree* and *(7) strongly agree*. Social interaction effects and network effects were each measured using eight items. The potential for scale effects and learning effects was measured using three items. The realization of scale and learning effects was also measured using three items. Complementarity and compatibility were each measured using two items, market predictability was measured using three items and substitution, path dependence and lock-in and were each measured using four items. Knowledge intensity was measured using three items, using seven point semantic differential scales. Product performance was measured using ten items adapted from Griffin & Page (1996) and organizational performance was measured using seven comparative items adapted from Naman and Slevin (1993) and Slater & Narver (1994). The scale items used in the final questionnaire are shown in *Appendix I*.

7.2 Sample and data description

Step five in the Churchill (1979) procedure, the collection of data, was done through a survey directed at managers of manufacturing firms, i.e., firms that supply tangible products to their customers. The sampling frame for this survey consisted of *2934* Dutch manufacturing initial firms with more than *25* employees in a number of specified industry sectors (see table 7.1). The identification data of these firms were derived from the *REACH database*.[53]

Using a telephone pre-survey among firms randomly drawn from the sampling frame, *998* were identified with a knowledgeable marketing manager in a position to generalize about patterns of behavior related to the content of inquiry. To ensure the suitability of the marketing managers we adopted a self-assessment of their knowledgeability through the telephone calls. In this telephone pre-survey, the firms' identification data were also checked. It turned out that from the computer services and IT agencies contacted, and classified in the database as performing manufacturing activities, that around *40%* reported performing no manufacturing activities. Hence, we corrected the sampling frame by removing these firms (see table 7.1).

[53] *Research and Analysis of Companies in Holland*, *Bureau van Dijk* (2001).

Industry	Initial sampling frame (2934 firms)	Corrected sampling frame (2661 firms)	Research sample (257 firms)
Manufacturing of:			
- Metal products	27.5%	30.3%	31.9%
- Machinery	26.8%	29.6%	33.9%
- Office machinery and computers	0.8%	0.9%	0.4%
- Electrical machinery and supplies	3.9%	4.3%	3.1%
- Audio, video and telecommunication	2.1%	2.4%	1.2%
- Medical instruments	6.0%	6.6%	6.2%
- Cars, trucks and trailers	4.4%	4.8%	5.1%
- Transport (not cars, trucks or trailers)	5.2%	5.7%	5.1%
- Computer services and IT agencies	23.3%	15.4%	13.1%
sum	100.0%	100.0%	100.0%

Table 7.1: Sample for the first empirical study

Of the *998* identified knowledgeable marketing managers, *283 (28.4%)* were willing to cooperate with the research. These *283* marketing managers were interviewed by phone using the standardized questionnaire discussed in the previous section. In answering the questions we asked the respondents to focus on their primary product in their principal served market segment. Our efforts yielded *257* usable responses, or a usable response rate of *25.8%.*

To check the representativeness of the research sample, we performed a *chi-square analysis* of the industry response distribution (Weinberg & Abramowitz, 2002). This analysis checks the null-hypothesis that the distribution of the research sample is equal to the distribution of the (corrected) sampling frame. With a significance level of $p<0.05$, our analysis showed that the null-hypothesis is not rejected ($\chi^2=6.066$, $df=8$). Therefore we conclude that the sample of firms is representative for the total population.

A routine check for respondent bias using *one-way ANOVA* indicated that no significant differences existed in the mean responses on the main constructs across respondents with different levels of education and different durations of employment. Moreover, no industry and firm size effects existed in the mean responses on the main constructs.[54] Only the constructs of market predictability and knowledge intensity showed significant differences, reflecting a problem of the reliability of these scales (see further section 7.3).

A time-trend extrapolation procedure was used to test for non-response bias (Armstrong & Overton, 1977). We divided the data set into quartiles based on the number of minutes it took to complete the questionnaire. The underlying rationale is that slow respondents are more similar to non-respondents than fast respondents. In comparing fast *(1st quartile)* and slow *(4th quartile)* respondents, no significant differences emerged in the mean responses on most of the constructs. Only on the construct of product performance was a significant difference detected between the first and the fourth quartiles. A more in-depth analysis into this construct however showed that no clear trend could be detected in the answering patterns.

Together these results suggest that respondent, industry, firm and non-response bias were not a major problem. Sample characteristics are shown in tables 7.2, 7.3 and 7.4.

Number of employees firm	Frequency	Percent	Valid percent
<= 25	10	3,9%	4,0%
26-50	72	28,0%	28,7%
51-100	68	26,5%	27,1%
101-200	40	15,6%	15,9%
>200	61	23,7%	24,3%
Missing	6	2,3%	
sum	257	100,0%	100,0%

Table 7.2: Sample characteristics: number of employees

[54] That is remarkable, because we expected that industry characteristics would have a major influence (see, e.g., Economides, 1996).

Respondent duration of employment relation	Frequency	Percent	Valid percent
1 year or less	39	15,2%	15,2%
1-2 years	33	12,8%	12,9%
2-5 years	50	19,5%	19,5%
5-10 years	53	20,6%	20,7%
10-20 years	52	20,2%	20,3%
More than 20 years	29	11,3%	11,3%
Missing	1	0,4%	
sum	257		100,0%

Table 7.3: Sample characteristics: respondent duration of employment

Respondent education	Frequency	Percent	Valid percent
University education	49	19,1%	19,3%
Higher vocational education	135	52,5%	53,1%
Intermediate vocational education	35	13,6%	13,8%
Other	35	13,6%	13,8%
Missing	3	1,2%	
sum	257		100,0%

Table 7.4: Sample characteristics: respondent education

7.3 Validation of the measures

Steps six, seven and eight in the Churchill (1979) procedure involve validating the measures and establishing the final measures. We discuss two main aspects of validity, *content validity* and *construct validity* (Churchill & Iacobucci, 2002; Kerlinger, 1986; Churchill, 1979). *Content validity* focuses on the adequacy with which the domain of the characteristic is captured by the measure (Churchill & Iacobucci, 2002, p.408). It is typically assured by deriving the measures from a thorough literature research and by doing thorough pre-tests of the measures. Content validity has been addressed in section 7.1. *Construct validity* is directly concerned with the question what the instrument is measuring (Churchill & Iacobucci, 2002, p.409). The different aspects of construct validity, i.e., *unidimensionality*, *reliability*, *within-method convergent validity* and *discriminant validity* (Churchill & Iacobucci, 2002; Steenkamp & Van Trijp, 1991; Kerlinger, 1986; Churchill, 1979) will be discussed below. Each of these aspects is a necessary condition for a construct to be valid.

7.3.1 Unidimensionality

To assess the unidimensionality of the scales, we computed the inter-item correlations and corrected item-to-total correlations for each item, taking one subscale at a time (Steenkamp & Van Trijp, 1991). We eliminated three items from the product performance construct and one item from the market predictability construct for which these correlations were not significant. The dimensionality of each purified scale was explored with *maximum likelihood factoring* using an *eigenvalue* of *1.0* and factor loadings of *0.30* as the cut-off points. This resulted in the purified measures shown in table 7.5.

Unidimensionality of the scales	No. of items deleted	No. of items remai-ning	Lowest item-to-total correlation	Eigen-value (ML factoring)	Variance explained
Network effects products	0	4	0.48	2.29	44.3%
Network effects technologies	0	4	0.62	2.79	59.9%
Social interaction effects products	0	4	0.59	2.61	53.7%
Social interaction effects technologies	0	4	0.67	2.86	62.2%
Potential for scale and learning effects	0	3	0.28	1.69	38.1%
Realization of scale and learning effects	0	3	0.32	1.99	57.1%
Product performance	3	7	0.29	2.43	29.3%
Organizational performance	0	7	0.62	4.37	56.1%
Substitution effects	0	4	0.42	2.12	40.0%
Lock-in effects	0	4	0.53	2.39	47.4%
Path dependence	0	4	0.47	2.44	49.7%
Market predictability	1	2	0.31	n.a.	n.a.
Product complementarity and compatibility	0	2	0.34	n.a.	n.a.
Technology complementarity and compatibility	0	2	0.45	n.a.	n.a.
Knowledge intensity of product	0	3	0.25	1.40	20.2%

Table 7.5: Unidimensionality of the scales

The unidimensionality of each purified scale was subsequently tested by estimating *confirmatory factor models* using *maximum likelihood estimation in LISREL 8.3* (Jöreskog & Sörbom, 1999), following Steenkamp & Van Trijp (1991). We chose to estimate five models to be able to fit the constraints of a five-to-one ratio of sample size to parameter estimates (Baumgartner & Homburg, 1996). Following Kumar & Dillon (1987), Steenkamp & Van Trijp (1991) state that the overall fit of the model provides the necessary and sufficient information to determine the unidimensionality. We examined the values of the standardized residuals to identify misspecifications of the measurement models. This resulted in a re-specification of the constructs regarding network effects and social interactions effects, into an integral second-order measurement model. In table 7.6 the results of this integral second-order measurement model are presented. The second-order measurement model for network effects comprised network effects on the product level and network effects on the technology level. Similarly, the second-order measurement model for social interaction effects comprises social interaction effects at the product level and social interaction effects at the technology level. The first-order constructs for network effects at the product level, network effects at the technology level, social interaction effects at the product level and social interaction effects at the technology level remained as in the statistical analysis. However, these first-order constructs have now been estimated on the basis of the integral second-order measurement model.

The *LISREL* analysis also resulted in a re-specification of the constructs of substitution and lock-in effects. For both it was established that instead of *4-item* constructs they should be split into two *2-item* constructs, reflecting the product level and the technological level, respectively. Further, the re-specification in *LISREL* resulted in one item being deleted from the construct of path dependence, three items being deleted from the product performance construct and one item being deleted from the knowledge intensity of product construct. The schematic compositions of the corrected constructs are shown in figures 7.1 through 7.5. The results of the five measurement models are shown in the corresponding tables 7.6 through 7.10.

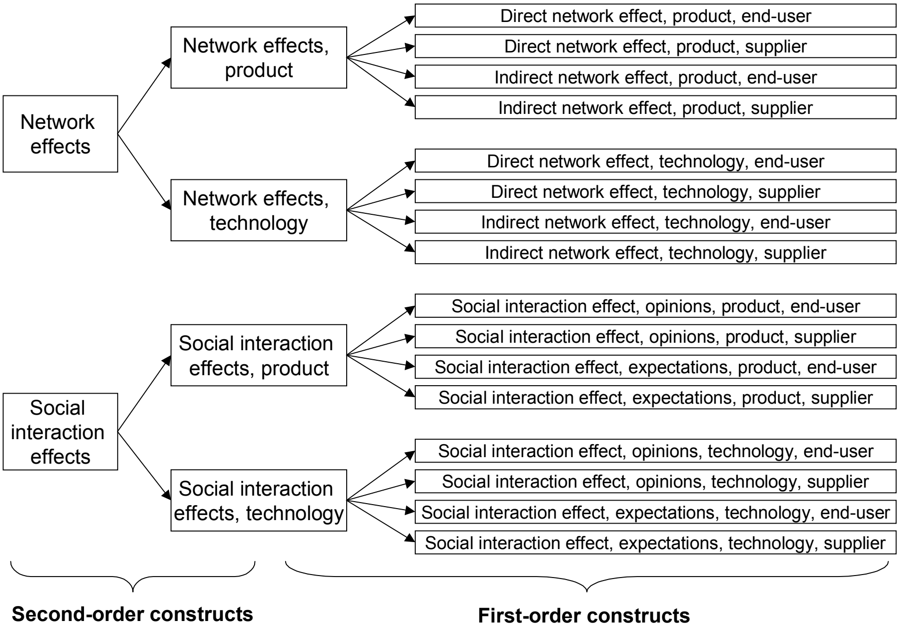

Figure 7-1: Measurement model 1 - second-order network effects and second-order social interaction effects

Measurement model 1	No. of items deleted	No. of items remaining	Lowest t-value	Average variance extracted	Composite reliability
Network effects products	0	4	7.20	46.0%	0.77
Network effects technologies	0	4	6.91	66.1%	0.89
Social interaction effects products	0	4	7.32	52.0%	0.81
Social interaction effect technologies	0	4	4.19	62.4%	0.87
Network effects (second-order)	0	2	5.08	43.3%	0.60
Social interaction effects (second-order)	0	2	3.66	71.6%	0.83
Evaluation of the model: χ^2/df= 1.76; GFI= 0.90; NFI= 0.91; NNFI= 0.93; CFI= 0.95; IFI= 0.95; RMSEA= 0.070					

Table 7.6: LISREL estimates of measurement model 1

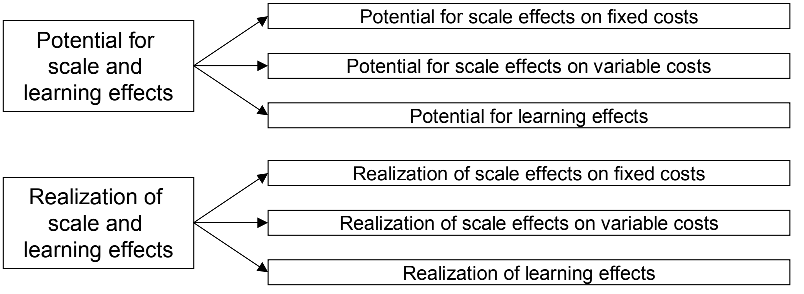

Figure 7-2: Measurement model 2 - potential and realization of scale and learning effects

Measurement model 2	No. of items deleted	No. of items remaining	Lowest t-value	Average variance extracted	Composite reliability
Potential for scale and learning effects	0	3	4.58	37.3%	0.62
Realization of scale and learning effects	0	3	5.07	56.5%	0.77
Evaluation of the model: χ^2/df= 0.80; GFI= 0.99; NFI= 0.99; NNFI= 1.00; CFI= 1.00; IFI= 1.00; RMSEA= 0.000					

Table 7.7: LISREL estimates of measurement model 2

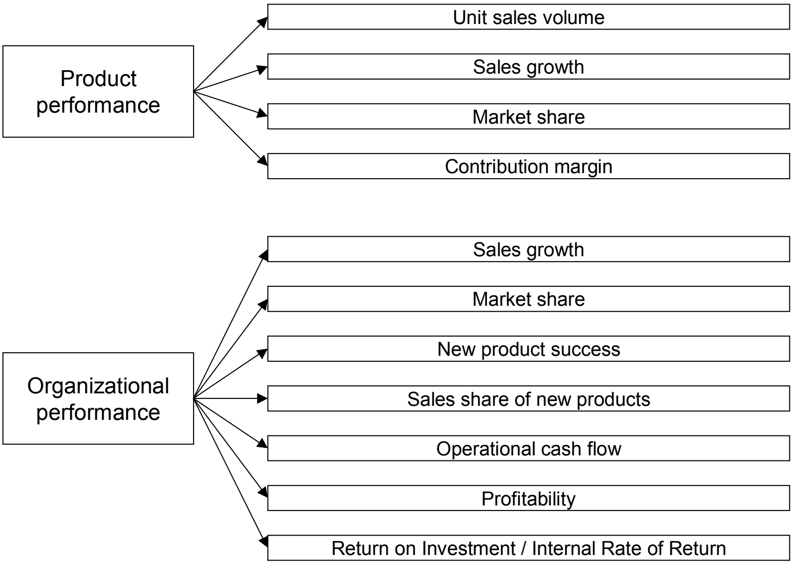

Figure 7-3: Measurement model 3 - product performance and organizational performance

Measurement model 3	No. of items deleted	No. of items remaining	Lowest t-value	Average variance extracted	Composite reliability
Product performance	3	4	6.87	43.8%	0.76
Organizational performance	0	7	8.97	54.7%	0.89
Evaluation of the model: χ^2/df= 1.34; GFI= 0.95; NFI= 0.95; NNFI= 0.98; CFI= 0.99; IFI= 0.99; RMSEA= 0.046					

Table 7.8: LISREL estimates of measurement model 3

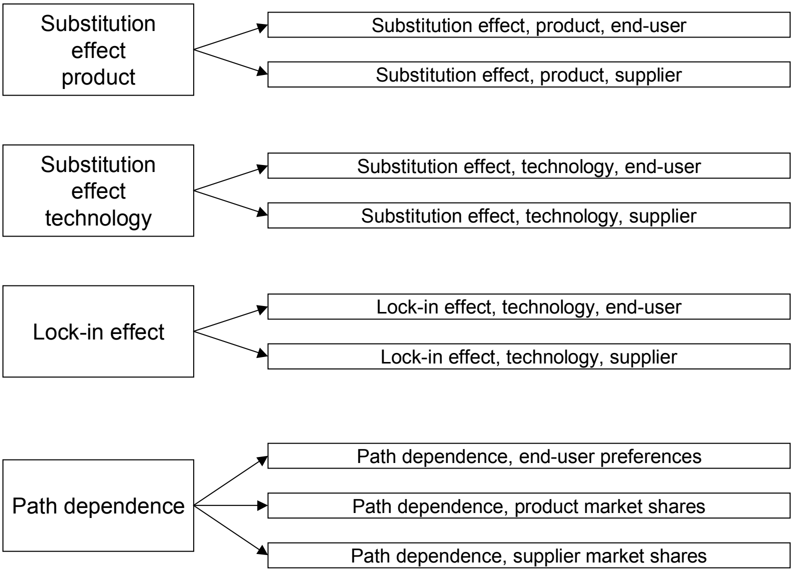

Figure 7-4: Measurement model 4 - product substitution, technology substitution, lock-in and path dependence

Measurement model 4	No. of items deleted	No. of items remaining	Lowest t-value	Average variance extracted	Composite reliability
Substitution effects product	0	2	7.13	47.6%	0.64
Substitution effects technology	0	2	9.18	65.9%	0.79
Lock-in effects	2	2	6.39	58.2%	0.73
Path dependence	1	3	8.23	60.4%	0.82
Evaluation of the model: χ^2/df= 1.43; GFI= 0.96; NFI= 0.94; NNFI= 0.96; CFI= 0.98; IFI= 0.98; RMSEA= 0.049					

Table 7.9: LISREL estimates of measurement model 4

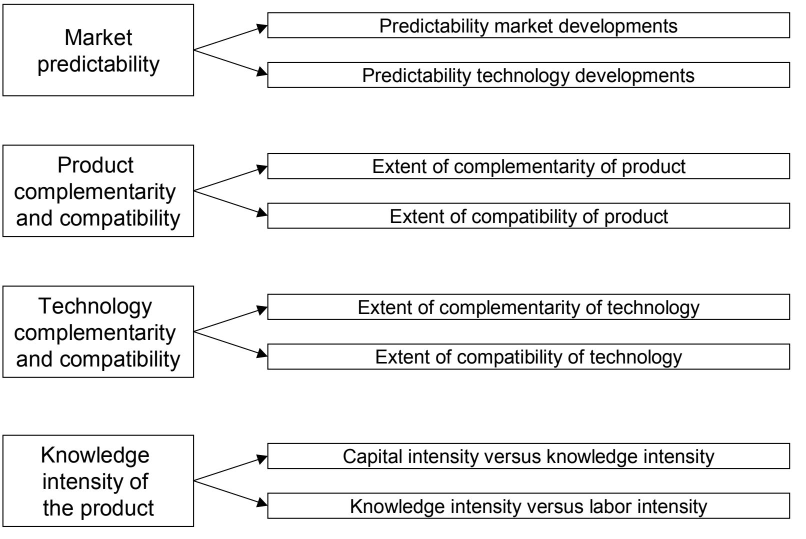

Figure 7-5: Measurement model 5 - market predictability, product complementarity and compatibility, technology complementarity and compatibility, and knowledge intensity of the product

Measurement model 5	No. of items deleted	No. of items remaining	Lowest t-value	Average variance extracted	Composite reliability
Market predictability	0	2	2.17	48.1%	0.63
Product complementarity and compatibility	0	2	4.29	41.1%	0.58
Technology complementarity and compatibility	0	2	2.90	54.4%	0.68
Knowledge intensity of product	1	2	3.01	37.2%	0.52
Evaluation of the model: χ^2/df= 1.37; GFI= 0.97; NFI= 0.84; NNFI= 0.87; CFI= 0.93; IFI= 0.94; RMSEA= 0.052					

Table 7.10: LISREL estimates of measurement model 5

As can be seen from the tables 7.6 through 7.10, the fits of the measurement models 1, 2, 3 and 4 are good, meeting the required *0.90* threshold values of the absolute, i.e., *GFI* and *NFI* and incremental, i.e., *NNFI*, *CFI* and *IFI* fit indices. Model 5 does not meet the threshold value for the *NFI* and *NNFI* fit indices, indicating possible problems with the dimensionality of the constructs market predictability, product complementarity and compatibility, technological complementarity and compatibility and knowledge intensity of the product.

The parsimonious fit measure of the *chi-square* value divided by the number of *degrees of freedom* was below the recommended level of *2.0* and the *root mean square error of approximation (RMSEA)* was below the recommended *0.08* level for each of the models.

7.3.2 Reliability

The most commonly used way to assess the reliability of a scale is to compute the coefficient alpha, or *Cronbach alpha*. According to Peter (1979) this is a useful and usable approach to assessing the reliability of measurement scales. We explored the reliability of each purified, unidimensional scale by computing the reliability coefficient. See table 7.11 below.

Reliability of the scales	No. of items	Lowest item-to-total correlation[#]	Cronbach alpha	Eigen-value (ML factoring)	Variance explained
Network effects products	4	0.48	0.75	2.29	44.3%
Network effects technologies	4	0.62	0.80	2.79	59.9%
Social interaction effects products	4	0.59	0.82	2.61	53.7%
Social interaction effects technologies	4	0.67	0.87	2.86	62.2%
Potential of scale and learning effects	3	0.28	0.60	1.69	38.1%
Realization of scale and learning effects	3	0.32	0.73	1.99	57.1%
Product performance	4	0.43	0.74	2.25	42.8%
Organizational performance	7	0.62	0.90	4.37	56.1%
Substitution effects product	2	0.41	n.a.	n.a.	n.a.
Substitution effects technology	2	0.65	n.a.	n.a.	n.a.
Lock-in effects	2	0.56	n.a.	n.a.	n.a.
Path dependence	3	0.52			
Market predictability	2	0.31	n.a.	n.a.	n.a.

Reliability of the scales	No. of items	Lowest item-to-total correlation#	Cronbach alpha	Eigen-value (ML factoring)	Variance explained
Product complementarity and compatibility	2	0.34	n.a.	n.a.	n.a.
Technology complementarity and compatibility	2	0.45	n.a.	n.a.	n.a.
Knowledge intensity of product	2	0.19	n.a.	n.a.	n.a.
# For the two-item scales the figure provided is the inter-item correlation					

Table 7.11: Reliability of the scales

The values of the *Cronbach alpha* for the different constructs indicate that for the multi-item constructs, with the exception of the potential for scale and learning effects, the reliability is adequate. In view of the early stage of survey research into increasing returns, see the argumentation in chapter three, the *Cronbach alpha* value for the construct potential for scale and learning effects is just acceptable. The computation of the *Cronbach alpha* is not meaningful for the two-item scales. The item-to-total correlation for the construct knowledge intensity of the product indicates that there may be a problem regarding this construct.

7.3.3 Within-method convergent validity

Convergent validity of the scales was investigated by estimating five *confirmatory factor models* using *maximum likelihood estimation in LISREL 8.3* (Jöreskog & Sörbom, 1999). For the models and the results, see section 7.3.1. Steenkamp & Van Trijp (1991) provide three conditions for convergent validity, namely (1) that the factor coefficients for all the items of a construct should be significant, (2) that the correlation between the item and the construct should exceed *0.50* and (3) that the overall fit of the measurement model should be acceptable.

Assessing measurement models 1 through 5, the first condition is met for all items on all constructs, i.e., each item loaded significantly *(t>2.0)* on its corresponding latent construct.

The second condition is met for all items in measurement model 1, addressing product and technological network effects and product and technological social interaction effects. This condition was not met for measurement model 2, addressing the potential for scale and learning effects and the realization of scale and learning effects. There was one item with a correlation of *0.33* for the construct potential for scale and learning effects, and there was one item with a correlation of *0.32* for the construct realization of scale and learning effects. In both cases the low-correlating item was the item on learning effects. The low correlations indicate a possible problem with the convergent validity of these scales. For measurement model 3, on product performance and organizational performance, all items met the condition. With measurement model 4, the second condition was met for all items. In measurement model 5 the market predictability scale had one item with a correlation of *0.49*, the technological complementarity and compatibility scale had one item with a correlation of *0.44* and the knowledge intensity of the product scale had one item with a correlation of *0.42*.

Regarding the third condition, the overall fit, models 1 through 4 all have acceptable fit (see tables 7.6 through 7.9). Model 5, reflecting the constructs of market predictability, product complementarity and compatibility, technological complementarity and compatibility and knowledge intensity of the product has a fit that is below the recommended *0.90* thresholds on the *NFI (0.84)* and *NNFI (0.87)* fit indices, indicating a possible problem with the convergent validity of these constructs.

7.3.4 Discriminant validity

Discriminant validity among the scales was assessed in two steps. First, we estimated a two-factor model for each possible pair of scales. Discriminant validity was indicated when the variance-extracted estimates for the two scales exceed the square of the correlation between them (Bagozzi & Yi, 1988). The results revealed that without exception the assessment supported the discriminant validity of the scales.

Second, we examined for every measurement model, the *chi-square difference* between the original models and similar models in which the correlations among the latent constructs were constrained to *1* (Bagozzi & Phillips, 1982, p.476). A significantly lower value of the *chi-square* of the constrained model indicates that the latent constructs are not perfectly correlated and that discriminant validity is achieved. The results shown in table 7.12 indicate that discriminant validity is achieved for all of the scales.

Discriminant validity	*Model with trait correlations constrained to unity*		*Unconstrained model*		*Chi-square difference*[#]	
	χ^2	*df*	χ^2	*df*	$\Delta\chi^2$	Δdf
Model 1 (second-order constructs)	118.95	77	134.05	76	15.10***	1
Model 1 (first-order constructs)	340.16	81	114.41	75	225.75***	6
Model 2	81.88	6	4.01	5	77.87***	1
Model 3	194.07	37	48.07	36	146.07***	1
Model 4	275.15	27	29.98	21	245.17***	6
Model 5	70.85	20	19.18	14	51.67***	6
*[#] Significance at 5% level is indicated by *, at 1% level by **, at 0.1% level by ****						

Table 7.12: Discriminant validity of the scales

7.3.5 Conclusions on construct validity

Together the results of the tests for unidimensionality, reliability, convergent validity and discriminant validity provided evidence of the validity of the scales. A summary of the results is provided in table 7.13.

Conclusions on construct validity	Content validity	Unidi-mensio-nality	Relia-bility	Within-method conver-gent validity	Discrimi-nant validity
Network effects products	OK	OK	OK	OK	OK
Network effects technologies	OK	OK	OK	OK	OK
Social interaction effects products	OK	OK	OK	OK	OK
Social interaction effects technologies	OK	OK	OK	OK	OK
Network effects (second-order construct)	OK	OK	OK	OK	OK
Social interaction effects (second-order construct)	OK	OK	OK	OK	OK
Potential for scale and learning effects	OK	OK	Just accep-table	Possible problem	OK
Realization of scale and learning effects	OK	OK	OK	Possible problem	OK
Product performance	OK	OK	OK	OK	OK
Organizational performance	OK	OK	OK	OK	OK

Conclusions on construct validity	Content validity	Unidi-mensio-nality	Relia-bility	Within-method conver-gent validity	Discrimi-nant validity
Substitution effects product	OK	OK	OK	OK	OK
Substitution effects technology	OK	OK	OK	OK	OK
Lock-in effects	OK	OK	OK	OK	OK
Path dependence	OK	OK	OK	OK	OK
Market predictability	OK	Possible problem	OK	Possible problem	OK
Product complementarity and compatibility	OK	Possible problem	OK	OK	OK
Technology complementarity and compatibility	OK	Possible problem	OK	Possible problem	OK
Knowledge intensity of product	OK	Possible problem	Possible problem	Possible problem	OK

Table 7.13: Conclusions on the validity of the scales

From these results we can conclude the following. There is enough evidence for the validity of the first-order and the second-order constructs of network effects and social interaction effects. Network effects and social interaction effects may therefore each be conceptualized as second-order constructs.

As argued in section 7.1.3, we restricted the measurement of the constructs of the potential and the realization of scale and learning effects to three items each for practical measurement reasons.[55] Moreover, we decided to join scale and learning effects in one measure and instead make a distinction between the potential and the realization because this fitted better with respondents' experiences. The joining of scale and learning effects may very well be the cause of the problems with the convergent validity of these scales. It may very well be that, although managers report that they are in practice unable to differentiate between scale effects and learning effects, they will still provide a different subjective answer when confronted with the questionnaire. To check on the correctness of our assumption, we analyzed the possibility of removing the items measuring learning effects from the constructs potential for scale and learning effects and realization of scale and learning effects. Our analysis showed that the fit of this alternative measurement model was much lower than that of the current model *(*$\chi^2/df=9.96$*; GFI=0.98; NFI=0.97; NNFI=0.82;*

[55] We argued in section 6.4 that although in theory scale effects and learning effects are different concepts, it is in management practice very difficult to distinguish between them.

CFI=0.97; IFI=0.97; RMSEA=0.199). We therefore decided to keep the current measurement model.

The validity analyses provided enough evidence to support the validity of the constructs of product performance and organizational performance. The same is true for the constructs of substitution effects, both at the product and the technology level, for lock-in effects and for path dependence. With respect to the validity of the constructs of market predictability, product complementarity and compatibility, technological complementarity and compatibility and knowledge intensity of products we need to be careful. The fit of the measurement model indicates possible problems with both the unidimensionality and the convergent validity of the constructs. Correlations between the items and the constructs below *0.50* indicated further problems with convergent validity for the market predictability scale, the technological complementarity and compatibility scale and the knowledge intensity of the product scale. There is also an indication of a possible problem with scale reliability for the construct knowledge intensity of the product. Alternative model specifications did not result in better fitting measurement models. We therefore conclude that the constructs of market predictability, product complementarity and compatibility and technological complementarity and compatibility may be applied only with the utmost care.

	Network effects	Social interaction effects	Potential for scale and learning effects	Realization of scale and learning effects	Product performance
Social interaction effects	0.734**				
Potential for scale and learning effects	0.223**	0.173*			
Realization of scale and learning effects	0.161*	0.155*	0.334**		
Product performance	0.167**	0.163*	0.171**	0.186**	
Organizational performance	0.133*	0.126	0.095	0.183**	0.337**
*# Significance at 5% level is indicated by *, at 1% level by ***					

Table 7.14: Correlations between the main constructs

Provided with this evidence the constructs were formed by averaging the responses to each item in a particular scale. The correlations between the main constructs are given in table 7.14.

7.4 Results of testing the research hypotheses

7.4.1 Research model and hypotheses

The hypotheses were tested using *causal modeling with LISREL 8.3* (Jöreskog & Sörbom, 1999). As our sample size was not sufficiently large to obtain a *combined measurement and structural equation model*, we used the constructs created for the estimation of the measurement model to obtain a structural equation model with a favorable ratio between our sample size and the number of parameters to be estimated (Baumgartner & Homburg, 1996). The discussion of the results is organized around the hypothesized relationships shown in figure 7.6.

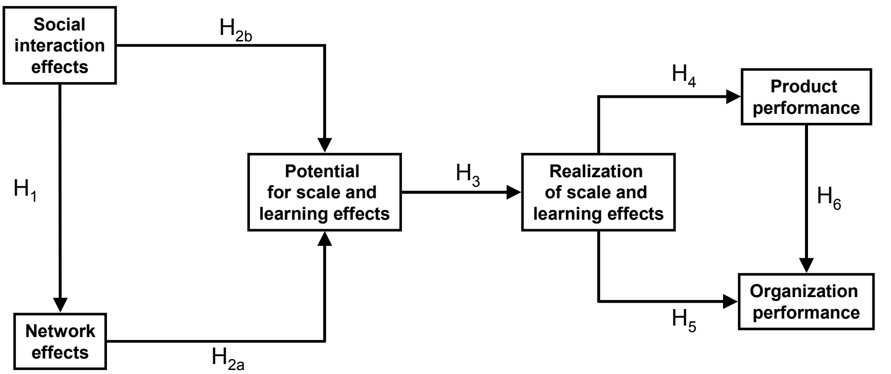

Figure 7-6: Research framework and hypotheses of the first empirical study

The analysis resulted in a good fit to the data *(χ^2/df=1.53; GFI=0.98; AGFI=0.95; NFI=0.95; NNFI=0.96; CFI=0.98; IFI=0.98; RMSEA=0.049).* The unstandardized estimates and *t-values* associated with the direct effects are presented in table 7.15. The unstandardized estimates and *t-values* associated with the indirect and total effects are presented in table 7.16.

Path to: / Path from:	Network effects	Potential for scale and learning effects	Realization of scale and learning effects	Product perfor-mance	Organi-zational perfor-mance
Social interaction effects	**0.71 (16.12)**	0.03 (0.29)			
Network effects		**0.19 (2.13)**			
Potential for scale and learning effects			**0.27 (4.12)**		
Realization of scale and learning effects				**0.15 (2.75)**	**0.10 (1.99)**
Product performance					**0.30 (5.01)**
Evaluation of the model: χ^2/df= 1.53; GFI= 0.98; AGFI= 0.95; NFI= 0.95; NNFI= 0.96; CFI= 0.98; IFI= 0.98; RMSEA= 0.049					
*Note: T-values above 1.96 (p<0.05) are shown in **bold**.*					

Table 7.15: LISREL path model direct effects

7.4.2 The relationship between social interaction effects and network effects

The findings support H_1, because social interaction effects have a positive significant *($p<0.05$)* direct effect on network effects *($b=0.71$)*. This finding is consistent with previous theoretical evidence that suggests that social interaction effects enhance the creation of network effects (Katz & Shapiro, 1986).

7.4.3 The relationship between social interaction effects and network effects and the potential for scale and learning effects

The results support H_{2a}, because network effects have a positive and significant direct effect on the potential for scale and learning *($b=0.19$)* effects.

The results, shown in tables 7.15 and 7.16, also reveal that social interaction effects do not have a significant *direct* effect on the potential for scale and learning effects *($b=0.03$)*. This means that we found no support for H_{2b}. However, social interaction effects do have a significant and positive *indirect* effect on the potential for scale and learning effects *($b=0.16$)*, through the positive and significant effect of social interaction effects on network effects.

Together these direct and indirect effects show that social interaction effects and network effects are a significant factor in creating a potential for scale and learning effects.

Path to:	Network effects	Potential for scale and learning effects		Realization of scale and learning effects		Product performance		Organiza-tional performance	
Path from:	Total	Indi-rect	To-tal	Indi-rect	To-tal	Indi-rect	To-tal	Indi-rect	To-tal
Social interac-tion effects	**0.71 (16.12)**	**0.14 (2.11)**	**0.16 (2.70)**	**0.04 (2.26)**	**0.04 (2.26)**	0.01 (1.74)	0.01 (1.74)	0.01 (1.75)	0.01 (1.75)
Network effects			**0.19 (2.13)**	0.05 (1.89)	0.05 (1.89)	0.01 (1.56)	0.01 (1.56)	0.01 (1.57)	0.01 (1.57)
Potential for scale and learning effects					**0.27 (4.12)**	**0.04 (2.29)**	**0.04 (2.29)**	**0.04 (2.31)**	**0.04 (2.31)**
Realiza-tion of scale and learning effects							**0.15 (2.75)**	**0.04 (2.41)**	**0.14 (2.79)**
Product perfor-mance									**0.30 (5.01)**
*Note: T-values above 1.96 (p<0.05) are shown in **bold**.*									

Table 7.16: LISREL path model indirect and total effects

7.4.4 The relationship between the potential for scale and learning effects and the realization of scale and learning effects

The results support H_3, because the potential for scale and learning effects has a significant and positive direct effect *(b=0.27)* on the realization of scale and learning effects. This finding is consistent with literature that illustrates that firms can exploit the potential for scale and learning effects through the pursuit of *increasing returns strategies* (Besen & Farrell, 1994), e.g., *shaper*, *follower* or *reserving the right to play*.

7.4.5 The relationship between the realization of scale and learning effects and product performance

The findings provide support for H_4, because the realization of scale and learning effects has a positive and significant effect on product performance *(b=0.15)*. These findings confirm prior research that suggests that the realization of scale and learning effects are the most important drivers for competitive advantage and hence superior product performance (Scherer & Ross, 1990).

7.4.6 The relationship between the realization of scale and learning effects and organizational performance

The results support H_5, because the realization of scale and learning effects has a significant and positive *direct* effect on organizational performance *(b=0.10).* This result confirms previous findings that show that scale and learning effects have a positive effect on organizational performance (Hatch & Mowery, 1999; Makadok, 1999). The results shown in table 7.16 also reveal that the realization of scale and learning effects has a positive and significant *indirect* effect *(b=0.04)* on organizational performance.

7.4.7 The relationship between product performance and organizational performance

The results provide support for H_6, because product performance has a significant and positive *(b=0.30)* effect on organizational performance. This finding is consistent with prior empirical research that has demonstrated the importance of primary product performance for organizational performance (Szymanski, Bharadwaj & Varadarajan, 1993).

7.5 Additional tests of the model

We performed two additional tests for the research model discussed above. One, we estimated an alternative research model, in which direct relations between social interaction effects and network effects and product and organizational performance were incorporated and we tested whether the fit of this alternative model was better than that of the original model. Two, we checked the stability of the original model by testing for possible moderating effects of complementarity, compatibility, substitution, path dependence, lock-in, market predictability and knowledge intensity.

7.5.1 Testing an alternative research model

The results of the model discussed above clearly show that product and organizational performance are achieved in markets where social interaction effects and network effects are present *only* through the recognition and the use by the firm of scale and learning effects. This can be seen in table 7.16 because the *total* effects of social interaction effects and of network effects on product performance and organizational performance are all nonsignificant. While in line with our theory and hypotheses this is nevertheless a finding that requires more attention. To check whether this finding is not a result of a misspecification of our model, we estimated an *alternative model* that includes the relationship between the market-based increasing returns mechanisms, representing market structure in the industrial organization framework and product and organizational performance, representing firm performance in the industrial organization framework. See figure 7.7.

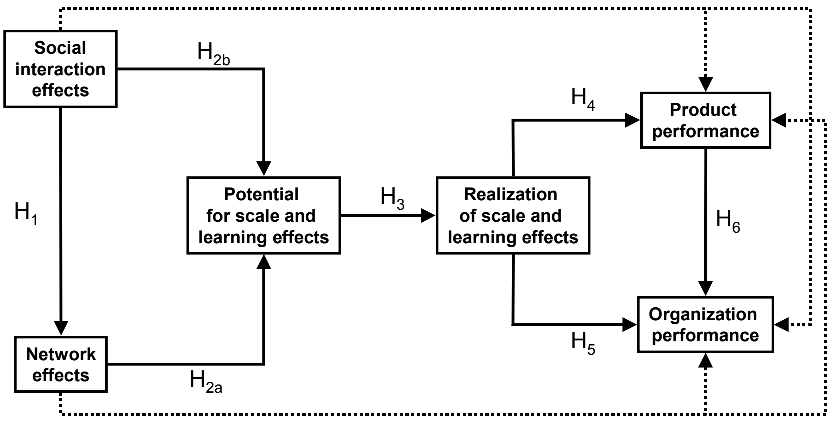

Figure 7-7: Alternative research model

This analysis also resulted in a good fit to the data *($\chi^2/df=1.50$; GFI=0.99; AGFI=0.95; NFI=0.98; NNFI=0.97; CFI=0.99; IFI=0.99; RMSEA=0.047)*. The unstandardized estimates and *t-values* associated with the direct effects are presented in table 7.17. The unstandardized estimates and *t-values* associated with the indirect and total effects are presented in table 7.18. The difference in *degrees of freedom* between the original and the alternative model is *$\Delta df=4$* and the difference in *chi-square* between the original model and the alternative model is *$\Delta\chi^2=6.25$*, which is below the threshold value of *$\chi^2=9.49$ ($p<0.05$)*. We therefore conclude that the alternative model is not significantly better than the original model.

Table 7.17 reveals that in this alternative model specification the *direct* effects of social interaction effects and network effects on product and organizational performance are all nonsignificant. The same is true for the indirect effects, as is revealed in table 7.18. The result is that, with the exception of the relationship between social interaction effects and product performance, also the *total* effects are nonsignificant. This adds confidence to our finding that product and organizational performance can be achieved in markets where social interaction effects and network effects are present *only* through the recognition and the use by the firm of scale and learning effects. The existence of a relationship between social interaction effects and product performance, the *total* effect being made significant by the addition of a nonsignificant direct and a nonsignificant indirect effect, indicates that there is some influence from the market-based mechanisms of increasing returns on firm performance, but that this influence is certainly not dominant and that it is much weaker than the influence of the firm-based mechanisms of increasing returns.

Path to: / **Path from:**	Network effects	Potential for scale and learning effects	Realization of scale and learning effects	Product perfor-mance	Organi-zational perfor-mance
Social interaction effects	**0.71 (16.12)**	0.03 (0.29)		0.07 (0.98)	0.00 (0.01)
Network effects		**0.19 (2.13)**		0.05 (0.67)	0.06 (0.94)
Potential for scale and learning effects			**0.27 (4.12)**		
Realization of scale and learning effects				**0.12 (2.38)**	0.09 (1.80)
Product performance					**0.29 (4.80)**
Evaluation of the model: χ^2/df= 1.50; GFI= 0.99; AGFI= 0.95; NFI= 0.98; NNFI= 0.97; CFI= 0.99; IFI= 0.99; RMSEA= 0.047					
*Note: T-values above 1.96 (p<0.05) are shown in **bold**.*					

Table 7.17: Alternative LISREL path model direct effects

Path to:	Network effects	Potential for scale and learning effects		Realization of scale and learning effects		Product performance		Organiza-tional performance	
Path from:	Total	Indi-rect	To-tal	Indi-rect	To-tal	Indi-rect	To-tal	Indi-rect	To-tal
Social interac-tion effects	**0.71 (16.12)**	**0.14 (2.11)**	**0.16 (2.70)**	**0.04 (2.26)**	**0.04 (2.26)**	0.04 (0.77)	**0.11 (2.26)**	0.08 (1.61)	0.08 (1.75)
Network effects			**0.19 (2.13)**	**0.05 (1.89)**	**0.05 (1.89)**	0.01 (1.48)	0.06 (0.75)	0.02 (0.94)	0.08 (1.19)
Potential for scale and learning effects					**0.27 (4.12)**	**0.03 (2.06)**	**0.03 (2.06)**	**0.03 (2.11)**	**0.03 (2.11)**
Realiza-tion of scale and learning effects							**0.12 (2.38)**	**0.04 (2.13)**	**0.12 (2.46)**
Product perfor-mance									**0.29 (4.80)**
Note: T-values above 1.96 (p<0.05) are shown in ***bold****.*									

Table 7.18: Alternative LISREL path model indirect and total effects

7.5.2 Testing model stability

We used the following procedure to test the stability of the original research model for the following variables: substitution effects product, substitution effects technology, lock-in effects, path dependence, market predictability, product complementarity and compatibility, technology complementarity and compatibility and knowledge intensity of the product. We split the sample into two subgroups for the test variables using the median as the split-up point. The path model used to test the hypotheses 1 through 6 was estimated for each subgroup. See figure 7.8.

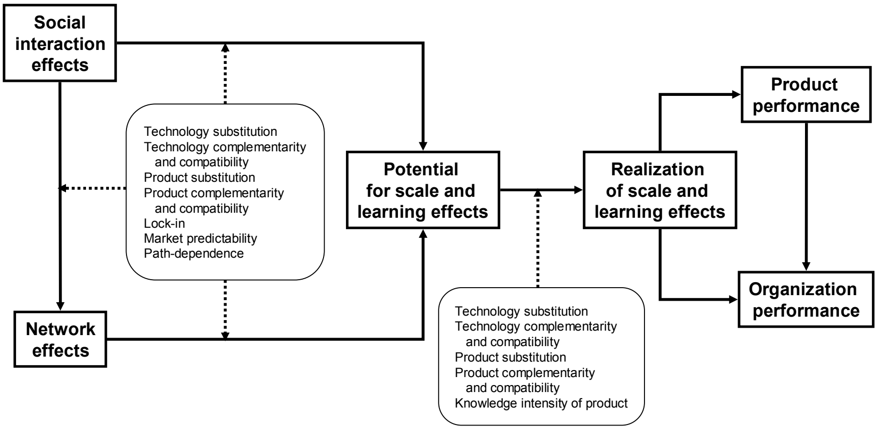

Figure 7-8: Testing the stability of the research model

We conducted a pair-wise comparison of the estimated parameters between the two subgroups. More specifically, the pair-wise comparisons were based on the *chi-square-difference ($\Delta\chi^2$)* between two models:

1. the first model constrained the parameters to be equal, i.e., it was an *equality-constraint model*, in which the relationships, on which the moderating variable was hypothesized to have its effect, are constrained to be equal across the subgroups
2. the second model left the parameters free to covary, i.e., it was a *free model,* in which the relationships, on which the moderating variable is hypothesized to have its effect, are allowed to be different across the subgroups

The significance of the *chi-square difference* between the two models was used as a test for the equality of the parameters, i.e., whether the *equality-constraint model* produced a better fit than the *free model*. When a significant *chi-square difference* was found in a model with two or more relationships on which the moderating variable was hypothesized to have its effect, this result was further explored by checking the *chi-square difference* for each of the individual relationships.

The discussion in the next three sections is set up according to the tested characteristics, i.e., technology characteristics, product characteristics and market characteristics.

7.5.3 Model stability for technology characteristics

The technology characteristics tested were technology substitutability and technology complementarity and compatibility. To test for the influence of these variables on the main relations, the free model allowed a comparison between the two subgroups on (1) the relationship between social interaction effects and network effects, (2) the relationship between network effects and the potential for scale and learning effects, (3) the relationship between social interaction effects and the potential for scale and learning effects, and (4) the relationship between the potential and the realization of scale and learning effects.

The *chi-square difference* statistics for the constraint and free models and the unstandardized estimates for the different subgroups of the free models are shown in table 7.19.

Test variable	**Con-straint model**		**Free model**		**Chi-square diffe-rence**[#]		**Free model estimates**[@]			
	χ^2	*df*	χ^2	*df*	$\Delta\chi^2$	Δ *df*	*Group*	*Relationship (dependent = independent)*	*Esti-mate*	*t-value*
Techno-logy substitu-tion	48.09	33	38.01	29	**10.08 (*)**	4	High	N=I	0.71	13.90
							Low	N=I	0.62	11.74
							High	SLPOT=N	0.14	1.12
							Low	SLPOT=N	0.28	2.08
							High	SLPOT=I	0.17	1.31
							Low	SLPOT=I	0.01	0.10
							High	SLUSE=SLPOT	0.26	3.52
							Low	SLUSE=SLPOT	0.22	2.82
Further analysis of techno-logy substitu-tion	48.09	33	39.95	32	**8.14 (**)**	1	High	N=I	0.71	13.90
							Low	N=I	0.62	11.74
	48.09	33	47.95	32	0.14	1	High	SLPOT=N	0.22	2.28
							Low	SLPOT=N	0.20	2.08
	48.09	33	47.75	32	0.34	1	High	SLPOT=I	0.10	1.09
							Low	SLPOT=I	0.08	0.81
	48.09	33	47.02	32	1.07	1	High	SLUSE=SLPOT	0.26	3.47
							Low	SLUSE=SLPOT	0.22	2.88
Techno-logy comple-mentarity and compati-bility	35.48	33	32.04	29	3.44	4	High	N=I	0.71	11.61
							Low	N=I	0.70	11.17
							High	SLPOT=N	0.24	1.57
							Low	SLPOT=N	-0.07	-0.46
							High	SLPOT=I	-0.01	-0.05
							Low	SLPOT=I	0.28	1.78
							High	SLUSE=SLPOT	0.28	3.17
							Low	SLUSE=SLPOT	0.20	2.22

[#] *Significance at 5% level is indicated by *, at 1% level by **, at 0.1% level by ****

[@] *In this table the constructs are abbreviated as follows:*
I = social interaction effects
N = network effects
SLPOT = potential for scale and learning effects
SLUSE = realization of scale and learning effects

Table 7.19: Stability tests of technology characteristics on LISREL path model

The first pair-wise comparison was between low and high technological substitution effects. The *chi-square difference (10.08)* between the constraint model and the free model was significant on the $p<0.05$ level, indicating that the model is not stable for variations in technological substitution (see table 7.19). A further analysis of this influence revealed that technological substitution effects only significantly and positively influence the relationship between social interaction effects and network effects ($\Delta\chi^2=8.14$, $p<0.01$) but do not significantly influence the other relationships (see table 7.19). We therefore conclude that only the relation between social interaction effects and network effects is unstable for variations in technological substitution. The most likely explanation for this is that when technologies are substitutes, it will increase uncertainty among buyers about which technology will eventually dominate the market. The risk of buying into the wrong technology will therefore be high. In view of this uncertainty it is likely that the influence of information exchange and expectations, i.e., social interaction effects, on behavior, i.e., network effects, will be larger.

The second pair-wise comparison was made between low and high technological complementarity and compatibility. The *chi-square difference (3.44)* between the constraint and the free model was nonsignificant, which means that the model is stable for variations in technological complementarity and compatibility. We recall from section 7.3 that there were some possible problems with the unidimensionality and the convergent validity of the technological complementarity and compatibility construct. We cannot therefore draw a definitive conclusion about the stability of the model for this variable. The model may be stable for variations in technology complementarity and compatibility, or the construct may not reflect adequately the compatibility and complementarity of the technologies.

7.5.4 Model stability for product characteristics

The product characteristics tested were product substitutability, product complementarity and compatibility and knowledge intensity of the product. To test for the influence of these variables on the main model relations, the free model allowed a comparison between the two subgroups on (1) the relationship between social interaction effects and network effects, (2) the relationship between network effects and the potential for scale and learning effects, (3) the relationship between social interaction effects and the potential for scale and learning effects, and (4) the relationship between the potential and the realization of scale and learning effects.

The *chi-square difference* statistics for the constraint and free models and the unstandardized estimates for the different subgroups of the free models are shown in table 7.20.

Test variable	**Constraint model**		**Free model**		**Chi-square difference#**		**Free model estimates@**			
	χ^2	*df*	*χ^2*	*df*	*$\Delta\chi^2$*	*Δ df*	*Group*	*Relationship (dependent = independent)*	*Estimate*	*t-value*
Product substitution	51.14	33	47.61	29	3.65	4	High	N=I	0.71	14.80
							Low	N=I	0.71	15.69
							High	SLPOT=N	0.18	1.47
							Low	SLPOT=N	0.20	1.58
							High	SLPOT=I	0.02	0.20
							Low	SLPOT=I	0.02	0.19
							High	SLUSE=SLPOT	0.32	4.66
							Low	SLUSE=SLPOT	0.24	3.55
Product complementarity and compatibility	74.53	33	63.83	29	**10.70 (*)**	4	High	N=I	0.71	15.01
							Low	N=I	0.64	12.64
							High	SLPOT=N	0.02	0.12
							Low	SLPOT=N	0.13	0.93
							High	SLPOT=I	0.19	1.59
							Low	SLPOT=I	0.03	0.23
							High	SLUSE=SLPOT	0.22	3.03
							Low	SLUSE=SLPOT	0.15	1.86
Further analysis of product complementarity and compatibility	74.53	33	68.22	32	**6.31 (*)**	1	High	N=I	0.71	15.01
							Low	N=I	0.64	12.64
	74.53	33	73.35	32	0.18	1	High	SLPOT=N	0.12	1.20
							Low	SLPOT=N	0.07	0.72
	74.53	33	72.92	32	1.61	1	High	SLPOT=I	0.12	1.33
							Low	SLPOT=I	0.07	0.76
	74.53	33	71.74	32	2.79	1	High	SLUSE=SLPOT	0.22	2.98
							Low	SLUSE=SLPOT	0.15	1.92
Knowledge intensity of product	34.73	33	27.78	29	6.95	4	High	N=I	0.70	15.46
							Low	N=I	0.72	15.19
							High	SLPOT=N	0.20	1.82
							Low	SLPOT=N	0.11	0.81
							High	SLPOT=I	-0.03	-0.26
							Low	SLPOT=I	0.16	1.16
							High	SLUSE=SLPOT	0.25	3.50
							Low	SLUSE=SLPOT	0.25	3.72

*# Significance at 5% level is indicated by *, at 1% level by **, at 0.1% level by ****

@ In this table the constructs are abbreviated as follows:
I = social interaction effects
N = network effects
SLPOT = potential for scale and learning effects
SLUSE = realization of scale and learning effects

Table 7.20: Stability tests of product characteristics on LISREL path model

The first pair-wise comparison was between low and high product substitution effects. The *chi-square difference (3.65)* between the constraint and the free model was nonsignificant, which means the model is stable for variations in product substitution effects.

The second pair-wise comparison was between low and high product complementarity and compatibility. The *chi-square difference (10.70)* between the constraint and the free model was significant on the $p<0.05$ level, indicating that the model is not stable for variations in product complementarity and compatibility (see table 7.20). A further analysis of this influence revealed that product complementarity and compatibility significantly and positively influence the relationship between social interaction effects and network effects ($\Delta\chi^2=6.31$, $p<0.05$) but do not significantly influence the other relationships (see table 7.20). We therefore conclude that only the relation between social interaction effects and network effects is unstable for variations in product complementarity and compatibility. The most likely explanation for this is that product complementarity and compatibility will increase the pay-off for customers if they behave, i.e., network effects, according to the dominant opinion or expectation, i.e., social interaction effects. We recall from section 7.3 that there were some possible problems with the unidimensionality and the convergent validity of the product complementarity and compatibility construct. We cannot therefore draw a definitive conclusion about the stability of the model for this variable. The model may be stable for variations in product complementarity and compatibility, or the construct may not adequately reflect the compatibility and complementarity of the products.

The third pair-wise comparison was between low and high knowledge intensity of products. The free model allowed a comparison between the two subgroups on the relationship between the potential and the realization of scale and learning effects (see table 7.20). The *chi-square difference* ($\Delta\chi^2=-0.02$) between the constraint and the free model was negligible and therefore nonsignificant, which means that the model is stable for variations in knowledge intensity of products. We concluded in section 7.3 that, in view of possible problems with unidimensionality, reliability and convergent validity of the knowledge intensity of the product construct, the usability of this construct is doubtful. We cannot therefore draw a definitive conclusion about whether the model is stable for variations in knowledge intensity of products or that the absence of influence is the result of the inadequacy of the construct.

7.5.5 Model stability for market characteristics

The market characteristics tested were lock-in, market predictability and path dependence. To test for the influence of these variables on the main model relations, the free model allowed a comparison between the two subgroups on (1) the relationship between social interaction effects and network effects, (2) the relationship between network effects and the potential for scale and learning effects, and (3) the relationship between social interaction effects and the potential for scale and learning effects. The *chi-square difference* statistics for the constraint and free models and the unstandardized estimates for the different subgroups of the free models are shown in table 7.21.

Test variable	**Constraint model**		**Free model**		**Chi-square difference**[#]		**Free model estimates**[@]			
	χ^2	*df*	χ^2	*df*	$\Delta\chi^2$	Δ *df*	*Group*	*Relationship (dependent = independent)*	*Estimate*	*t-value*
Lock-in	36.07	33	35.54	30	0.53	3	High	N=I	0.67	13.34
							Low	N=I	0.66	11.78
							High	SLPOT=N	0.16	1.33
							Low	SLPOT=N	0.28	2.05
							High	SLPOT=I	0.13	1.14
							Low	SLPOT=I	0.02	0.15
Market predictability	37.78	33	34.01	30	3.77	3	High	N=I	0.73	15.70
							Low	N=I	0.69	14.88
							High	SLPOT=N	0.14	1.13
							Low	SLPOT=N	0.21	1.72
							High	SLPOT=I	0.09	0.73
							Low	SLPOT=I	-0.02	-0.13
Path dependence	46.19	33	42.79	30	3.40	3	High	N=I	0.72	15.95
							Low	N=I	0.69	13.83
							High	SLPOT=N	0.30	2.49
							Low	SLPOT=N	0.04	0.29
							High	SLPOT=I	-0.07	-0.64
							Low	SLPOT=I	0.17	1.36

*[#] Significance at 5% level is indicated by *, at 1% level by **, at 0.1% level by ****

[@] In this table the constructs are abbreviated as follows:
I = social interaction effects
N = network effects
SLPOT = potential for scale and learning effects
SLUSE = realization of scale and learning effects

Table 7.21: Stability tests of market characteristics on LISREL path model

The first pair-wise comparison was between low and high lock-in effects. The *chi-square difference (0.53)* between the constraint and the free model was nonsignificant, which means that the model is stable for variations in lock-in effects.

The second pair-wise comparison was made between low and high market predictability. Here, the *chi-square difference* ($\Delta\chi^2=3.77$) between the constraint and the free model was nonsignificant, which means that the model was stable for variations in market predictability. We recall from section 7.3 that there may be some problems with the unidimensionality and the convergent validity of the market predictability construct. We cannot therefore draw a definitive conclusion about the reason for the model stability for variations in market predictability. This may be because market predictability does not influence the model, or because the construct does not adequately reflect the (un)predictability of the market.

The third pair-wise comparison was made between low and high path dependence. In this case, the *chi-square difference* ($\Delta\chi^2=3.40$) between the constraint and the free model was nonsignificant, which means that the model is stable for variations in path dependence.

7.6 Conclusions

We may conclude the following with respect to the cross-sectional management survey among managers of *257* Dutch manufacturing firms.

As no existing measures were available on the main constructs, these had to be developed. Four new constructs were developed to measure the market-based mechanisms of increasing returns, i.e., social interaction effects at the product level, social interaction effects at the technology level, network effects at the product level and network effects at the technology level. A further analysis showed that social interaction effects at the product level and social interaction effects at the technology level belong to the second-order construct social interaction effects and that network effects at the product level and network effects at the technology level belong to the second-order construct network effects. All of these constructs proved to be valid measurements.

Two new constructs were developed to measure the firm-based mechanisms of increasing returns, i.e., the potential for scale and learning effects and the realization of scale and learning effects. For practical measurement reasons no distinction was made between scale effects and learning effects, which may be the cause of a possible problem with the convergent validity of these constructs. We conclude that the measurement model for scale and learning effects should be further explored and that it is recommended to try and measure scale and learning effects objectively.[56]

[56] This will be done in chapters eight and nine.

Eight new constructs were developed for measuring effects that could be expected to moderate the main model relationships, i.e., substitution effects on the product level, substitution effects on the technology level, lock-in effects, path dependence, market predictability, product complementarity and compatibility, technological complementarity and compatibility and knowledge intensity of products. The measurement models for substitution effects, lock-in effects and path dependence were proven to be valid. The measurement models for market predictability, product complementarity and compatibility, technological complementarity and compatibility and knowledge intensity of products showed possible problems with unidimensionality and convergent validity and should therefore be used with care.

The developed constructs were used to test the hypotheses of the research model, to do a test for an alternative model and to do tests for the stability of the model. The results of the testing of the research hypotheses are summarized in table 7.22 below.

Research hypotheses:		**Result:**
H_1	The larger the social interaction effects, the larger the network effects	Supported
H_{2a}	The larger the network effects, the larger the potential for scale and learning effects	Supported
H_{2b}	The larger the social interaction effects, the larger the potential for scale and learning effects	Not supported#
H_3	The larger the potential for scale and learning effects, the higher the realization of scale and learning effects	Supported
H_4	The higher the realization of scale and learning effects, the higher the level of product performance	Supported
H_5	The higher the realization of scale and learning effects, the higher the level of organizational performance	Supported
H_6	The higher the level of product performance, the higher the level of organizational performance	Supported
# There is, however, an indirect influence of social interaction effects on the potential for scale and learning effects through the support of hypotheses H_1 and H_{2a}		

Table 7.22: Results on the research hypotheses

The most noticeable result is that firm performance is achieved in a market where market-based mechanisms of increasing returns are present *only* through the firm-based mechanisms of increasing returns. Specifically, product and organizational performance are achieved in markets where social interaction effects and network effects are present only through internalization of the potential for scale and learning effects and the subsequent realization of scale and learning effects by the firm.

A test of an alternative model, incorporating direct effects from the market-based mechanisms of increasing returns on firm performance, showed that this influence is very weak compared to the influence through the firm-based mechanisms.

Tests for the stability of the model showed that model is generally stable for variations in product substitution effects, technology substitution effects, lock-in effects, path dependence, market predictability, product complementarity and compatibility, technology complementarity and compatibility and knowledge intensity of the product. Only the relation between social interaction effects and network effects is influenced by technology substitution and by product complementarity and compatibility.

The stability of the model for all these variables means that the model relations hold for a much wider range of product, technology and market characteristics than is usually assumed in literature. Usually, increasing returns is associated with knowledge intensive products in highly turbulent markets with locked-in customers and high path dependence. Our results indicate that this may be too limited a view on increasing returns. We should be careful, however, because in view of the possible problems with the unidimensionality and convergent validity of the measurement models for technological complementarity and compatibility, product complementarity and compatibility, market predictability and knowledge intensity of products, no definitive conclusions can be drawn on whether the model is stable for the variations in these variables, or that the constructs for these variables are not sufficiently robust.

8. REPORT SECOND EMPIRICAL STUDY

In this chapter we report on the research process and the results of the second empirical study, consisting of a cross-sectional management survey among managers of *36* firms listed on the *Amsterdam Stock Exchange* combined with a measurement of these firms' financial data. This study differs from the first empirical study in that its timeframe was *comparative static* instead of *static*, in that it uses different measures for the firm-based mechanisms of increasing returns and in that it addresses a different research sample.

In this chapter we start in section one by describing the development of the measures. We continue in section two with a description of the process of data collection and describing the research sample. In section three we address the validation of the subjective measures and in section four we address the validation of the objective measures. In section five we report on the results of this empirical study, i.e., on the testing of the hypotheses. We provide conclusions in section six.

8.1 Development of the measures

The time frame of this study is *comparative static*, i.e., comparing the situation at the time with the situation of five years earlier, whereas the first empirical study was *static*, i.e., only considering the situation at the time. This meant that the measures of the different mechanisms of increasing returns had to be adjusted to accommodate the comparative static timeframe. The period of analysis was taken from 1995 until 2000, i.e., including the annual results from the year 2000, but not from 2001 because these were not yet available for all firms when the questionnaire was sent out.

The domain specification for the measures was done in the theoretical part of this thesis. The two market-based increasing returns mechanisms were theoretically specified in chapter four while the firm-based mechanisms of increasing returns were theoretically specified in chapter five.

8.1.1 Measuring social interaction effects, network effects and market dominance

We chose to adapt the measures of social interaction effects and network effects developed for the first empirical study for measuring social interaction effects and network effects in a *comparative static* timeframe. We may recall from the previous chapter that the validity of these measures was good. A re-test of these measures for a different research sample may further enhance their validity (see section 8.3). For measuring market dominance, i.e., the potential for scale and learning effects, we chose to adapt a *3-item* measure that was also used in the questionnaire of the first empirical analysis and that asked about the increasing dominance of a technology, a product or a supplier in the market.[57]

Initially, the items measuring social interaction effects, network effects and technological dominance were kept semantically equal. The only difference with the measurement in the first empirical study was that every item had a *double* instead of a *single seven-point Likert scale*. On the first scale the respondent was expected to judge the current situation, on the second scale the respondent was expected to judge the situation of about five to ten years ago. This way of questioning was chosen to get an adequate picture of the changes in the period between roughly 1995 and the time of the questionnaire, i.e., 2001.

Following the Churchill (1979) procedure we collected initial data to pre-test and purify the measures. We pre-tested the questionnaire with *5* academics and *5* practitioners. All participants were asked to identify items that were confusing, tasks that were difficult to respond to and any other problems they encountered when filling out the questionnaire.

The major concern of all the participants was the double scale on the items measuring social interaction effects, network effects and market dominance. The practitioners reported problems with the workload and boredom of filling out every item on two scales. The academics reported possible risks with self-enforced correlations between the first and the second scales.

It was therefore decided to reduce the items measuring social interaction effects, network effects and market dominance to a *single seven-item Likert scale*, asking respondents to indicate the *changes in the past five to ten years* on each of these items. This implied a slight change in the formulation of the questions, from static, as in the first empirical study, to comparative dynamic.

[57] This measure was a part of the questionnaire used in the first empirical study but was not used in the analysis of the first empirical study. In the pre-test phase of the first empirical study, the measure was judged to be satisfactory by academics and practitioners.

After this change, the academics reported some problems with understanding the questions on social interaction effects and network effects. As a result of this feedback the formulation of the questions was slightly adjusted. The academics also signaled that, according to the theory of increasing returns, market dominance is best measured by the item on the dominance of a technology in the market rather than by the items on product or supplier dominance in the market. As a result, these two items were deleted and market dominance was measured on a single item. After this adjustment neither the practitioners nor the academics reported any further concerns and the questionnaire was therefore ready for final administration. The scale items used in the final questionnaire are shown in *Appendix II*.

8.1.2 Measuring scale effects and learning effects

We chose to follow a different approach for measuring scale and learning effects. Instead of using subjective constructs, we chose to measure scale and learning effects using publicly available financial data. As separate data on scale effects and learning effects are not publicly available, we decided, as in the previous empirical study, to develop a single measure to measure scale and learning effects. According to the theoretical specification of scale and learning effects provided in chapter five, an explicit distinction should be made between the *potential* for scale and learning effects and the *realization* of scale and learning effects.

The potential for scale and learning effects was measured by the firm's average growth rate in output over the period of analysis. The realization of scale and learning effects was measured by the firm's average growth rate in productivity over the period of analysis. We therefore needed clear concepts of measuring the change in output and of measuring the change in productivity. As productivity change means a change in the ratio of the volume of output to the volume of the inputs, we need measurements of outputs and inputs. For each of these, there are two questions to be answered: (1) *Will the measurement be in units or in monetary terms?* (2) *Which correlator will be chosen for the measurement?*

8.1.3 Measurement in physical or monetary units

First is the issue of what to measure: physical units or monetary units. Production functions are usually measured in physical units on both axes, i.e., units of output versus units of input. Cost functions are usually measured in a mixed way, i.e., units of output versus monetary measurement of cost. Both ways of measurement are used in the literature for learning and experience curves. *Theoretically*, there is no difference between these two ways of measuring because "… a production technology is always identically represented by either a production function or the corresponding cost function" (Chung, 1994, p.104).

Taking a management perspective, initially a complete measurement in money terms, i.e., measuring both outputs and inputs in money terms, rather than in quantities, seems to be preferable. The manager gains nothing by increased unit *output*, if it reduces turnover or profit level; also nothing is gained by a reduction in unit *input*, e.g., less employees, if this increases employment cost. Regarding productivity, money is eventually the most important variable for managers. To quote Salter (1960, p.3): "Businessmen – despite what they say at productivity congresses – are interested in prices, costs, and profits, and to them increasing productivity is simply one means of reducing labor costs." The well-known counter-argument is that measurement in monetary terms means *units*prices* and, since prices are competitively determined, this measurement implicitly includes competition and market forces (Marshall, 1890). For managers, however, this is not undesirable per se, because they always deal with the interaction between their firm and the market forces.

For measuring output, measurement in monetary units has a large advantage over measurement in physical units. For firms or industries with strongly diversified outputs it is in principle impossible to measure physical units of output at the firm level. What is the unit output of a large diversified firm, e.g., *AKZO Nobel*, *DSM*, *Philips* or *Royal Dutch/Shell*? This question is fundamentally unanswerable at the firm level, unless the firm happens to deal in a very limited scope of plain commodities. We will therefore measure output in monetary terms, because this enables us to make comparisons across firms.

This problem of physical or monetary measurement is less severe for measuring inputs if we limit the productivity measurement to labor productivity, as is done in the next section.[58] A homogenous measure can be taken for labor input, e.g., *number of employees*, *number of full time equivalents of employees* or *hours worked*. Hours worked means the total number of hours worked added over all employees of a firm.

[58] Although, when we want to have a single measure combining different classes of inputs, measurement in money terms could be preferable, just as with the measurement of outputs.

8.1.4 Correlators for measuring output and input

The second issue is about the correlator chosen to measure output and input. For output, when measurement in monetary terms is chosen, there are still different possible correlators. The most important ones are *turnover* and *added value*. Of these, turnover comes closest to indices of volume of gross output that are often used in productivity analyses at the industry or country level. The turnover measure, however, suffers from the problem that, when a firm produces intermediate goods that are sold within the firm for further processing, the gross output figure results in an overstatement of true gross output of the firm (cf., Kennedy, 1971). Another problem of the turnover approach is that insourcing or outsourcing of activities by firms may distort productivity statistics. For example, when a firm outsources an activity, this will show in a reduction of the number of employees, but not necessarily in the turnover figures, e.g., when outsourcing the internal IT department.

Added value, i.e., turnover minus all external cost, does not suffer from these shortcomings. Turnover is an indicator of the value that the firm's products generate for customers, in comparison to the products of other suppliers. The external cost the firm has to pay to its suppliers is an indicator of the part of this value that is created by the firm's suppliers. Turnover minus the external cost is therefore an indicator of the part of the customer value that is created by the firm. The added value measure also conforms to what is customary in other productivity studies. We therefore use the average growth rate of added value over the period 1995-2000 for measuring the *potential* for scale and learning effects.

A partial productivity index can be derived for any input by dividing the index of volume of output by an index of the volume of that specific input. We may choose to include either labor, i.e., measuring *labor productivity*, capital, i.e., measuring *capital productivity*, or a combination of a number of inputs, i.e., measuring *multi-factor productivity*. We chose to measure labor productivity for this study. Labor as an input is customarily expressed in number of employees, number of full-time-equivalent employees or in hours worked. Measuring full-time-equivalent employees is preferred over just measuring the normal number of employees, because the full-time-equivalent measurement corrects for the increasing numbers of part-time jobs. Measuring hours worked is to be preferred over full-time-equivalent employees because it corrects for the general tendency that exists, at least in the Netherlands, for employees to work less hours per week today than they did five years ago. We therefore measured labor inputs in number of hours worked.

Productivity in this study can then be defined as the ratio between output and input, where output is measured as added value and input is measured as hours worked. We used the average growth rate of productivity for the period 1995-2000 as a measure of the *realization* of scale and learning effects.

8.1.5 Measuring firm performance

We chose to use an objective measureme based on publicly available financial data for measuring firm performance. Firm performance was therefore measured by the firm's average growth rate in net profit over the period 1995-2000.

8.2 Sample and data description

The data for this study were collected from two different sources. The data on social interaction effects, network effects and market dominance were collected through a mail questionnaire, whereas the data on the potential and realization of scale and learning effects and the data on firm performance were collected from publicly available data sources, i.e., the firms' annual reports.

The sampling frame for this study consisted of *131* firms listed on the *Amsterdam Stock Exchange* over the period 1983-2002.[59] Of these *131*, we chose the ones that were listed in 2001 and we eliminated firms that had not been listed for six years, to ensure that we had the data points from 1995 and 2000 for every firm.[60] Further, we eliminated firms with missing data that were crucial for our computations. This resulted in a corrected sampling frame of *83* firms.

We made a firm-specific graphic analysis, relating the annual growth in productivity to the annual growth in output, for each of these *83* firms to increase the expected response rate.[61] We also made an analysis of the industry in which the firm is mainly active and related the performance of the firm to that of the industry as a whole. These analyses were sent to the *83* selected firms, accompanied by the questionnaire

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[59] This comprises all firms listed on the *Amsterdam Exchange Index (AEX)* and the *Amsterdam Midkap Index (AMX)* and a number of the firms listed on the *Dutch national market*. The sampling frame also included firms that had been listed in any sequences of years during the period 1983-2002, but were not listed in 2002. The full list of firms is included in *Appendix III*.

[60] As all the measurements are on growth rates, the number of usable comparative static data points is always one less than the number of static data points.

[61] This is a graphic representation of the *Verdoorn law*, see chapter nine. Specifically we sent the contact persons a graph resembling figure 9.3.

for collecting the data on social interaction effects, network effects and market dominance. To further increase the response rate, we identified two contact persons for each firm from eiher general management, financial management, marketing management or public relations, who both received the graphic analysis and the questionnaire. Contact persons who did not respond were reminded twice by telephone, after two weeks and after four weeks, respectively. The eventual response consisted of *38* completed and usable questionnaires, representing *36* different firms. The answers were compared for the two cases where two questionnaires per firm were received. In both cases, there were no significant differences in the contact persons' answers on any of the constructs. For these firms, the answers of the two contact persons were averaged. This resulted in usable answer sets for *36* firms, or a response rate of *43.4%.* An overview of the firms included in this sample is provided in *Appendix III*. An overview of the industry response distribution is provide in table 8.1 below.[62]

Industry	Initial sampling frame (131 firms)		Corrected sampling frame (83 firms)		Research sample (36 firms)	
	No.	%	No.	%	No.	%
Basic industry	14	10.7 %	9	10.8 %	5	13.9 %
Food industry	9	6.9 %	7	8.4 %	2	5.6 %
Media	7	5.3 %	5	6.0 %	2	5.6 %
Engineering industry	14	10.7 %	9	10.8 %	2	5.6 %
Construction industry	10	7.6 %	8	9.6 %	4	11.1 %
Wholesale	14	10.7 %	7	8.4 %	2	5.6 %
Transport	10	7.6 %	5	6.0 %	2	5.6 %
Telecommunications	4	3.1 %	1	1.2 %	1	2.8 %
Financial services	15	11.5 %	10	12.0 %	5	13.9 %
IT services	9	6.9 %	4	4.8 %	2	5.6 %
Other professional services	8	6.1 %	6	7.2 %	4	11.1 %
Retail	10	7.6 %	6	7.2 %	1	2.8 %
Electronics industry	7	5.3 %	6	7.2 %	4	11.1 %
sum	131	100.0%	83	100.0%	36	100.0%

Table 8.1: Sample for the second empirical study

[62] The industry classification was chosen to conform to the classification used in the Dutch financial daily *Het Financieele Dagblad*. It was established during the testing of the questionnaire that this classification would have the best *face validity* with the targeted contact persons.

We performed a *chi-square analysis* of the industry response distribution to check the representativeness of the research sample (Weinberg & Abramowitz, 2002). This analysis checks the null-hypothesis that the distribution of the research sample is equal to the distribution of the (corrected) sampling frame. With a significance level of $p<0.05$ our analysis showed that the null-hypothesis is not rejected ($\chi^2=5.231$, $df=12$). Therefore we conclude that the sample of firms is representative for the total population.

A routine check for respondent bias using *one-way ANOVA* indicated that no significant differences existed in the mean responses on the main constructs and main financial measurements across respondents with different durations of employment in the industry. Moreover, no industry effects existed in the mean responses on the main constructs and financial measurements.[63] The *ANOVA* analysis showed, however, that significant differences exist in the mean responses on the main constructs and on the measurement of average annual growth of net profit across different *firm sizes*. This indicates that firm size may be a factor that significantly correlates with the presence of the market-based mechanisms of increasing returns. A more detailed inspection showed that there appears to be a *U-shaped relationship* between firm size and the market-based mechanisms of increasing returns: for small firms the responses on the scales measuring the market-based mechanisms of increasing returns are about *average*, for medium-size firms they are significantly *below average* and for large firms they are significantly *above average*.[64] These results have to be interpreted with some caution though, because of the small size of the sample.

A time-trend extrapolation procedure was used to test for non-response bias (Armstrong & Overton, 1977). We divided the data set into quartiles based on the order of receipt of the questionnaire. The underlying rationale is that slow respondents are more similar to non-respondents than fast respondents. In comparing fast *(1st quartile)* and slow *(4th quartile)* respondents, no significant differences

[63] Again, as also noted in the previous chapter, this is remarkable, because we expected that industry characteristics would have a major influence.

[64] There may be different explanations for this correlation. One possible explanation is that it is purely coincidence, caused by the small size of the sample. Another possible explanation is that medium-sized firms are more often than small and large firms active in saturated markets in which no new, increasing returns-sensitive, technologies are present and that large firms, more often than small and medium-sized firms, are able to evoke increasing returns mechanisms in their markets because of their market power. This remains highly speculative, however.

existed in the mean responses on the main constructs or on the financial measurements.

Together these results suggest that respondent, industry and non-response bias were not a major problem. Sample characteristics are shown in tables 8.2 and 8.3.

Number of employees of the firm	Frequency	Percent	Valid percent
<= 1000	5	13.9 %	13.9 %
1000-5000	9	25.0 %	25.0 %
5000-25000	13	36.1 %	36.1 %
> 25000	9	25.0 %	25.0 %
Missing	0	0.0 %	0.0 %
sum	36	100.0 %	100.0 %

Table 8.2: Sample characteristics of the second empirical study: number of employees

Respondent duration of employment in industry	Frequency	Percent	Valid percent
5 years or less	6	16.7 %	17.1 %
5-10 years	7	19.4 %	20.0 %
10-20 years	16	44.4 %	45.8 %
More than 20 years	6	16.7 %	17.1 %
Missing	1	2.8 %	
sum	36	100.0 %	100.0 %

Table 8.3: Sample characteristics of the second empirical study: respondent duration of employment

The publicly available data for every firm are the annual profit & loss accounts, the annual balance sheets and the annual number of employees. The format of the profit & loss accounts and the balance sheets is the one that was maintained by *Euronext Amsterdam (the Amsterdam Stock Exchange)* in its publications and on its website.[65] When a firm's data were available in a different format, the firm's annual reports were scrutinized and if necessary recalculated to fit the database format.

[65] As from 2000, the data in these formats were only available from the *Amsterdam Stock Exchange* website*, www.aex.nl*, and as from 2004 the data in these formats are not longer available from this website.

In the previous section, we argued to take added value as the correlator for output. Given the format of the profit & loss account, added value can be calculated in different ways, additive or subtractive. In the additive approach, we calculate added value as the sum of employment costs, depreciation and net profit. In the subtractive approach, we calculate added value as turnover minus all external cost. Due to, e.g., extraordinary results, there may be differences between these two calculations. For this study, we chose to use the additive calculation of added value, because for this is calculation it is least necessary to correct firm data for extraordinary results. The calculation of added value has been corrected for the rise in general producers' prices, with *1990 = 100*. This price data was obtained from the *Centraal Bureau voor de Statistiek (CBS).*[66]

As stated earlier, productivity is taken as added value divided by hours worked, corrected for the rise in general producer's prices. To compute *hours worked* we multiplied the number of employees with the annual labor duration in hours. This data was also obtained from the *Centraal Bureau voor de Statistiek (CBS).*

8.3 Validation of the subjective measures

The measures used for this study fall into two groups: first, the subjective scales used to measure social interaction effects and network effects and second, the objective measures for the potential and the realization of scale and learning effects and for firm performance. These will be discussed separately below.

We reassessed the *construct validity* of the measures for social interaction effects and network effects for this second empirical study. There were two reasons for this. First, the items in the questionnaire had been adjusted compared to the first empirical study, warranting a check on construct validity. Second, a further test for construct validity may contribute to our confidence in the stability of these constructs.

Below we address the different aspects of construct validity, i.e., *unidimensionality*, *reliability*, *within-method convergent validity* and *discriminant validity* (Churchill & Iacobucci, 2002; Steenkamp & Van Trijp, 1991; Kerlinger, 1986; Churchill, 1979).

[66] This is the Dutch central bureau of statistics, i.e., the census agency.

8.3.1 Unidimensionality

We computed the inter-item correlations and corrected item-to-total correlations for each item, taking one subscale at a time, to assess unidimensionality of the scales (Steenkamp & Van Trijp, 1991). This resulted in the elimination of one item from the construct social interaction effects at the product level. The dimensionality of each purified scale was explored with *maximum likelihood factoring* using an *eigenvalue* of *1.0* and factor loadings of *0.30* as the cut-off points. This resulted in the purified measures as shown in table 8.4.

Unidimensionality of the scales	No. of items deleted	No. of items remaining	Lowest item-to-total correlation	Eigen-value (ML factoring)	Variance explained
Network effects products	0	4	0.47	2.21	40.9%
Network effects technologies	0	4	0.62	2.73	57.7%
Social interaction effects products	1	3	0.44	2.00	54.6%
Social interaction effects technologies	0	4	0.64	2.90	63.6%

Table 8.4: Unidimensionality of the subjective scales

The unidimensionality of each purified scale was subsequently tested by estimating confirmatory factor models using *maximum likelihood estimation in LISREL 8.3* (Jöreskog & Sörbom, 1999), following Steenkamp & Van Trijp (1991). We chose to estimate two models to fit as well as possible the constraints of a five-to-one ratio of sample size to parameter estimates (Baumgartner & Homburg, 1996). Note that, because of the data constraint, it was not possible to estimate the second-order constructs for network effects and social interaction effects in *LISREL* as was done for the first empirical study.

Following Kumar & Dillon (1987), Steenkamp & Van Trijp (1991) state that the overall fit of the model provides the necessary and sufficient information to determine the unidimensionality. We examined the values of the standardized residuals to identify misspecifications of the measurement models. This did not result in any re-specification. The schematic compositions of the constructs are shown in figures 8.1 and 8.2. The results of the two measurement models are shown in the corresponding tables 8.5 and 8.6.

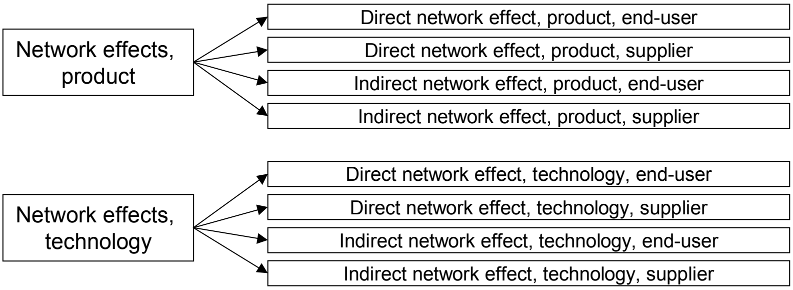

Figure 8-1: Measurement model 1 - network effects

Measurement model 1	No. of items deleted	No. of items remaining	Lowest t-value	Average variance extracted	Composite reliability
Network effects products	0	4	3.36	49.4%	0.79
Network effects technologies	0	4	4.72	64.2%	0.88
Evaluation of the model: χ^2/df= 0.98; GFI= 0.92; NFI= 0.92; NNFI= 0.97; CFI= 0.99; IFI= 0.99; RMSEA= 0.000					

Table 8.5: LISREL estimates of measurement model 1

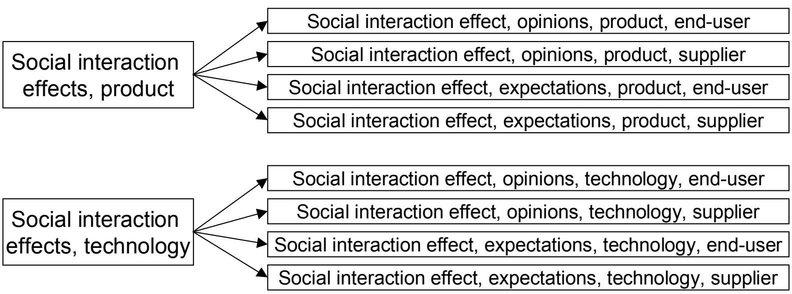

Figure 8-2: Measurement model 2 - social interaction effects

Measurement model 2	No. of items deleted	No. of items remaining	Lowest t-value	Average variance extracted	Composite reliability
Social interaction effects products	0	3	2.94	54.5%	0.77
Social interaction effects technologies	0	4	4.12	63.5%	0.87
Evaluation of the model: χ^2/df= 1.23; GFI= 0.91; NFI= 0.91; NNFI= 0.92; CFI= 0.96; IFI= 0.97; RMSEA= 0.084					

Table 8.6: LISREL estimates of measurement model 2

As can be seen from the tables, the fits of both of the measurement models are good, meeting the required *0.90* threshold values of the absolute, i.e., *GFI* and *NFI* and incremental, i.e., *NNFI*, *CFI* and *IFI* fit indices. The parsimonious fit measure of the *chi-square value divided by the number of degrees of freedom* was below the recommended level of *2.0* and the *root mean square error of approximation (RMSEA)* was almost at or below the recommended *0.08* level for each of the models.

8.3.2 Reliability

We explored the reliability of each purified, unidimensional scale by computing the *Cronbach alpha* reliability coefficient. The values of the *Cronbach alpha* for the different constructs indicate that the reliability is adequate. See table 8.7 below.

Reliability of the scales	No. of items	Lowest item-to-total correlation #	Cronbach alpha	Eigen-value (ML factoring)	Variance explained
Network effects products	4	0.47	0.73	2.21	40.9%
Network effects technologies	4	0.62	0.84	2.73	57.7%
Social interaction effects products	3	0.44	0.74	2.00	54.6%
Social interaction effects technologies	4	0.64	0.87	2.90	63.6%
# *For the two-item scales the figure provided is the inter-item correlation*					

Table 8.7: Reliability of the subjective scales

8.3.3 Within-method convergent validity

Convergent validity of the scales was investigated by estimating two confirmatory factor models using *maximum likelihood estimation in LISREL 8.3* (Jöreskog & Sörbom, 1999). See section 8.3.2 for the models and the results. Steenkamp & Van Trijp (1991) provide three conditions for convergent validity, namely (1) that the factor coefficients for all the items of a construct should be significant, (2) that the correlation between the item and the construct should exceed *0.50* and (3) that the overall fit of the measurement model should be acceptable. The first and second conditions are met for all items and their corresponding latent constructs. The third condition, the overall fit of the model is met for both measurement models.

8.3.4 Discriminant validity

Discriminant validity among the scales was assessed in two steps. First, we estimated a two-factor model for each possible pair of scales. Discriminant validity was indicated when the variance-extracted estimates for the two scales exceed the square of the correlation between them (Bagozzi & Yi, 1988). The results revealed that without exception the assessment supported the discriminant validity of the scales.

Second, we examined for the measurement models the *chi-square difference* between the original models and similar models in which the correlations among the latent constructs were constrained to unity (Bagozzi & Phillips, 1982, p.476). A significantly lower value of the *chi-square* of the constrained model indicates that the latent constructs are not perfectly correlated and that discriminant validity is achieved. The results, shown in table 8.8, indicate that discriminant validity is achieved for both of the scales.

Discriminant validity	*Model with trait correlations constrained to unity*		*Unconstrained model*		*Chi-square difference*[#]	
	χ^2	*df*	χ^2	*df*	$\Delta\chi^2$	Δdf
Model 1 Network effects	20.28	12	10.75	11	9.53 (**)	1
Model 2 social interaction effects	28.37	10	11.07	9	17.30 (***)	1
[#] *Significance at 5% level is indicated by *, at 1% level by **, at 0.1% level by ****						

Table 8.8: Discriminant validity of the subjective scales

8.3.5 Conclusions on construct validity

Together the results of the tests for unidimensionality, reliability, convergent validity and discriminant validity provided further evidence on the validity of the scales. A summary of the results is provided in table 8.9 below.

Conclusions on construct validity	Content validity	Unidi-mensio-nality	Relia-bility	Within-method conver-gent validity	Discrimi-nant validity
Network effects products	OK	OK	OK	OK	OK
Network effects technologies	OK	OK	OK	OK	OK
Social interaction effects products	OK	OK	OK	OK	OK
Social interaction effects technologies	OK	OK	OK	OK	OK

Table 8.9: Conclusions of the validity of the subjective scales

From these results we can conclude that the validity of the first-order constructs of network effects and social interaction effects is confirmed.

The combined results from the validity test in the first empirical study and the confirmation of the validity in this second empirical study provide enough confidence to use both the first-order and the second-order constructs for network effects and social interaction effects as measurements of the market-based mechanisms of increasing returns in this study. On this basis the constructs were formed by averaging the responses to each item in a particular scale.

Besides the scales measuring social interaction effects and network effects, the single item of technological dominance was used in the analysis as an additional measure of the potential for scale and learning effects.

8.4 Validation of the objective measures

Validating objective measurements is quite different from validating subjective measurement scales. Still, the goal is the same: to ensure that we measure what we want to measure. The content validation of the objective measures was discussed in section 8.1. Below, we deal with solving possible distortions in the measurements of output growth, productivity growth and net profit growth.

Our data is made up of financial data for firms listed on the *Amsterdam Stock Exchange*, and is derived from these firms' annual reports. A number of issues have to be addressed with regard to these data, i.e., the consistency in the data definitions over time, corrections for inflation, corrections for *outliers* and corrections for negative output values.

8.4.1 Consistency of the data definitions

A first possible problem with firm-level data from annual reports is that firms sometimes adjust the way they calculate or present their annual figures. When major adjustments are made there is a danger that this will distort the computed growth rates of output, productivity or net profit.

The consistency in the data definitions was checked for all the firms in the sample. When any inconsistencies were found between the report years 1995 and 2000, the data were adjusted according to information given by the firm in its annual report to provide the same data definition for both observations. In cases where this was not possible, we deleted the observation from the sample.

A second issue is that there will be differences in how financial figures are calculated and presented between firms. This means that when working with the nominal figures, firm data may be incomparable. In our case, this is not a problem, because we calculate the percentage changes between 1995 and 2000. This made the data comparable across firms.

8.4.2 Correction for inflation

An important issue when we measure in monetary units is how to correct for inflation. A correction for inflation is necessary for all three measures, output growth, productivity growth and net profit growth. Failing to correct for inflation may lead to strong correlations between, e.g., output growth and productivity growth, because both are influenced by the general level of price increases.

The next important question is: Which deflator should be used for this correction? To answer this question, we have to know the relevant price developments for each firm. Inflation is likely to be different for different countries, for different industries and for different firms. Contrary to firm-level data, industry-level and country-level data are readily available. The problem with these however is their application to individual firms, when we consider that many firms in our sample perform activities in multiple industry sectors and many of the firms in our sample, while having their headquarters in the Netherlands, have large parts of their operations abroad.

Even if we know the appropriate inflation figure, how can we be sure it is right? Any firm-level differentiated inflation correction is a hazardous task, e.g.: Are rising prices in a specific industry not simply a reflection of increasing product quality? When we make the correction at the industry level: Do we destroy the inherent variance that exists between industries? In view of these problems, the only deflator that can be used, and with some caution, is the general producers' price-index number. This number deflates the general cost level and leaves the variance between specific industries and specific firms intact. Therefore, the measurements of output, of productivity and of net profit were deflated using the general producers' price index published by the *Centraal Bureau voor de Statistiek (CBS)*.[67]

8.4.3 Correction for outliers

There are years for which the financial data stand out, positively or negatively, for some firms in the sample. This may have different reasons, e.g., the firm may have had an especially bad year, the firm may have 'financially engineered' its figures, there may have been major portfolio changes like mergers and acquisitions or there may have been other *out of the ordinary* events within the firm. For all the firms in the sample, we checked the data on such possible outliers. When possible, the data were adjusted using the information provided by the firm in its annual report. When such a correction was not possible, we deleted the observation from the sample.

8.4.4 Correction for negative growth rates

A final problem in calculating the average annual growth rates for output and productivity is negative growth rates. In very exceptional cases, output, and therefore also productivity, may have a negative value for a certain year. For net profit, negative values are a more common phenomenon. As a consequence of negative values, a problem appears when calculating the growth rate with respect to the year with the negative value. The calculation will still give a number, but the growth rate in relation to the negative value is of course undefined. Therefore, these observations were deleted from our sample.

[67] This is the Dutch central bureau of statistics, i.e., the census agency.

The above corrections resulted in a data file that could be used with confidence to measure the potential of scale and learning effects, the realization of scale and learning effects and firm performance. In total, as a consequence of the above corrections, five observations were deleted from the sample, some of these for more than one of the above reasons.

8.4.5 Conclusions on construct validity

As a result of the validation, we concluded that we could use the main constructs with confidence. We report the correlations between these main constructs in table 8.10.

	Network effects	Social interaction effects	Potential for scale and learning effects *measured as technological dominance*	Potential for scale and learning effects *measured as growth of output*	Realization of scale and learning effects
Social interaction effects	0.872***				
Potential for scale and learning effects *measured as technological dominance*	0.604***	0.518***			
Potential for scale and learning effects measured as growth of output	0.248	0.273	0.350*		
Realization of scale and learning effects	0.293	0.223	0.403**	0.431**	
Firm performance	0.191	0.224	0.311	0.943***	0.498***
*# Significance at 10% level is indicated by *, at 5% level by **, at 1% level by ****					

Table 8.10: Correlations between the main constructs

8.5 Results

8.5.1 Research model and hypotheses

The research model for this second empirical study is presented in figure 8.3.

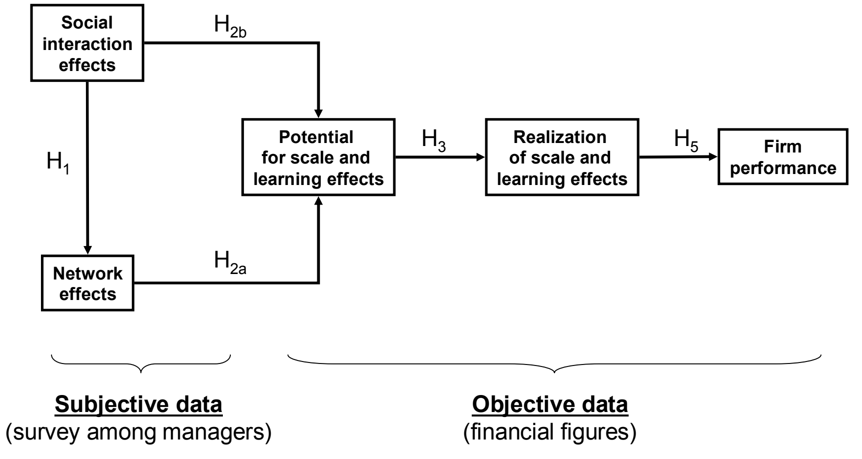

Figure 8-3: Research model and hypotheses of the second empirical study

This research model reveals a number of relationships. First, social interaction effects were hypothesized to have a positive effect on network effects (H_1). Second, social interaction effects and network effects were hypothesized to have a positive effect on the firm's potential for scale and learning effects (H_{2a} and H_{2b}). Third, the firm's potential for scale and learning effects was hypothesized to have a positive impact on its realization of these effects (H_3). Finally, the realization of scale and learning effects was hypothesized to have a positive influence on firm performance (H_5). We will subsequently test these hypotheses.

8.5.2 Results for the main effects

The hypotheses were tested using *linear regression models*. As our sample size was relatively small, it was not possible to estimate a *structural equation model with LISREL 8.3* (Jöreskog & Sörbom, 1999). The linear regression models offer a more favorable ratio between our sample size and the number of parameters to be estimated (Baumgartner & Homburg, 1996). For the regression models we used the constructs created for the estimation of the measurement model, i.e., social interaction effects and network effects, and we used the objective measures of productivity growth and net profit growth as measures for the realization of scale and learning effects and firm performance, respectively. On the basis of the correlations presented in table 8.10, we decided to use the single-item measure of technological dominance as the measure for the potential of scale and learning effects.

The results of the individual linear regression models are presented in table 8.11 below. Note, this table is spread over two pages, the left page covering the first five columns and the right page the last six columns.

Independent variable	**Dependent variable**	**Total number of obser-vations**	**Valid number of obser-vations**	**Unstan-dardized beta**
Social interaction effects	Network effects	36	31	0.979 (***)
Social interaction effects	Potential for scale and learning effects	36	31	0.858 (**)
Network effects	Potential for scale and learning effects	36	31	0.891 (***)
Potential for scale and learning effects	Realization of scale and learning effects	36	31	0.244 (*)
Realization of scale and learning effects	Firm performance	36	31	0.365 (**)
Relationships from alternative research framework				
Social interaction effects	Firm performance	36	31	0.165
Network effects	Firm performance	36	31	0.126
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)				

The findings support H_1, as social interaction effects have a positive and significant effect on network effects. This finding is consistent with previous theories suggesting that social interaction effects enhance the creation of network effects (Katz and Shapiro, 1986; Rosenberg, 1976).

The findings support H_{2a} and H_{2b}, as both network effects and social interaction effects have a positive and significant effect on the potential for scale and learning effects. This finding is consistent with previous theoretical findings that a standards battle is likely to be won by one of the competing technologies, i.e., that there are multiple possible equilibria (Farrell & Saloner, 1985; 1986; Katz & Shapiro, 1985;

1986; Arthur, 1989; Besen & Farrell, 1994). As a consequence, the winning technology will dominate the market, causing a large potential for scale and learning effects.

T-value of beta	Constant term	T-value of constant term	R square	Standard error of estimate	F-statistic
9.606	0.299	0.773	0.761	0.666	92.272
3.258	1.295	1.297	0.268	1.720	10.614
4.076	0.976	1.103	0.364	1.600	16.614
2.285	-0.315	-0.624	0.162	1.121	5.222
2.984 (**)	0.664 (***)	3.895	0.248	0.779	8.903
1.236	0.279	0.550	0.050	0.874	1.527
1.050	0.392	0.808	0.037	0.880	1.102

Table 8.11: Results of the individual regression models

The results support H_3, as the potential for scale and learning effects has a significant and positive effect on the realization of scale and learning effects. This finding is consistent with literature which shows that firms can exploit the potential for scale and learning effects through the pursuit of alternative competitive strategies (Besen & Farrell, 1994; Hagel, 1996; Shapiro & Varian, 1999).

Finally, the results support H_5, as the realization of scale and learning effects has a significant and positive effect on firm performance. This result confirms previous findings that show that scale and learning effects have a positive effect on performance (Hatch and Mowery, 1999; Makadok, 1999).

We also studied the relationships between social interaction effects and firm performance and between network effects and firm performance. Analogous to the first empirical study, an alternative research framework can be drawn that includes these relationships (see figure 8.4).

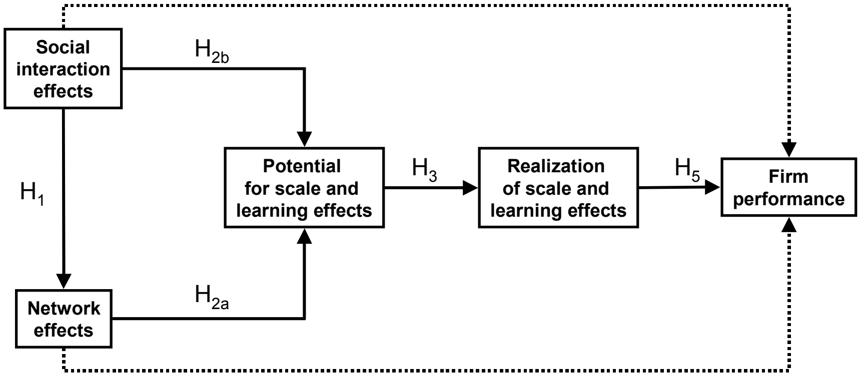

Figure 8-4: Alternative research model for the second empirical study

As can be seen in table 8.11, the relationship between social interaction effects and firm performance and between network effects and firm performance were found to be nonsignificant. This supports our finding of the first empirical study that firm performance can *only* be achieved in markets where social interaction effects and network effects are present *through* the internalization and exploitation of scale and learning effects.

8.5.3 Tests for mediation effects

While we did not present hypotheses on mediation effects in chapter six, it is nevertheless interesting to investigate the presence of such mediation effects in our model. Mediation means that the relationship between an independent and a dependent variable goes *through* a third variable, the mediator. In other words, the relationship is *indirect*, namely from independent to mediator and from mediator to dependent. When there is only an indirect relationship between the independent and the dependent variable, we speak of *complete mediation*. When there is both a direct and an indirect relationship between the independent and the dependent variable, we speak of *partial mediation* (Baron & Kenny, 1986).

For example, the results from section 7.4 on the relationships between social interaction effects, network effects and the potential for scale and learning effects suggest that the presence of network effects may be a mediator of the relationship between social interaction effects and the potential for scale and learning effects. In the same way, we could test whether the potential for scale and learning effects is a mediator of the relationship between network effects and the realization of scale and learning effects. Finally, we could test whether the realization of scale and learning effects is a mediator of the relationship between the potential for scale and learning effects and firm performance.

We tested these relationships for mediation by estimating and comparing three models (Baron & Kenny, 1986).

- Model 1: the influence of the independent variable on the mediator
- Model 2: the influence of the independent on the dependent variable
- Model 3: the influence of the independent variable and the mediating variable on the dependent variable

For *complete mediation*, in model 1 the relationship between the independent variable and the mediator should be significant, in model 2 the relationship between the independent variable and the dependent variable should be significant and in model 3 the relationship between the independent variable and the dependent variable should be nonsignificant and the relationship between the mediating variable and the dependent variable should be significant (Baron & Kenny, 1986). For *partial mediation*, in model 3 the relationship between the independent variable and the dependent variable should be significant, but smaller than in model 1 (Baron & Kenny, 1986). The results of the mediation tests are presented in tables 8.12, 8.13 and 8.14 below. Note, these tables are spread over two pages, the left page covering the first seven columns and the right page the last six columns.

Model	Independent variable	Mediator	Dependent variable	Total number of obser-vations	Valid number of obser-vations	Unstan-dardized beta
1	Social interaction effects	Network effects		36	31	0.979 (***)
2	Social interaction effects		Potential for scale and learning effects	36	31	0.858 (**)
3	Social interaction effects	Network effects	Potential for scale and learning effects	36	31	Independent: -0.061
						Mediator: 0.939 (*)
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

Model	Independent variable	Mediator	Dependent variable	Total number of obser-vations	Valid number of obser-vations	Unstan-dardized beta
1	Network effects	Potential for scale and learning effects		36	31	0.891 (***)
2	Network effects		Realization of scale and learning effects	36	31	0.257
3	Network effects	Potential for scale and learning effects	Realization of scale and learning effects	36	31	Independent: 0.075
						Mediator: 0.214
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

T-value of beta	Constant term	T-value of constant term	R square	Standard error of estimate	F-statistic	Variance inflation factor (VIF)
9.606	0.299	0.773	0.761	0.666	92.272	-
3.258	1.295	1.297	0.268	1.720	10.614	-
Independent: -0.119	1.015	1.061	0.365	1.630	8.032	4.182
Mediator: 2.063						

Table 8.12: Results of the mediation test for network effects

T-value of beta	Constant term	T-value of constant term	R square	Standard error of estimate	F-statistic	Variance inflation factor (VIF)
4.076	0.976	1.103	0.364	1.600	16.614	-
1.590	-0.240	-0.368	0.086	1.171	2.529	-
Independent: 0.384	-0.468	-0.721	0.167	1.139	2.602	1.531
Mediator: 1.591						

Table 8.13: Results of the mediation test for the potential for scale and learning effects

Model	Independent variable	Mediator	Dependent variable	Total number of obser-vations	Valid number of obser-vations	Unstan-dardized beta
1	Potential for scale and learning effects	Realization of scale and learning effects		36	31	0.244 (*)
2	Potential for scale and learning effects		Firm performance	36	31	0.139
3	Potential for scale and learning effects	Realization of scale and learning effects	Firm performance	36	31	Independent: 0.088 Mediator: 0.307 (*)
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

From these results it can be concluded that:

- network effects *completely mediate* the relationship between social interaction effects and the potential for scale and learning effects
- the potential for scale and learning effects *does not mediate* the relationship between network effects and the realization of scale and learning effects
- the realization of scale and learning effects *does not mediate* the relationship between the potential for scale and learning effects and firm performance

T-value of beta	Constant term	T-value of constant term	R square	Standard error of estimate	F-statistic	Variance inflation factor (VIF)
2.285	-0.315	-0.624	0.162	1.121	5.222	-
1.764	0.266	0.704	0.097	0.852	3.111	-
Independent: 1.094	0.326	0.926	0.281	0.776	5.082	1.193
Mediator: 2.301						

Table 8.14: Results of the mediation test for the realization of scale and learning effects

8.6 Conclusions

From the report on the second empirical study, a management survey among managers of *36* firms listed on the *Amsterdam Stock Exchange*, intended to measure network effects and social interaction effects, combined with an objective measurement of scale and learning effects and firm performance, we may conclude the following.

The same measures as developed for the first empirical study were used for measuring the market-based mechanisms of increasing returns. They were slightly adapted to accommodate the comparative static time frame of the current study. The adapted measures of network and social interaction effects were re-validated for the current study. This confirmed the validity of the constructs of network effects at the product level, network effects at the technology level, social interaction effects at the product level and social interaction effects at the technology level. The number of observations from the survey was not large enough to test the validity of the second-order constructs for network effects and social interaction effects, but the results of the first-order construct provided enough confidence to use these second-order constructs in the current study.

New objective measures were created for measuring the firm-based mechanisms of increasing returns and for measuring firm performance. Analogous to the first empirical study, a distinction was made between the potential for scale and learning effects and the realization of scale and learning effects. The potential for scale and learning effects was measured as the average annual growth of output over the period of analysis (1995-2000). We took added value as the definition of output. The realization of scale and learning effects was measured as the average annual growth of productivity over the period of analysis. We took the added value divided by hours worked as the definition of productivity. Firm performance was measured as the average annual growth rate of net profit over the period of analysis.

With this empirical study we addressed hypotheses 1, 2, 3 and 5. These hypotheses are supported by the results. See table 8.15 below.

Main hypotheses:		**Result:**
H_1	The larger the social interaction effects, the larger the network effects	Supported
H_{2a}	The larger the network effects, the larger the potential for scale and learning effects	Supported
H_{2b}	The larger the social interaction effects, the larger the potential for scale and learning effects	Supported
H_3	The larger the potential for scale and learning effects, the higher the realization of scale and learning effects	Supported
H_4	The higher the realization of scale and learning effects, the higher the level of product performance	Not tested
H_5	The higher the realization of scale and learning effects, the higher the level of organizational performance	Supported
H_6	The higher the level of product performance, the higher the level of organizational performance	Not tested

Table 8.15: Results on the main hypotheses

This study delivered some noticeable results. First, even with the small number of observations, the validity of the measures of the market-based mechanisms of increasing returns was supported. Second, there was support in this study for a relationship between the market-based mechanisms of increasing returns, i.e., network effects and social interaction effects and the firm-based mechanisms of increasing returns, i.e., a potential for scale and learning effects. A test on mediation effects reveals that network effects completely mediate the relationship between social interaction effects and the potential for scale and learning effects.

Analogous to the results of the first empirical study, we may conclude from this second study that firm performance is achieved in a market where market-based mechanisms of increasing returns are present *through* the firm-based mechanisms of increasing returns. Specifically, firm performance is achieved in markets where social interaction effects and network effects are present *through* the realization of scale and learning effects by the firm.

9. REPORT THIRD EMPIRICAL STUDY

In this chapter we report on the research process and the results of the third empirical study, an estimation of the Verdoorn law and the productivity-performance relationship for *118* firms listed on the *Amsterdam Stock Exchange*. In this study we did not address the market-based mechanisms of increasing returns but we focused on the relationship between the firm-based mechanisms of increasing returns and firm performance.

The relationship between the potential and the realization of scale and learning effects was investigated using a firm-level conceptualization of the Verdoorn law. The Verdoorn law is an empirical, long-run linear relationship between the growth of output and the growth of labor productivity. It was originally conceived at the industry level. The empirical study reported on in this chapter differs in one important respect from previous Verdoorn law studies: in this study we aimed to conceptualize and measure the Verdoorn law at the firm level, previously it has only been applied at country, industry or regional level. Analogous to the Verdoorn law, we will model the relationship between productivity, i.e., the realization of scale and learning effects, and firm performance.

We start in section one of this chapter by explaining the reasons for choosing the Verdoorn law as a concept for measuring the firm-based mechanisms of increasing returns. We continue in section two by describing the development of the measures and the models of the Verdoorn law and the productivity-performance relationship for our specific purpose. We describe the data collection and research sample in section three. We address the validation of the measures in section four. In section five we provide the results of the research, addressing the results for individual firms, for industries and for the total sample, respectively. We provide conclusions in section six.

9.1 Why the Verdoorn law?

As we saw before in section 2.4, there is close link between increasing returns and economic growth theory at the macro level (Romer, 1986; 1990b; Fingleton & McCombie, 1998). Therefore, to measure firm-based increasing returns, we turn towards macroeconomic growth models that can be adapted to be applied at the firm level. The basic question in such models is: Where does economic, or firm, growth come from? Classical economic growth theory has assumed that the quantity of land available was the most important driver of growth. This made for Malthus' (1798) famous population theory, i.e., that population would increase geometrically whereas the means of subsistence, i.e., the food supply, would only increase arithmetically (Ekelund & Hébert, 1997). Alternatively, classical growth theory has assumed that growth is associated with the increase of the working population as an external source of energy. This would increase the extent of the market, enabling further division of labor, resulting in increased productivity. International comparisons at the country level should suffice to prove that this is not the case. At the firm level, this explanation is equally unlikely. The central question of modern growth theory can therefore be restated as: Where does economic (firm) growth come from, when not from the increase of the classical input factors, i.e., from the increase of labor and capital?

If growth does not come from the increased quantities of input factors, it must come from the more efficient use of the existing input factors, i.e., from rising productivity of those factors. In the course of recent economic history, different explanations have been proposed for this rise of productivity. We focus on three of those: (1) the traditional, neoclassical analysis, exemplified by the work of Solow (1957), (2) the endogenous growth analysis related to the work of Romer (1986, 1990b) and Lucas (1988) and (3) an alternative analysis related to the work of Verdoorn (1949) and Kaldor (1966). These explanations are partly opposing and partly complementary.

9.1.1 Neoclassical analysis and the Solow residual

The traditional model rests on four key assumptions (Cripps & Tarling, 1973): (1) resources are allocated efficiently between alternative uses, (2) for the economy as whole there are constant returns to scale (3) prices of factors behave as if perfect competition prevailed in all markets and (4) any improvements in productivity can be attributed to the growth of knowledge.

The assumption that productivity improvements must be attributed to the growth of knowledge stems from the prior assumptions of efficient resources allocation and constant returns to scale (Cripps & Tarling, 1973). When input factors can have no increasing marginal product, there has to be 'something else' that is different from other input factors to explain residual growth of output. We call this 'something else' by different names, e.g., technology, knowledge, creativity, inventiveness or entrepreneurship. In the neoclassical tradition, the growth of this 'something else' is supposed to be an independent and exogenous determinant of economic growth and, consequently, of the productivity of the input factors.

One of the prime examples of the traditional, neo-classical analysis is the analysis of Solow (1957) on the growth of the American economy. He reasoned as follows: society's aggregate production function was traditionally assumed to be dependent on capital *(K)* and labor *(L)*. Solow's aim was to segregate variations in output *(Q)* due to exogenous technological change $(A_{(t)})$ from those due to changes in availability of capital.

Technical change to Solow was an expression of any kind of shift in the production function, because of, e.g., technological development or improved national education. The aggregate production function according to Solow then takes the following shape:

$$Q = A_{(t)} * f(K,L)$$

The rate of exogenous technological change $\Delta A_{(t)}/A_{(t)}$ can be computed from differentiating and rewriting this function. Solow tested this technological change for a time series from the United States economy (1909-1949) and found that approximately *20%* of the total output increase is traceable to increases in capital and labor and the remaining *80%* to exogenous technological change. Solow did not explicitly mention knowledge as an input factor, but designated all economic growth that could not be attributed to increasing in capital and labor as 'residual'. A further analysis of this residual shows that it involves among others technological developments and new forms of organization, aspects that may also be conceptualized as *knowledge*. Although opinions differ on what exactly the residual represents, it is commonly accepted that *technology* or *knowledge* forms the most substantial part of it. Many studies in *growth accounting* have reported similar results, e.g., Griliches (1994; 1998) and Nelson & Winter (1974).

9.1.2 Zegveld's firm-level analysis

Solow's (1957) reasoning can, with some caution, be translated to the firm level, as has been done by Zegveld (2000).[68] Research on the relationship between knowledge

[68] Zegveld's reasoning differs from Solow's, however, in the explanation of the cause of the residual. Rather than assuming that there is an exogenous growth of knowledge, he regards knowledge as an *interaction factor*, i.e., something that emerges from the interaction between

creation and growth theory at the firm level is relatively new. While several well-known authors have partly paved the way (Griliches, 1994; 1998; Roach, 1996) or have indicated the relevance of this research area (Drucker, 1999; Kim & Mauborgne, 1997), very few authors have explored firm-level production functions in relation to knowledge creation.

In a study of *85* Dutch firms, listed on the *Amsterdam Stock Exchange* over the period 1985-1997, Zegveld (2000) has translated the residual concept to the firm level.[69] He concluded that only *46%* of the productivity growth of these firms could be explained from the input factors labor and capital. The residual factor knowledge therefore explains more than half, i.e., *54%,* of the productivity growth. Moreover, Zegveld's (2000) study shows that there are significant differences in residual build-up between firms. This means that, independent of increasing capital market efficiency and the hiring of better-educated employees, more than half of productivity growth in the period of analysis cannot be assigned to the primary input factors capital and labor.

For our purpose, the main problem of the Solow model is the assumption that all technical change is exogenous. If we accept this assumption, the implication is that this knowledge will be more or less equally accessible to most countries, industries or firms to the same extent. This is questionable, as the residuals for different economic entities are far from uniform. Therefore, we should expect some endogenous effects to be present. In the theoretical sections 5.2 and 5.3 we explicitly included endogenous explanations of scale and learning effects as the cause of productivity improvements. Therefore, the Solow method is unfit for our purpose.

9.1.3 Endogenous growth

This neoclassical explanation would only suffice if technology were external to the economic system, e.g., something that is 'produced' in government-sponsored universities. It can be argued that knowledge growth or technological improvement will be, at least partly, endogenous: either R&D realted endogenous, in the sense that knowledge gained through R&D is an output of labor, information and/or capital

the core stakeholders of the firm (Zegveld & Den Hartigh, 2002). This is in fact close to the ideas of endogenous growth theory.

[69] Please note that Zegveld (2000) used an earlier version of the database that was used for our second and third empirical study. Hence Zegveld tested the firm-level residual build-up for a sample of firms that is largely comparable to ours.

investments or autonomous learning related endogenous, in the sense that knowledge generates itself in the transformation process.

If we accept that knowledge or technology is, at least partly, a product of economic action within the economic system, than it cannot be fully exogenous, but it has to be explained from within the system.

This is exactly what *new* or *endogenous growth theory* tries to do, albeit at the macro level. By allowing for increasing returns, i.e., increasing marginal productivity of an input factor, in at least one sector of the economy, economic growth can be endogenously explained (e.g., Romer, 1986, 1990b, 1994; Lucas, 1988; Grossman & Helpman, 1994; Pack, 1994). As a consequence the debate shifts to the question which input factor is primarily responsible for this economic growth: Is it the continuous improvement of capital that leads to ever-larger productivity? This is the point of view expressed by Arrow (1962), whose model is in the opinion of Solow (1997) a predecessor of endogenous growth models. The argument may easily be extended to take the developments in ICT, sometimes labeled as *knowledge capital* as the driving force of economic growth. Alternatively, we may regard what is commonly called *human capital* as the driver of growth. This is the point of view of Romer (1990b) and many of the management scientists involved in the knowledge debate, e.g., Weggeman (1997). The implication is that in the production function we have to make a distinction between physical labor and knowledge labor. The third alternative is to regard the 'stock of knowledge' as a separate input factor, as is done by Romer (1986).

Though opinions are divided, researchers seem to agree over two issues. First, knowledge, or the buildup of knowledge, i.e., learning, is crucial in explaining economic growth. Second, this crucial role is due to the increasing marginal productivity of knowledge, i.e., the inherent possibility of increasing returns.

Still, however, there is no theoretical rationale for introducing either knowledge itself, or knowledge labor, or knowledge capital as a production factor determining increasing returns. Doing this would mean that endogenous technological growth would be *only and completely* embodied by this production factor *knowledge* and not by the conventional production factors *labor* or *capital*. This does not conform to our theory that scale and learning effects result, at least partly, from division of labor and learning-by-doing by the conventional production factors. Therefore, while the endogenous growth models explicitly incorporate increasing returns, they are unfit for our purpose.

9.1.4 The Verdoorn law

In 1949, the Dutch economist Verdoorn published an article in the Italian journal *L'Industria* in which he explored the relationship between the growth of labor productivity and the growth of output.[70] He hypothesized an empirical regularity in the sense that there is a constant elasticity of labor productivity with respect to output. In other words, there appears to be a linear causal relationship between the growth of labor productivity and the growth of output. Verdoorn illustrated this relationship with output and productivity data over the periods 1870-1914 and 1914-1930 for a number of countries and a number of industrial sectors.

In 1952, Verdoorn formulated *two growth laws* for industry. The first one is that the level of labor productivity in an industrial sector in a certain country at a specified point in time is for a large part determined by the total accumulated production in that country up to that point in time (1952, p.57). From experience in the airframe industry and with the building of *liberty ships*, see, e.g., Wright (1936), Hirsch (1952), Alchian (1963), Argote, Beckman & Epple (1990) and Thornton & Thompson (2001), it became known that the ratio between the percentage rise in accumulated output and the percentage rise in productivity was fairly stable. In the literature this relationship is known as *the learning curve*.

Reasoning further, Verdoorn states that when there is a fairly stable relationship between the percentage rise in accumulated production and that of productivity, it is mathematically deducible that there must also be a fairly stable relationship between the rise in non-accumulated production and productivity. That is, when we take a long-term view, abstracting from short-term fluctuations. This is the *second growth law* that states that the rise in labor productivity in an industrial sector in a certain country will be largely determined by the growth of the production volume. This second growth law has become known as *Verdoorn's law* through Kaldor's (1966) inaugural lecture.

Apart from a few scattered studies, e.g., Salter (1960), the Verdoorn relationship might have been completely forgotten were it not for the fact that Kaldor (1966) gave

[70] An English translation of this paper by *Thirlwall* is available in McCombie, J., M. Pugno & B. Soro (eds.), *Productivity growth and economic performance*.

it a prominent place in his inaugural lecture at the *University of Cambridge*. Kaldor referred to the relationship as *Verdoorn's law*.

Having been a notorious critic of neoclassical economics for many years, Kaldor has put the Verdoorn law in the tradition of increasing returns thinking that started with the first chapters of Smith (1776) and was developed by Young (1928); see section 2.4.1. Kaldor specifically tried to provide an alternative explanation for differences in the rate of growth between countries. The Verdoorn law provides this alternative to neoclassical convention by being a dynamic relationship, by allowing for increasing returns in the production function and by providing a basis for theories of cumulative causation. To this end, Kaldor reinterpreted Verdoorn's relationship as a regression equation in which the growth of productivity is linearly dependent on the growth of output. In Kaldor's interpretation, the coefficient of this regression equation represents the extent to which a country or an industry realizes scale and learning effects.

Since Kaldor's (1966) inaugural lecture, many publications have appeared in which Kaldor's interpretation is accepted, attacked, extended or empirically tested. Some of the most recent of these are Jefferson (1988), Harris & Lau (1998), Fingleton & McCombie (1998) and Fase & Winder (1999). An extensive overview of publications on the Verdoorn law is provided by McCombie, Pugno & Soro (2003).

Kaldor's interpretation brings up the question of cause and effect in the Verdoorn relationship: Why would the growth of productivity be the result of a faster growth rate of output? Why would the relationship not simply reflect that a faster growth rate of productivity induces, via its effect on relative costs and prices, a faster growth of demand? Kaldor (1975) reasons that economic growth is demand-induced instead of constrained by exogenously given rates of growth of labor and capital combined with exogenously given technological progress, as the neo-classical economists assume. In Kaldor's reasoning it is primarily demand growth that through increased division of labor and learning-by-doing stimulates technical progress. This is only the first part of the reasoning however. Following the logic of cumulative causation (Myrdal, 1957), the increased productivity will lead to increased output, the extension of existing markets or the opening up of new ones (see figure 9.1).

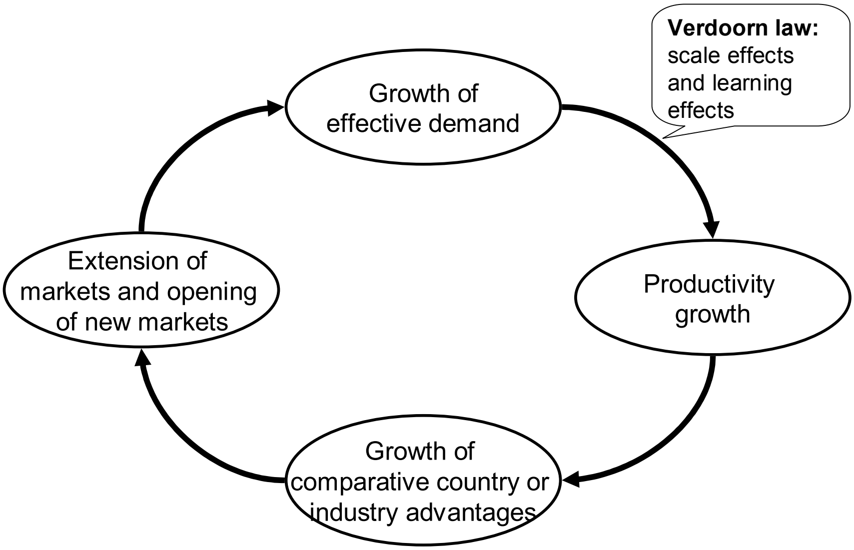

Figure 9-1: Cumulative causation at the country and industry level

The Verdoorn law has been empirically observed across countries, regions and industries using country-level, region-level and industry-level data (Fingleton & McCombie, 1998; Harris & Lau, 1998). To date the Verdoorn law has to our knowledge not been estimated using firm-level data. We think that the argument of cumulative causation also applies at the firm level.

Our reasoning in sections 5.5 and 5.6 with regard to the relationship between the potential and the realization of scale and learning effects is in fact a firm-specific reflection of Kaldor's macro-economic cumulative causation argument (see figure 9.2). The growth of a firm's output over time causes productivity improvements through the realization of scale effects and autonomous learning effects. At the same time the firm can realize productivity improvements as the result of induced and exogenous learning effects. The firm can use these productivity gains to increase its output by stimulating additional market-demand for its products. This can be achieved by using the cost advantage to win market share by: (1) offering products at lower prices than competitors for equivalent benefits, i.e., a *volume-efficiency strategy* or by: (2) providing customers with unique benefits at higher prices than competitors, i.e., a *volume-differentiation strategy*. Either one of these strategies allows productivity gains and growth of output to become a positive feedback loop. This reasoning of cumulative causation at the firm level implies that the Verdoorn law can also be used to measure the realization of scale and learning effects using firm-level data.

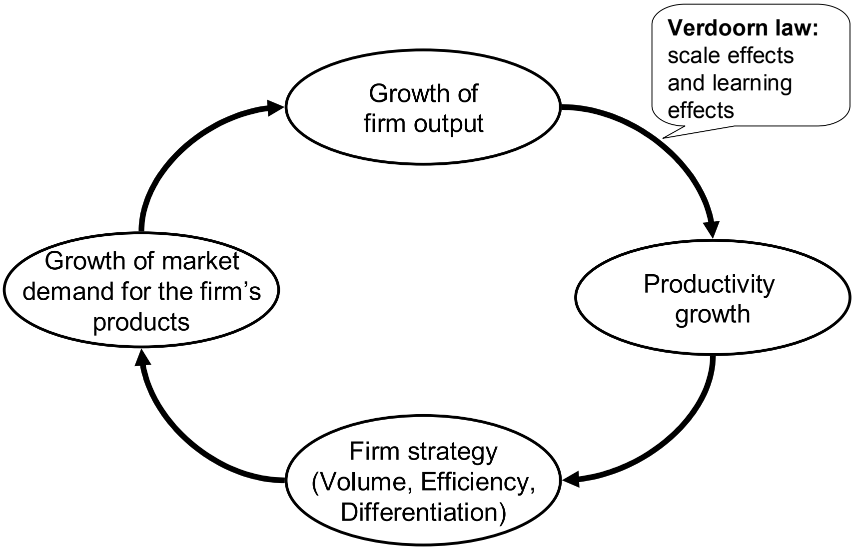

Figure 9-2: Cumulative causation at the firm level

Therefore, if we can draw up a firm-level measurement model of the Verdoorn law, this measurement model may be fit to measure the relationship between the potential and the realization of scale and learning effects as discussed in chapter five. On this basis we consider it worthwhile to use the Verdoorn law to conceptualize the measurement of the relationship between the potential and the realization of scale and learning effects.

9.2 The Verdoorn model and its interpretation

As stated above, the Verdoorn relationship has been empirically observed across industries, regions and countries (Kaldor, 1966; Fingleton & McCombie, 1998). We may therefore conclude that it is useful in measuring the potential and realization of scale and learning effects. Still, for application at the firm level, the measure needs to be adjusted and further developed.

9.2.1 The original Verdoorn model

The original Verdoorn model has been conceptualized at the country and industry level. It can be written as:

$$\dot{p} = a + b\dot{q}$$

Here, *p-dot* is the exponential growth rate of labor productivity, *q-dot* is the exponential growth rate of output and *a* and *b* are constants. The value of *b*, the *Verdoorn coefficient*, reflects the elasticity of the productivity of labor with respect to output volume. This interpretation is widely accepted in the literature, see, e.g., McCombie & De Ridder (1984), McCombie (1985), Fingleton & McCombie (1998), Harris & Lau (1998) and Fase & Winder (1999). Verdoorn (1949) himself found values for this coefficient between *0.41* and *0.57*. This means that a growth of *1%* in the volume of output causes a growth of between *0.41%* and 0.57% in labor productivity. The magnitude of these values and of the range of values has, over the decades, been confirmed by many empirical contributions; see McCombie, Pugno & Soro (2003) for an overview.

While the coefficient has received wide attention in the literature over the past few decades, the importance of the constant term *(a)* has been largely neglected. Verdoorn (1949) himself does not offer an interpretation for the constant term. However, Kaldor (1966), in his interpretation of the Verdoorn law, interprets this constant term as an 'autonomous' rate of productivity growth.[71] Kaldor (1968. p.389): "It is a constant term, which reflects explanatory variables that were excluded, one of which may be an autonomous time trend." In other words, it reflects the productivity change as far as this is not dependent on output growth.

9.2.2 Choosing a model specification

Over the years, many authors have specified and re-specified the Verdoorn law for the purposes of theory building and empirical testing, e.g., McCombie & De Ridder (1984), McCombie (1985), Fingleton & McCombie (1998), Harris & Lau (1998) and Fase & Winder (1999). The specification of the Verdoorn law by Fingleton & McCombie (1998) comes closest to our theoretical specifications of scale and

[71] Note that Kaldor uses the word *autonomous* in the opposite way to which we use it in the phrase *autonomous learning effects*. We will continue to use the word *autonomous* as described in section 5.3 under *autonomous learning effects*.

learning effects. We will shortly address their reasoning below. Fingleton & McCombie (1998) start from the following *Cobb-Douglas production function*:

$$Q = A_0 e^{\lambda t} K^{\alpha} L^{\beta}$$

Where Q represents output, A represents the state of technology, λ represents exogenous technological progress, K represents capital, L represents labor and α and β are parameters.

Taking the natural logarithm gives:

$$\ln Q = \ln A_0 + \ln e^{\lambda t} + \ln K^{\alpha} + \ln L^{\beta}$$

or

$$\ln Q = \ln A_0 + \lambda t + \alpha \ln K + \beta \ln L$$

Differentiating with respect to time gives:

$$q = \lambda + \alpha k + \beta l$$

Where q represents the growth of output, k represents the growth of capital inputs and l represents the growth of labor inputs. Since $p \equiv q-l$, or the growth of labor productivity is by definition equal to the growth of output minus the growth of labor input, we can write this as:

$$\beta q - \beta l = \lambda + \beta q - q + \alpha k$$

or

$$\beta p = \lambda + \beta q - q + \alpha k$$

or

$$p = \lambda / \beta + ((\beta - 1) \beta) q + (\alpha / \beta) k$$

Assuming a constant *capital-output ratio* means that $k = q$ and therefore:

$$p = \lambda / \beta + ((\alpha + \beta - 1) \beta) q$$

Where *(α+β-1)/β* represents the Verdoorn coefficient and *λ/β* represents the constant term. It now becomes clear that:

- a positive Verdoorn *coefficient* measures increasing returns, because it is only positive when *(α+β)>1*
- *exogenous* technological change *(λ)*, is part of the *constant term* of the Verdoorn relationship

When we assume that technological change is *partly exogenous* and *partly endogenous*, or: $\lambda=\lambda'+\xi q$, the Verdoorn equation becomes:

$$p = \lambda'/\beta + ((\xi + \alpha + \beta - 1)\beta)q$$

Where *(ξ+α+β-1)/β* represents the Verdoorn coefficient and *λ'/β* represents the constant term. In this case, the Verdoorn coefficient measures both static increasing returns, i.e., static scale effects, and dynamic increasing returns, i.e., dynamic scale and learning effects.

There are three major controversies surrounding the specification and study of the Verdoorn law (see also Harris & Lau, 1998): the first one revolves around the question of whether or not to include capital in the equation. The second one is the question of whether a single relationship may be estimated or rather a set of simultaneous equations should be used. The third one is the paradox that static estimations of the Verdoorn law seem to deliver radically different results than the usual dynamic estimation. We will subsequently address these controversies and explain how we dealt with them in our model.

9.2.3 Including capital in the Verdoorn equation

The first Verdoorn law controversy is about the inclusion of capital in the Verdoorn equation. Wolfe (1968) argued, in a critique of Kaldor's (1966) inaugural lecture, that measuring the effect of labor productivity without including the effects of capital would result in exaggerated values for the Verdoorn coefficient. Kaldor (1968) responded by stating that this is not necessarily the case, as the role of capital will be reflected in the value of the constant term. Including capital in the regression will likely reduce the constant term, but will not necessarily reduce the Verdoorn coefficient (Kaldor, 1968). Let us further explore the way in which the Verdoorn coefficient is dependent on capital.

The original Verdoorn (1949) model was based on a *Cobb-Douglas production function* of the following form:

$$x = a^{\alpha} * b^{\beta}$$

In this function, x is output, a is labor input and b is capital input.[72] From this function, Verdoorn (1949) derived the elasticity of labor productivity with respect to output, which later became known as the Verdoorn coefficient *(K)*:

$$K = 1 - 1 \Bigg/ \left[\alpha + \beta \left(\frac{\dot{b}/b}{\dot{a}/a} \right) \right]$$

In this equation, *a-dot* and *b-dot* indicate the first derivative of a and b with respect to time. It clearly shows that the Verdoorn coefficient is influenced by the ratio between the use of capital and the use of labor inputs. This is confirmed by Thirlwall (1980). Therefore, the Verdoorn coefficient will indeed be higher when in the long run labor is substituted by capital, which is exactly what has been empirically observed in economic literature (Rowthorn, 1999).[73]

Alternatively we can substitute a growth of capital-labor ratio into the specification of the Verdoorn law by Fingleton & McCombie (1998) addressed in the previous section. When the capital-labor ratio grows or declines, we get $k=\delta \cdot l$ and, therefore:

$$q = \lambda + \alpha\delta \cdot l + \beta \cdot l$$

or

$$q = \lambda + (\alpha\delta + \beta)l$$

Where q represents the growth of output, l represents the growth of labor inputs and δ represents the growth of the capital-labor ratio. Since $p \equiv q-l$, or the growth of (labor) productivity is by definition equal to the growth of output minus the growth of labor input, we can write this as:

---

[72] Note that $\alpha+\beta$ is not restricted to be smaller than or equal to *1*.

[73] Rowthorn (1999) performed a meta-analysis of *33* econometric studies in which he shows that the substitution coefficient between capital and labor is considerably below unity. In other words, labor is substituted by capital.

$$(\alpha\delta+\beta)q-(\alpha\delta+\beta)l=\lambda+(\alpha\delta+\beta)q-q$$

or

$$(\alpha\delta+\beta)p=\lambda+(\alpha\delta+\beta)q-q$$

or

$$p=\lambda/(\alpha\delta+\beta)+(1-1/(\alpha\delta+\beta))q$$

Here, $1-1/(\alpha\delta+\beta)$ represents the Verdoorn coefficient and $\lambda/(\alpha\delta+\beta)$ represents the constant term. It now becomes clear that the growth of the capital-labor ratio affects both the Verdoorn coefficient and the constant term. The Verdoorn coefficient will be higher when the capital-labor ratio grows, confirming Wolfe's (1968) statements, and the constant term will be lower, partly confirming Kaldor's (1968) reply.

De Vries (1980, p.274) states that "As easily can be verified at least the condition of equality of the growth rates of output and capital should be satisfied." This is confirmed by Fase & Winder (1999, p.279): "… Verdoorn's law applies if the capital-output ratio is constant." Again going back to the specification of the Verdoorn law by Fingleton & McCombie (1998) addressed in the previous section, it becomes clear that the Verdoorn coefficient is dependent on the capital-output ratio. When the capital-output ratio grows or declines, we get $k=\gamma\cdot q$ and, therefore:

$$p=\lambda/\beta+((\gamma\alpha+\beta-1)\beta)q$$

Where $(\gamma\alpha+\beta-1)/\beta$ represents the Verdoorn coefficient and λ/β represents the constant term. We can see that the Verdoorn coefficient is affected by the capital-output ratio. Therefore, the Verdoorn coefficient will be higher when in the long run capital becomes more prominent as an input factor.

It can be concluded from the argumentations above that the Verdoorn coefficient is dependent on the long-run growth of the capital-labor and the capital-output ratios and that the constant term is dependent on the capital-labor ratio. It also becomes clear, however, that the Verdoorn coefficient can be *corrected* for a growth of the *capital-labor and the capital-output ratios* and that the constant term can be *corrected* for a growth of the *capital-labor ratio*. Contrary to what De Vries (1980) and Fase & Winder (1999) state, the above means that the capital-output ratio does not have to be equal to unity per se to be able to calculate the Verdoorn relationship. When this ratio is non-constant, but steadily growing or declining, in accordance with the steady-state assumption of the Verdoorn law, we can calculate the value of γ

and use this value to correct the Verdoorn coefficient. The same is true for the capital-labor ratio: when it is non-constant, but steadily growing or declining, in accordance with the steady-state assumption of the Verdoorn law, we can calculate the value of δ and use this value to correct the Verdoorn coefficient and the constant term. In section 9.5.7 we explain how these corrections are calculated in this study.

9.2.4 Single relationship or system of equations

The second Verdoorn law controversy is whether it should be conceptualized as a single relationship or as a system of equations. The original Verdoorn (1949) model, being a model at the country level, is formulated as a system of five equations, incorporating the national production function, the labor demand equation, the labor supply equation, the capital supply equation and the population growth. This system of equations makes it possible, again at the country level, for economic growth to become endogenous as a consequence of increasing returns in the production function. It will be clear however, that this specific system of equations only makes sense for relatively self-contained economic units. All equations, on population growth, on labor supply and demand, on capital supply and on production should relate to the same unit of analysis: a specific country. When labor, capital or production does not obey the country borders, however, the system of equations becomes less valid and may even become meaningless. In other words, the smaller the unit of analysis becomes and the more intertwined it becomes with other units, the less valid this particular system of equations becomes. Most of the researchers of the Verdoorn law have recognized this problem and have therefore estimated only the primary Verdoorn relationship, e.g., McCombie & De Ridder (1984), McCombie (1985), Jefferson (1988) and Fingleton & McCombie (1998).

At the firm level, too, we have provided a logical explanation for how the Verdoorn relationship reflects part of a larger positive feedback loop; see section 9.1.4 and figure 9.2. In our overall research model (see section 6.1), we hypothesize a system of relationships in which the existence of social interaction effects and network effects will cause a market potential for scale and learning effects. This relationship has been investigated in chapters seven and eight (hypothesis H_{2a} and H_{2b}). This potential is still exogenous to the firm, but endogenous to the market. It parallels Kaldor's (1966) concept of growth of effective demand. With the firm-level Verdoorn relationship we then estimate the extent to which the firm is able to convert the growth of effective market demand into productivity improvements, i.e., the extent to which the firm is able to convert the potential for scale and learning effects into realization of these scale and learning effects (hypothesis H_3). This realization of scale and learning effects, i.e., the productivity improvement, will in turn cause a higher firm performance (hypothesis H_5). This relationship is investigated in chapter eight and in the current chapter. As has been argued in sections 5.5 and 5.6, an increase in productivity and performance can in turn be used by the firm to improve its market and competitive position, which will further stimulate the effective demand for the firm's products. To make this effective demand for the firm's products endogenous in a firm-level model, however, would require us to investigate fully the ways in which the firm influences the market forces, e.g., how the firm can influence the extent of the social interaction effects and the network effects. This would require a dynamic version of our full research model, which is beyond the scope of this thesis. Therefore, we will limit ourselves in this chapter to estimating (1) the Verdoorn law at the firm level, i.e., the relationship between the potential and the realization of scale and learning effects (hypothesis H_3), and (2) the relationship between the growth of productivity and the growth of performance, i.e., the relationship between the realization of scale and learning effects and firm performance (hypothesis H_5).

9.2.5 The static-dynamic paradox

Harris & Lau (1998) state that estimations of the Verdoorn law have delivered different values of the Verdoorn coefficient when estimating in static terms, i.e., with variables as levels, than when estimating in dynamic terms, i.e., with the variables as first differences. This effect they refer to as the *static-dynamic paradox*.

The argument for using the static model is that the original Verdoorn law was based on a static *Cobb-Douglas production function*. In the specification of Verdoorn, this production function allows for non-increasing returns to scale, but not for exogenous technological change. The consequence of this reasoning would be that the distinction between static and dynamic economies of scale is irrelevant for estimation purposes (McCombie, 1982). Hence the static and dynamic coefficients should be the same, which is not the case.

This argument is however based on a misunderstanding of Verdoorn's law, at least as interpreted by Kaldor (1966, p.288): "It is a dynamic rather than a static relationship – between the rates of change of productivity and of output, rather than between the level of productivity and the scale of output – primarily because technological progress enters into it, and it is not just a reflection of the economies of large-scale production." The *Cobb-Douglas production function* in the specification of Verdoorn may not allow for exogenous technological change, it does allow for endogenous technological change (De Vries, 1985). The consequence of this is that the dynamic model will show values of the coefficient that are different from the static model because the dynamic model incorporates technological change and the static model does not. When we accept this reasoning, there is no matter of a paradox. For this study we will adopt the dynamic model.

9.2.6 The firm-level Verdoorn model and its interpretation

The Verdoorn law model used in this study can be expressed in the following regression equation:

$$\Delta P_{(t,t-1)} = a + b \cdot \Delta Q_{(t,t-1)} + \varepsilon$$

In which ΔP represents the growth of productivity between year t-1 and year t; ΔQ represents the growth of output between year t-1 and year t; b represents the uncorrected Verdoorn coefficient at the firm level; a represents the uncorrected constant term at the firm level and ε represents the error term.

A value of the Verdoorn coefficient *(b)* larger than *0* means that the firm has realized scale effects and autonomous learning effects as a consequence of the growth of output over time.[74] This is the *endogenous* part of productivity growth. The value of the intercept *(a)* indicates whether there has simultaneously been growth of productivity as a consequence of induced and/or exogenous learning effects.[75] This is the *exogenous* part of productivity growth. Thus the Verdoorn law measures the relationship between the potential and the realization of scale and learning effects (see figure 9.3).

Following what Kaldor (1966) does at the macro level, we can mark a firm's annual score by judging the deviation of that year's productivity growth from the Verdoorn regression line. In this way, we can relate the firm's actual productivity growth in that year to what it is expected to be on the basis of the growth rate of its output (see figure 9.4).

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[74] For an explanation of scale effects and autonomous learning effects, see sections 5.2.1 and 5.3.4, respectively.

[75] For an explanation of induced and exogenous learning effects, see sections 5.3.2 and 5.3.3, respectively.

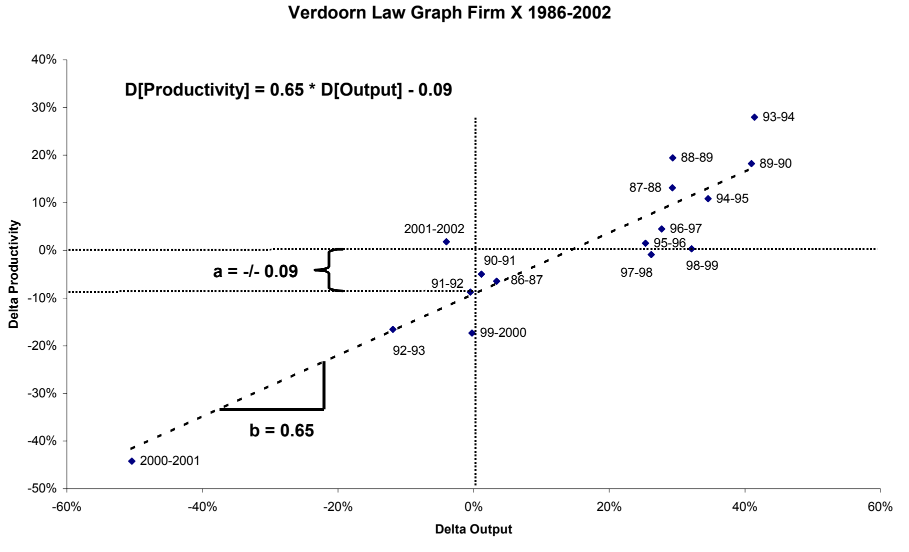

Figure 9-3: The firm-level Verdoorn relationship

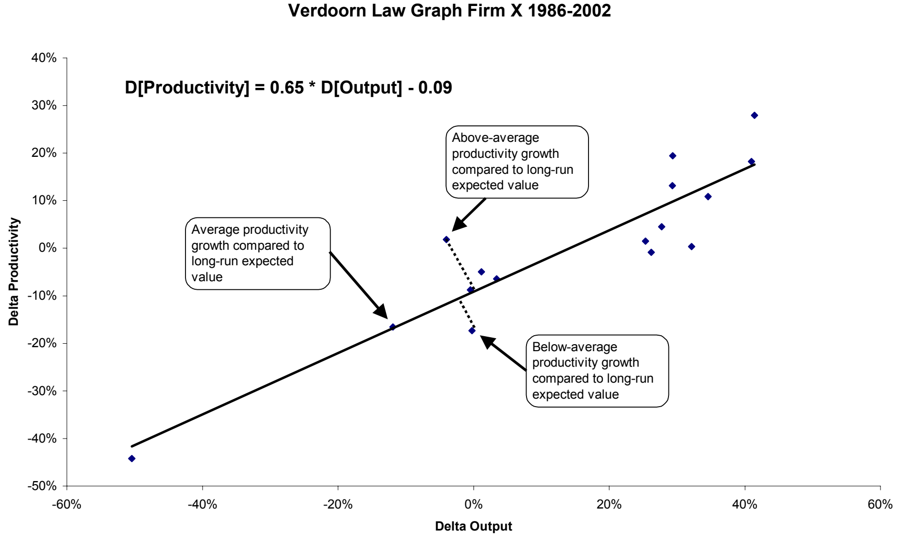

Figure 9-4: Annual scores on the firm-level Verdoorn relationship

9.2.7 The productivity-performance model and its interpretation

The model used in this study to estimate the productivity-performance relationship can be expressed in the following regression equation:

$$\Delta FP_{(t,t-1)} = c + d \cdot \Delta P_{(t,t-1)} + \varepsilon$$

In which *ΔFP* represents the growth of firm performance between year *t-1* and year *t*; *ΔP* represents the growth of productivity between year *t-1* and year *t*; *d* represents the uncorrected regression coefficient at the firm level; *c* represents the uncorrected constant term at the firm level and *ε* represents the error term.

A value of the coefficient *(d)* larger than *0* means that firms have realized better performance as a consequence of the growth of productivity over time. The value of the intercept *(c)* indicates whether there has been a growth of firm performance independent of productivity growth (see figure 9.5)

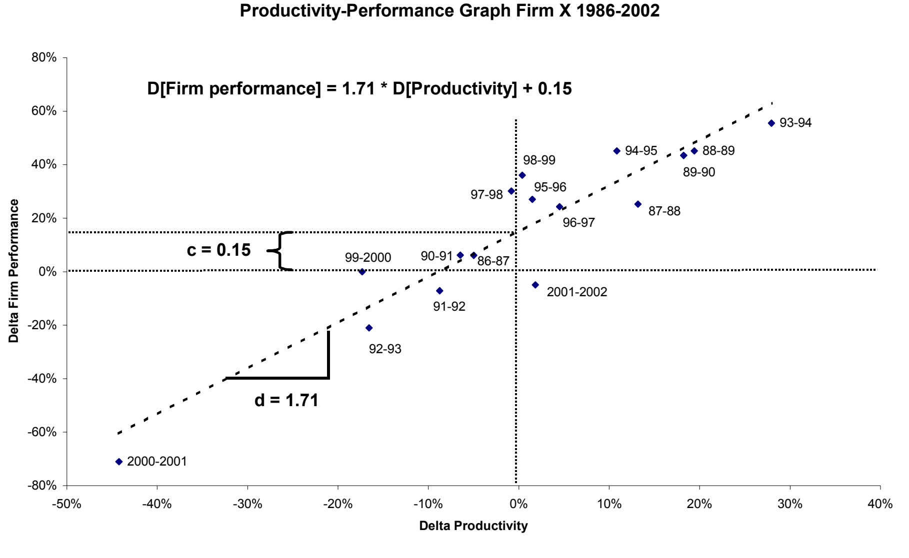

Figure 9-5: The productivity-performance relationship

Analogous to the procedure for the firm-level Verdoorn relationship, we can mark a firm's annual score by judging the deviation of that year's firm performance growth from the productivity-performance regression line. In this way, we can relate the firm's actual performance growth in that year to what it is expected to be on the basis of the growth rate of its productivity (see figure 9.6).

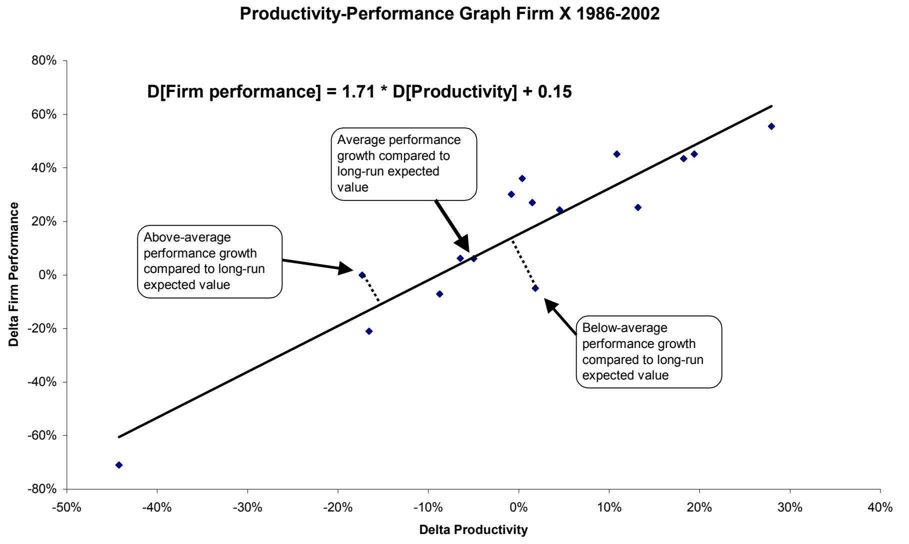

Figure 9-6: Annual scores on the productivity-performance relationship

9.3 Operational measurements of growth of output, productivity and firm performance

We need clear concepts for measuring the change in output, the change in productivity and the change in firm performance to be able to estimate the Verdoorn law and the productivity-performance relationship. For measuring in physical or monetary units and for the chosen correlators for input, output and performance we restate the arguments used in section 8.1.2 through 8.1.5.

We chose to measure scale and learning effects and firm performance using publicly available financial data again for this third study. As in the previous empirical studies, we decided to measure scale and learning effects together. We did this by conceptualizing a firm-level Verdoorn law, the development of which has been covered in detail in the previous sections. According to the theoretical specification of scale and learning effects provided in chapter five, an explicit distinction should be made between the *potential* for scale and learning effects and the *realization* of scale and learning effects.

The firm's annual growth rate of output over the period of analysis was used as the measure of the potential for scale and learning effects. The firm's annual growth rate of productivity over the period of analysis was used as the measure of the realization of scale and learning effects. We therefore need clear concepts of measuring the change in output and of measuring the change in productivity. As productivity change means a change in the ratio of the volume of output to the volume of the inputs, we need measurements of outputs and inputs. For each of these, there are two questions to be answered: (1) *Will the measurement be in units or in monetary terms?* (2) *Which correlator will be chosen for the measurement?*

First is the issue of what to measure: physical units or monetary units. Production functions are usually measured in physical units on both axes, i.e., units of output versus units of input. Cost functions are usually measured in a mixed way, i.e., units of output versus monetary measurement of cost. Both ways of measurement are used in the literature for learning and experience curves. *Theoretically*, there is no difference between these two ways of measuring because "… a production technology is always identically represented by either a production function or the corresponding cost function" (Chung, 1994, p.104).

Taking a management perspective, initially a complete measurement in monetary terms, i.e., measuring both outputs and inputs in money terms, rather than in quantities, seems to be preferable. The manager gains nothing by increased unit *output*, if it reduces turnover or profit level; also nothing is gained by a reduction in unit *input*, e.g., less employees, if this increases employment cost. Regarding productivity, money is eventually the most important variable for managers. To quote Salter (1960, p.3): "Businessmen – despite what they say at productivity congresses – are interested in prices, costs, and profits, and to them increasing productivity is simply one means of reducing labor costs." The well-known counter-argument is that measurement in money terms means *units*prices* and since prices are competitively determined, this measurement implicitly includes competition and market forces (Marshall, 1890). For managers, however, this is not undesirable per se, because they always deal with the interaction between their firm and the market forces.

Measurement in monetary units has a large advantage over measurement in physical units for measuring output. For firms or industries with strongly diversified outputs it is in principle impossible to measure physical units of output at the firm level. What is the unit output of a large diversified firm, e.g. *AKZO Nobel*, *DSM*, *Philips* or *Royal Dutch/Shell*? This question is fundamentally unanswerable at the firm level, unless the firm happens to deal in a very limited scope of plain commodities. We will therefore measure output in monetary terms, because this enables us to make comparisons across firms.

This problem of physical or monetary measurement is less severe for measuring inputs if we limit the productivity measurement to labor productivity, as is done in the next section. A homogenous measure can be taken for labor input, e.g., *number of employees*, *number of full time equivalents of employees* or *hours worked*. Hours worked means the total number of hours worked added over all employees of a firm.

The second issue is about the correlator chosen to measure output and input. When measurement in monetary terms is chosen, there are still different possible definitions of output. The most important ones are *turnover* and *added value*. Of these, turnover comes closest to indices of volume of gross output which are often used in productivity analyses at the industry or country level. The turnover measure suffers of the problem however that, when a firm produces intermediate goods that are sold within the firm for further processing, the gross output figure results in an overstatement of true gross output of the firm (cf., Kennedy, 1971). Another problem of the turnover approach is that insourcing or outsourcing of activities by firms may distort productivity statistics. For example, when a firm outsources an activity, this will show in a reduction of the number of employees, but not necessarily in the turnover figures, e.g., when outsourcing the internal IT department.

Added value, i.e., turnover minus all external cost, does not suffer from these shortcomings. Turnover is an indicator of the value that the firm’s products generate for customers, in comparison to the products of other suppliers. The external cost the firm has to pay to its suppliers is an indicator of the part of this value that is created by the firm’s suppliers. Turnover minus the external cost is therefore an indicator of the part of the customer value that is created by the firm. The added value measure also conforms to what is customary in other productivity studies. We therefore use the firm’s annual growth rate of added value for measuring the potential for scale and learning effects.

A partial productivity index can be derived for any input by dividing the index of volume of output by an index of the volume of that specific input. We may choose to include either labor, i.e., measuring *labor productivity*, capital, i.e., measuring *capital productivity*, or a combination of a number of inputs, i.e., *measuring multi-factor productivity*. We chose to measure labor productivity for this study. Labor as an input is customarily expressed in number of employees, number of full-time-equivalent employees or in hours worked. Measuring full-time-equivalent employees is preferred over just measuring the normal number of employees, because the full-time-equivalent measurement corrects for the increasing numbers of part-time jobs. Measuring hours worked is to be preferred over full-time-equivalent employees because it corrects for the general tendency for employees, at least in the Netherlands, for working less hours per week over the past years. We therefore measured labor inputs in number of hours worked.

Productivity in this study can then be defined as the ratio between output and input, where output was measured as added value and input was measured as hours worked. We used the firm's annual growth rate of productivity as a measure of the realization of scale and learning effects.

We also chose to use an objective measurement based on publicly available financial data for measuring firm performance. Firm performance is measured by the firm's annual growth rate of net profit.

The main difference between the measurements used in this third empirical study and in the second empirical study is that here we have multiple observations, i.e., multiple years, available per firm instead of just one observation per firm. Thus, where the second empirical study only allowed a comparative static analysis, in this third study we aim to analyze specific firms over time, i.e., a dynamic analysis.

Our way of calculating the annual rates of output growth ($\Delta Q_{t,t-1}$), productivity growth ($\Delta P_{t,t-1}$) and net profit growth ($\Delta FP_{t,t-1}$) for year *t* is by calculating the annual differences (Kennedy, 1971).

$$\Delta Q_{t,t-1} = \left(\frac{Q_t - Q_{t-1}}{Q_{t-1}} \right)$$

$$\Delta P_{t,t-1} = \left(\frac{P_t - P_{t-1}}{P_{t-1}} \right)$$

$$\Delta FP_{t,t-1} = \left(\frac{FP_t - FP_{t-1}}{FP_{t-1}} \right)$$

The consequence of this calculation is that we need two years of firm data to calculate one observation. Therefore, when we have firm data from years 1983-2002, we have *20* years of data, but only *19* observations of annual growth rates. The data are discussed in the next section.

9.4 Sample and data description

The data from this study were collected from publicly available data sources, i.e., the annual reports of firms listed on the *Amsterdam Stock Exchange* over the period 1983-2002. The sampling frame for this study consisted of *131* firms listed on the *Amsterdam Stock Exchange* over the period 1983-2002.[76] Of these *131*, we eliminated firms for which less than eight years of data were available, to ensure that we had at least seven data points per firm.[77] Further, we eliminated firms with missing data that were crucial for our computations. For firms that were the result of past mergers or large acquisitions, in the case of more or less equal partnership we aggregated the data of the merging partners before the merger and in the case of acquisitions we used the data of the dominant partner before the acquisition. These operations resulted in a sample of *118* firms. An overview of the industry distribution is provided in table 9.1 below. [78]

To check the representativeness of the research sample, we performed a *chi-square analysis* of the industry response distribution (Weinberg & Abramowitz, 2002). This analysis checks the null-hypothesis that the distribution of the research sample is equal to the distribution of the sampling frame. With a significance level of $p<0.05$ our analysis showed that the null-hypothesis is not rejected ($\chi^2=4.015$, $df=12$).

[76] This comprises most firms listed on the *Amsterdam Exchange Index (AEX)* and the *Amsterdam Midkap Index (AMX)* and a number of the firms listed on the *Dutch national market*. The sampling frame also included firms that had been listed in any sequence of years during the period 1983-2002, but were no longer listed in 2002. The full list of firms is included in *Appendix III*.

[77] As all the measurements are on growth rates, the number of usable comparative static data points is always one less than the number of static data points.

[78] The industry classification was chosen to conform to the classification used in the Dutch financial daily *Het Financieele Dagblad*. It was established during the testing of the questionnaire used for the second empirical study that this classification has the best *face validity* among managers.

Therefore we conclude that the sample of firms is representative for the total population.

Industry	Sampling frame (131 firms)		Research sample (118 firms)	
	No.	%	No.	%
Basic industry	14	10.7 %	14	11.9 %
Food industry	9	6.9 %	8	6.8 %
Media	7	5.3 %	6	5.1 %
Engineering industry	14	10.7 %	14	11.9 %
Construction industry	10	7.6 %	9	7.6 %
Wholesale	14	10.7 %	14	11.9 %
Transport	10	7.6 %	8	6.8 %
Telecommunications	4	3.1 %	1	0.8 %
Financial services	15	11.5 %	15	12.7 %
IT services	9	6.9 %	5	4.2 %
Other professional services	8	6.1 %	7	5.9 %
Retail	10	7.6 %	10	8.5 %
Electronics industry	7	5.3 %	7	5.9 %
sum	131	100.0%	118	100.0%

Table 9.1: Sample for the third empirical study

The data available for every firm are the annual profit & loss accounts, the annual balance sheets and the annual number of employees. The format of the profit & loss accounts and the balance sheets is the one that was maintained by *Euronext Amsterdam (the Amsterdam Stock Exchange)* in its publications and on its website.[79] When a firm's data were available in a different format, the firm's annual reports were scrutinized and if necessary recalculated to fit the database format.

In the previous section, we argued that we would take added value as the correlator for output. Given the format of the profit & loss account, added value can be calculated in different ways, additive or subtractive. In the additive approach, we calculate added value as the sum of employment costs, depreciation and net profit. In the subtractive approach we calculate added value as turnover minus all external cost.

[79] As from 2000, the data in these formats were only available from the *Amsterdam Stock Exchange* website, *www.aex.nl*, and as of 2004 the data in these formats are not longer available from this website.

Due to, e.g., extraordinary results, there may be differences between the two calculations. For this study, we chose to use the additive calculation of added value, because, for this is calculation, it is least necessary to correct firm data for extraordinary results. The calculation of added value was corrected for the rise in general producers' prices, with *1990 = 100*. This price data was obtained from the *Centraal Bureau voor de Statistiek (CBS)*.[80]

As stated earlier, productivity is taken as added value, corrected for the rise in producer's prices, divided by hours worked. To compute hours worked we multiplied the number of employees with the annual labor duration in hours. Labor duration data for the years 1983-2002 were also obtained from the *Centraal Bureau voor de Statistiek (CBS)*.

We calculated two control variables: the capital-output ratio and the capital-labor ratio and their annual growth. Output is again taken as the additive calculation of added value corrected for producers' price changes. Labor is again taken as the number of hours worked. Capital is taken as the annual balance sheet total. It was corrected for industry-specific changes in capital prices, with *1995=100*. These price data were also obtained from the *Centraal Bureau voor de Statistiek (CBS)*.

9.5 Validation of the measures

The goal of validation of the measures was to make sure that we actually measure what we meant to measure. A number of checks and corrections have to be made to the raw data to achieve validity of the measures, i.e., the consistency of the data definitions, the correction for inflation, the correction for outliers and the correction for negative growth rates. Additionally, there are some issues regarding the validity of the estimation of the firm-level Verdoorn relationship and the productivity-performance relationship, i.e., the small number of data points, the danger of spurious regression, the correction for a growing capital-labor ratio and a growing capital-output ratio and the test for autocorrelation. All the issues will be discussed below.

9.5.1 Consistency of the data definitions

A first possible problem with firm-level data from annual reports is that firms sometimes adjust the way they calculate and/or present their annual figures. When

[80] This is the Dutch central bureau of statistics, i.e., the census agency.

these adjustments are major there is the danger that this will distort the computed growth rates of output, productivity or net profit.

The consistency in the data definitions was checked for all the firms in the sample. When any inconsistencies were found between two subsequent annual reports, the data were adjusted according to the information given by the firm in its annual report to provide the same data definitions for all years in the entire period of analysis. In cases where this was not possible, we deleted the calculation of the growth between the two years that the data definition change took place, from the firm's observations.

A second issue is that there will be differences in how financial figures are calculated and presented between firms. This means that when working with the nominal figures, firm data may be incomparable. In our case, this was not a problem, because we calculated the percentage changes between subsequent years. This made the data comparable across firms.

9.5.2 Correction for inflation

An important issue when we measure in monetary units is how to correct for inflation. A correction for inflation is necessary for the measures of output growth, productivity growth and net profit growth. Failing to correct for inflation may lead to strong correlations between, e.g., output growth and productivity growth, because both are influenced by the general level of price increases.

An important question is: Which deflator should be used for this correction? To answer this question, we have to know the relevant price developments for each firm. Inflation is likely to be different for different countries, for different industries and for different firms. Contrary to firm-level data, industry-level and country-level data are readily available. The problem with these however is their application to individual firms, when we consider that many firms in our sample perform activities in multiple industry sectors and many of the firms in our sample, while having their headquarters in the Netherlands, have large parts of their operations abroad.

Even if we know the appropriate inflation figure, how can we be sure it is right? Any firm-level differentiated inflation correction is a hazardous task, e.g.: Are rising output prices in a specific industry not simply a reflection of increasing product quality? When we make the correction at the industry level: Do we not destroy the inherent variance that exists between industries? In view of these problems, the only deflator that can be used, and with some caution, is the general producers' price-index number. This number deflates the general cost level and leaves the variance between specific industries and specific firms intact. Therefore, the measurements of output, of productivity and of net profit were deflated by the *general producers' price index* published by the *Centraal Bureau voor de Statistiek (CBS)*.[81]

A separate issue was the inflation correction for the two control variables: the capital-output ratio and the capital-labor ratio. The measure of output is again corrected for the general producers' price changes. The measure of labor is non-monetary and therefore does not need to be inflation-corrected. There are different possible corrections for the development of capital prices, however. We can either correct for the *general* changes in capital prices or for the *industry-specific* changes in capital prices. Here, the problem with an industry-differentiated correction is not as severe as with output, because these corrections do not affect the variance in our main data. Moreover, we preferred to make the capital-labor and capital-output controls as precise as possible. Therefore we decided to correct the capital measure for the *industry-specific capital price index*, with *1995=100*. These price index data were also obtained from the *Centraal Bureau voor de Statistiek (CBS)*.

9.5.3 Correction for outliers

There are years for which the financial data stand out, positively or negatively, for some of the firms in our sample. This may have different reasons, e.g., the firm may have had an especially bad year, the firm may have 'financially engineered' its figures, there may have been major portfolio changes like mergers and acquisitions or there may have been any other *out of the ordinary events* within the firm. For all the firms in the sample, we checked the data on such possible outliers. When possible, the data were adjusted using the information provided by the firm in its annual report. When such a correction was not possible, we deleted the data from such a year from the range of observations. This corresponds to the deletion of two growth observations from the firm data, i.e., the observation *previous year – extraordinary year* and the observation *extraordinary year – next year*.

[81] This is the Dutch central bureau of statistics, i.e., the census agency.

9.5.4 Correction for negative growth rates

Another problem in calculating the average annual growth rates for output, for productivity and for net proft is negative growth rates. In very exceptional cases, output, and therefore also productivity, for a certain year may have a negative value. For net profit, negative values are a more common phenomenon. As a consequence of negative values, a problem appears when calculating the growth rate with respect to the year with the negative value, i.e., the calculation *year with negative value – next year*. The calculation will still give a number, but the growth rate in relation to the negative value is of course undefined. Therefore, these growth observations were deleted from the firm's range of observations.

The above corrections resulted in a data file that could be used with confidence to measure the potential for scale and learning effects, the realization of scale and learning effects and firm performance. In total, as a consequence of the above corrections, *22* observations were deleted from the sample, some of these for more than one of the above reasons.

9.5.5 Small number of data points

One of the characteristics of our data set is that the number of data points per firm is relatively limited. For the best firms in our sample we have *20* annual observations (1983 to 2002), resulting in a maximum of *19* data points for the firm-level Verdoorn law and productivity-performance estimations. For other firms, the number of observations is even less. We limited our sample to firms for which at least seven data points were available for estimation. Rowthorn (1975) points out the danger of drawing conclusions on the basis of such a limited number of data points. He demonstrates that in the study of Cripps & Tarling (1973) the exclusion of *one* observation from the analysis makes a slightly positive Verdoorn relationship turn into a strongly negative relationship. The same objection applies to our estimation of the productivity-performance relationship.

We might ask whether our data sets per individual firm, limited as it they are in the number of data points, cause the same risks. We think this is in general not the case, for two reasons. First, because every firm's data set was scrutinized for outliers. Second, because the number of data points may be significantly increased by the pooling of individual firm data and then analyzing at a higher level, e.g., the industry level, as has been done in section 9.6.5 and 9.6.6. These analyses show values of the parameters of the relationship that are comparable to the individual firm estimates.

Therefore, in general it is unlikely that the Verdoorn relationship is significantly under- or overstated. At the individual firm level, however, sometimes a single observation may tilt the entire regression. These specific observations have been closely scrutinized and, when appropriate, have been deleted from the analysis. In *Appendix IV* we provide a detailed account of how this was done for each firm.

9.5.6 The danger of spurious regression

It has been argued that the regression of the Verdoorn law is a somewhat spurious exercise (Wolfe, 1968). This is true insofar as the dependent and independent variables both have *growth of output* in them. Therefore, if the denominator of *productivity*, i.e., the number of hours worked, were, over time, completely independent from the level of output and therefore a completely random factor in the equation, we would be essentially regressing growth of output on growth of output. Hence the regression coefficient would be equal to or close to unity. This is a point that requires further investigation.[82]

Let us translate the problem to the specification of the firm-level Verdoorn law as presented in section 9.2.6.

The firm-level Verdoorn relationship, excluding the statistical error term, is:

$$\Delta P_{(t,t-1)} = a + b \cdot \Delta Q_{(t,t-1)}$$

Where:

$$\Delta Q_{(t,t-1)} = \left(\frac{Q_t - Q_{t-1}}{Q_{t-1}} \right) = \frac{Q_t}{Q_{t-1}} - 1$$

And:

$$\Delta P_{(t,t-1)} = \left(\frac{P_t - P_{t-1}}{P_{t-1}} \right) = \frac{(Q_t / I_t)}{(Q_{t-1} / I_{t-1})} - 1 = (I_{t-1} / I_t) * (Q_t / Q_{t-1}) - 1$$

[82] We would like to thank *Dr. C.W.M. Naastepad* of the *Delft University of Technology* for bringing the seriousness of this point to our attention.

Here, I represents input, in our case, hours worked.

Substitution of the above equation in the firm-level Verdoorn relationship gives:

$$\left(I_{t-1}/I_t\right)*\left(Q_t/Q_{t-1}\right)-1=a+b*\left(\left(Q_t/Q_{t-1}\right)-1\right)$$

Replacing (I_{t-1}/I_t) with ψ we get:

$$\psi*\left(Q_t/Q_{t-1}\right)-1=a+b*\left(\left(Q_t/Q_{t-1}\right)-1\right)$$

This can be rewritten as:

$$\psi*\left(Q_t/Q_{t-1}\right)-1=b*\left(Q_t/Q_{t-1}\right)-\left(b-a\right)$$

Wolfe's (1968) argument is that the Verdoorn relationship is an identity when the growth of labor input is very low, i.e., when ψ is almost equal to unity. On the basis of the above equation, the further argument is that the left side and the right side of this equation are almost equal, that therefore the estimation of parameter b will be almost equal to ψ and, consequentially, b will be close to unity. Assuming this is true, it follows that:

$$b*\left(Q_t/Q_{t-1}\right)-1=b*\left(Q_t/Q_{t-1}\right)-\left(b-a\right)$$

Or:

$$b=1+a$$

There are three arguments why this is not the case. The first is that the equality of ψ and b does not follow at all from the above equation. Or, *almost equal* is not the same as *equal*. The argument *only* applies when we assume beforehand that $b=\psi=1$, but this exactly what we are trying to prove. In other words, when we assume that $b=\psi$, the consequence is that $b=\psi$, this is circular reasoning and therefore invalid.

The second argument is that it is unlikely that b is equal to unity. Starting from a default *constant returns to scale* model, we would normally expect a duplication of output to coincide with a duplication of all inputs. Therefore, based on such a constant returns to scale model, we would expect the Verdoorn coefficient *(b)* to revolve around *0* rather then around *1*.

Regarding the value of ψ, it is unlikely that a firm would be able to grow significantly in output over time without at a certain point extending its labor input, or, when $\Delta Q_{t,t-1}$ is positive, ψ will likely have a value smaller than unity. If this is not the case, the firm would enjoy infinitely increasing returns to scale. It is therefore unlikely that *at the firm level* the value of ψ is equal to unity. This argument was phrased for the country and industry level by Kaldor (1966, p.299) as: "Indeed all historical evidence suggests that a fast rate of industrial growth has invariably be associated with a fast rate of growth of employment in both the secondary and the tertiary sectors of the economy."

The third argument is that the empirical values of *b* and *a* do not correspond to the unity assumption. The values found for *b* and *a* in our empirical analyses are as follows.

- The average value of *b* over all the firm-level analyses is *0.542*, with a maximum of *2.451*, a minimum of *–0.462* and a standard deviation of *0.416*. The average value of *a* over all the firm-level analyses is equal to *–0.006*, with a maximum of *0.125*, a minimum of *–0.185* and a standard deviation of *0.043*. A *t-test* on the average value of *b* with test value *1* shows that *b* is significantly different from *1* $(t=-11.889, p<0.001)$. A *t-test* on the average value of *a* as *b-1*, and therefore with test value *–0.458,* shows that *a* is significantly different from *b-1* $(t=114.098, p<0.001)$.
- The average value of *b* over all the industry-level analyses is *0.399*, with a maximum of *0.672*, a minimum of *0.100* and a standard deviation of *0.189*. The average value of *a* over all the industry-level analyses is *–0.003*, with a maximum of *0.024*, a minimum of *–0.041* and a standard deviation of *0.016*. A *t-test* on the average value of *b* with test value *1* shows that *b* is significantly different from *1* $(t=-11.460, p<0.001)$. A *t-test* on the average value of *a* as *b-1*, and therefore with test value *–0.601,* shows that *a* is significantly different from *b-1* $(t=134.197, p<0.001)$.
- The value of *b* from the analysis of the total population is *0.476*, with a *95%* confidence interval between *0.451* and *0.502*. The value of *a* from the analysis of the total population is *–0.014*, with a *95%* confidence interval between *–0.020* and *–0.008*, which is nowhere near the value of *b-1*.

In our total dataset, the average value of ψ is *0.950*, with a standard deviation of *0.152*. We can therefore confirm the expectation that the average value of ψ is indeed close to unity. A *t-test* with test value *1* shows, however, that ψ is still significantly different from *1* $(t=-14.491, p<0.001)$. Moreover, the value of the standard deviation of ψ combined with a check on individual firms in our data-set indicates that there is quite some variance between firms and that therefore *at the firm level* ψ is certainly not equal to unity as a general rule.

Regarding the productivity-performance relationship, the dependent and independent variables, net profit and productivity, are not by definition related. Therefore, there is no risk of spurious regression between the variables in the productivity-performance relationship.

9.5.7 Check for changes in the capital-labor and capital-output ratio

In section 9.2.3 we addressed the issue of correcting the Verdoorn coefficient and the constant term for a change in the capital-labor ratio and correcting the coefficient for a change in the capital-output ratio.

For every individual firm model, for every industry model and for the model of the total population both the constancy of the capital-labor ratio and the capital-output ratio were checked. This was done through *t-tests* with test value *0* on the growth observations of the capital-labor ratio and the capital-output ratio. Nonsignificance of this *t-test* indicates that the average growth rate does not differ significantly from *0*. Significance of the *t-test* indicates that the average growth rate is significantly different from *0*. In these cases, the data were checked for stability, i.e., it was judged whether the *change in the growth rate*, hence the significance of the *t-test*, was due to outliers. When this was the case, these observations were removed from the analysis and the *t-test* was re-run.

Regarding the *capital-labor ratio*, for the firm-specific Verdoorn models we found *84* firms for which the *t-test* was nonsignificant, i.e., the change of the capital-labor ratio was not significantly different from *0*, and *33* firms for which the *t-test* was significant, i.e., the change in the capital-labor ratio differed significantly from *0* (see table 9.2 below).[83] For the industry-specific Verdoorn models, we found *4* industries for which the *t-test* was nonsignificant, i.e., the change in the capital-labor ratio was

[83] These numbers add up to 117 instead of 118, because one firm was excluded from the firm-specific Verdoorn analysis.

not significantly different from *0*, and *9* industries for which the *t-test* was significant, i.e., the change in the capital-labor ratio did differ significantly from *0* (see table 9.3 below). For the Verdoorn model on the total population, we also found that the *t-test* was significant, i.e., the change in the capital-labor ratio did differ significantly from *0* (see table 9.4 below). For these models, therefore, a correction has to be made to the Verdoorn coefficient and to the constant term.

Regarding the *capital-output ratio*, for the firm-specific Verdoorn models we found *113* firms for which the *t-test* was nonsignificant, i.e., the change in the capital-output ratio was not significantly different from *0*, and *4* firms for which the *t-test* was significant, i.e., the change in the capital-output ratio did differ significantly from *0* (see table 9.2 below).[84] For the industry-specific Verdoorn models, we found *12* industries for which the *t-test* was nonsignificant, i.e., the change in the capital-output ratio was not significantly different from *0*, and *1* industry for which the *t-test* was significant, i.e., the change in the capital-output ratio did differ significantly from *0* (see table 9.3 below). For the Verdoorn model on the total population, we also found that the *t-test* was significant, i.e., the change in the capital-output ratio did differ significantly from *0* (see table 9.4 below). For these models, therefore, a correction has to be made to the Verdoorn coefficient.

[84] These numbers add up to 117 instead of 118, because one firm was excluded from the firm-specific Verdoorn analysis.

Checks for changes in capital-labor and capital-output ratios							T-test for change in capital-labor ratio (test value = 0)		T-test for change in capital-output ratio (test value = 0)	
Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	Number of obser-vations in model	Deleted number of obser-vations	Mean of change in capital-labor ratio	T-value	Mean of change in capital-output ratio	T-value
Aalberts Industries	1983	2002	19	19	18	1	0.018	0.930	0.011	0.476
ABN-Amro	1983	2002	19	19	18	1	0.040 (**)	2.792	-0.018	-0.954
Achmea	1993	2002	9	9	8	1	0.018	0.507	-0.034	-1.360
Achmea	1993	2002	9	9	8	1	0.018	0.507	-0.034	-1.360
AEGON	1983	2002	19	19	18	1	0.108 (*)	2.152	0.036	0.849
Ahold	1983	2002	19	19	18	1	0.034	0.864	0.035	0.942
Ahrend	1983	2000	17	17	14	3	0.038	1.377	0.016	0.559
AKZO-Nobel	1983	2002	19	19	16	3	0.039 (**)	2.743	0.017	1.012
Arcadis	1983	2002	19	19	18	1	0.018	0.858	-0.007	-0.376
ASM International	1994	2002	8	8	7	1	0.086	1.299	-0.032	-0.215
ASM Lithography	1993	2002	9	9	7	2	0.150 (*)	2.227	0.105	0.864
ASR Verzekeringsgroep	1984	1999	15	15	14	1	0.087 (***)	8.098	0.004	0.193
Atag	1986	1999	13	13	12	1	-0.014	-0.282	0.003	0.077
Athlon	1983	2002	19	19	17	2	0.065 (*)	2.016	0.083 (**)	2.940
Ballast-Nedam	1986	2002	16	16	15	1	-0.009	-0.205	0.007	0.172
BAM	1983	2002	19	19	17	2	0.070	1.361	0.043	0.821
Batenburg	1985	2002	17	17	15	2	0.024	1.536	-0.003	-0.229
Beers	1983	1999	16	16	15	1	0.074 (**)	3.478	-0.005	-0.214
Begemann	1983	1994	11	11	8	3	0.136	1.546	0.116	0.936
BE Semiconductor Industries	1994	2002	8	8	8	0	0.170	1.662	0.301	1.421
Blydenstein-Willink	1983	2002	19	19	17	2	-0.020	-0.842	-0.016	-0.432

Checks for changes in capital-labor and capital-output ratios							T-test for change in capital-labor ratio (test value = 0)		T-test for change in capital-output ratio (test value = 0)	
Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	Number of obser-vations in model	Deleted number of obser-vations	Mean of change in capital-labor ratio	T-value	Mean of change in capital-output ratio	T-value
Boskalis-Westminster	1983	2002	19	19	18	1	0.018	0.563	0.002	0.051
Brocacef	1983	1999	16	16	15	1	0.047	1.643	0.027	0.619
Buhrmann	1983	2002	19	19	16	3	0.015	0.560	-0.001	-0.038
CAP Gemini	1986	1999	13	13	13	0	-0.019	-0.764	-0.022	-1.054
Cindu	1983	1997	14	14	12	2	-0.011	-0.490	-0.034	-1.486
CMG	1993	2002	9	9	6	3	0.075 (*)	2.535	0.043	0.819
Content	1985	1997	12	12	10	2	0.007	0.141	0.006	0.139
Corus	1983	2002	19	19	17	2	0.034 (*)	1.756	-0.002	-0.062
Crédit Lyonnais Nederland	1983	1997	14	14	13	1	0.096	1.590	0.047	0.733
CSM	1983	2002	19	19	16	3	0.016	0.849	-0.014	-0.756
Delft Instruments	1984	2002	18	18	16	2	0.031	1.295	0.000	0.015
Draka	1988	2002	14	14	13	1	0.024	0.355	-0.010	-0.160
DSM	1983	2002	19	19	17	2	0.069 (*)	1.980	0.018	0.496
EVC	1993	2002	9	9	6	3	0.057	0.927	0.048	0.334
Exendis	1985	2002	17	17	14	3	0.020	0.415	0.027	0.571
Fortis	1983	2002	19	19	14	5	0.033	1.588	0.021	0.967
Frans Maas	1986	2002	16	16	16	0	0.003	0.155	-0.009	-0.642
Free Record Shop	1989	2001	12	12	11	1	-0.037	-1.301	-0.024	-0.810
Fugro	1989	2002	13	13	13	0	0.061	1.235	0.021	0.567
Gamma Holding	1983	2002	19	19	18	1	0.021	0.802	0.008	0.393
Gelderse Papier	1985	1999	14	14	14	0	0.002	0.078	-0.006	-0.107
Getronics	1984	2002	18	18	15	3	-0.048 (*)	-0.196	-0.075 (*)	-2.552

Checks for changes in capital-labor and capital-output ratios							T-test for change in capital-labor ratio (test value = 0)		T-test for change in capital-output ratio (test value = 0)	
Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	Number of obser-vations in model	Deleted number of obser-vations	Mean of change in capital-labor ratio	T-value	Mean of change in capital-output ratio	T-value
Geveke	1984	2001	17	17	15	2	0.071	1.648	0.037	0.878
Van der Giessen	1983	1996	13	13	9	4	0.041	0.629	0.008	0.125
Gist-Brocades	1983	1997	14	14	13	1	0.016	0.540	0.010	0.357
Grolsch	1983	2002	19	19	17	2	0.038 (*)	2.406	0.009	0.468
Grontmij	1983	2002	19	19	18	1	0.055 (*)	2.528	0.032	1.574
GTI	1983	2000	17	17	17	0	0.029	1.323	-0.002	-0.086
Gucci	1993	2002	9	9	6	3	0.147	1.573	0.011	0.273
Hagemeyer	1983	2002	19	19	19	0	0.039	0.540	0.013	0.192
HBG	1983	2000	17	17	15	2	0.047 (*)	2.240	0.007	0.360
Heijmans	1990	2002	12	12	12	0	0.086 (*)	2.430	0.047	1.308
Heineken	1983	2002	19	19	19	0	0.029 (*)	2.194	-0.006	-0.519
Hunter Douglas	1983	2002	19	19	15	4	0.020	0.937	0.005	0.339
IHC Caland	1983	2002	19	19	12	7	0.111 (*)	2.110	0.088	1.582
Imtech	1983	2002	19	19	17	2	0.035 (*)	2.195	-0.009	-0.523
ING Group	1988	2002	14	14	12	2	0.067 (**)	3.660	-0.025	-1.150
KAS Bank	1983	2002	19	19	18	1	0.080 (*)	1.815	0.019	0.659
KBB	1983	1997	14	14	14	0	0.010	0.610	-0.023	-1.466
Kempen & Co.	1986	2000	14	14	12	2	0.036	0.685	-0.022	-0.308
KLM	1983	2002	19	19	17	2	0.006	0.257	0.046	1.374
KPN	1983	2002	19	19	13	6	0.039 (*)	2.208	-0.005	-0.194
Landré	1983	1998	15	15	11	4	-0.018	-0.509	-0.018	.-488
Laurus	1986	2002	16	16	11	5	0.031	1.660	0.002	0.084

Checks for changes in capital-labor and capital-output ratios							T-test for change in capital-labor ratio (test value = 0)		T-test for change in capital-output ratio (test value = 0)	
Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	Number of obser-vations in model	Deleted number of obser-vations	Mean of change in capital-labor ratio	T-value	Mean of change in capital-output ratio	T-value
LCI	1988	2001	13	13	10	3	0.023	0.439	0.046	0.881
Van Leer	1983	1998	15	15	14	1	0.026	1.444	-0.005	-0.294
Macintosh	1983	2002	19	19	16	3	0.015	0.679	-0.026	-1.300
Van Melle	1983	1999	16	16	15	1	0.031	1.638	0.010	0.500
Bank Mendes Gans	1983	1998	15	13	12	1	-0.051	-1.689	-0.069 (*)	-2.082
Van der Moolen	1986	2002	16	16	16	0	0.067	0.477	0.212	0.853
NBM	1983	2000	17	17	16	1	0.047	1.197	0.022	0.567
NEDAP	1983	2002	19	19	19	0	0.045 (*)	2.227	0.070	0.540
Nedlloyd	1983	2001	18	16	13	3	0.009	0.518	-0.005	-0.228
Neways	1985	2002	17	17	16	1	0.027	0.576	-0.003	-0.079
NIB Capital	1983	2002	19	19	16	3	0.047 (*)	1.811	-0.015	-0.436
NKF	1986	1997	11	11	10	1	0.029	0.391	0.010	0.153
Norit	1983	2000	17	17	16	1	0.002	0.124	-0.017	-0.817
NS	1995	2002	7	7	7	0	0.072	0.849	0.018	0.634
Numico	1983	2002	19	19	14	5	0.022	1.102	-0.026	-1.518
Nutreco	1995	2002	7	7	7	0	0.034	0.591	0.029	0.379
Océ	1983	2002	19	19	16	3	0.013	0.983	-0.005	-0.268
Van Ommeren	1983	1998	15	15	11	4	0.006	0.220	-0.012	-0.462
OPG	1984	2002	18	18	14	4	0.014	0.498	0.006	0.174
Ordina	1985	2002	17	17	16	1	-0.005	-0.107	-0.018	-0.389
Otra	1983	1997	14	14	11	3	0.030 (**)	2.831	-0.015	-0.718
P&C Group	1983	1997	14	14	13	1	0.055 (**)	2.910	0.024	0.997

Checks for changes in capital-labor and capital-output ratios							T-test for change in capital-labor ratio (test value = 0)		T-test for change in capital-output ratio (test value = 0)	
Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	Number of obser-vations in model	Deleted number of obser-vations	Mean of change in capital-labor ratio	T-value	Mean of change in capital-output ratio	T-value
Pakhoed	1983	1998	15	15	12	3	0.062	1.349	0.027	0.593
Philips	1983	2002	19	19	18	1	0.048 (*)	2.270	0.003	0.074
Polygram	1988	1997	9	9	9	0	0.078 (*)	1.965	0.023	0.752
Polynorm	1983	2000	17	17	16	1	0.037 (*)	2.118	0.012	0.681
Randstad	1986	2002	16	16	14	2	0.005	0.197	-0.001	-0.021
Reed Elsevier	1983	2002	19	19	18	1	0.077 (**)	2.718	0.023	0.623
Rood Testhouse	1986	2002	16	16	16	0	-0.045	-0.758	0.020	0.270
Royal Begemann Group	1995	2002	7	3	Ex-cluded from analy-sis					
Samas	1983	2002	19	19	13	6	0.026	0.718	-0.017	-0.833
Schuitema	1983	2002	19	19	16	3	0.059 (*)	2.116	0.018	0.733
Royal Dutch/Shell Group	1983	2002	19	19	16	3	0.036	1.220	-0.004	-0.250
Simac	1985	2002	17	17	14	3	-0.001	-0.013	-0.011	-0.170
Smit Internationale	1983	2002	19	19	16	3	0.014	0.396	0.037	1.072
SNS Bank	1990	2002	12	12	11	1	0.119 (**)	3.315	0.058	1.785
Sphinx	1984	1998	14	14	14	0	-0.003	-0.089	-0.013	-0.231
Staal Bankiers	1984	1997	13	13	9	4	0.025	0.706	-0.037	-0.547
Stork	1983	2002	19	19	19	0	0.025	1.625	0.020	1.113
Telegraaf	1983	2002	19	19	16	3	0.043 (**)	2.708	0.010	0.554
Ten Cate	1983	2002	19	19	19	0	0.043 (*)	1.805	0.006	0.168
Tulip	1983	2002	19	16	13	3	0.046	0.697	0.072	1.002
Twentsche Kabel Holding	1983	2002	19	19	16	3	0.028	1.340	0.010	0.450

Checks for changes in capital-labor and capital-output ratios							T-test for change in capital-labor ratio (test value = 0)		T-test for change in capital-output ratio (test value = 0)	
Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	Number of obser-vations in model	Deleted number of obser-vations	Mean of change in capital-labor ratio	T-value	Mean of change in capital-output ratio	T-value
Unilever	1983	2002	19	19	16	3	0.026	0.774	0.009	0.227
Vendex KBB	1990	2002	12	12	9	3	-0.024	-0.811	-0.055 (*)	-2.731
Vilenzo	1989	2002	13	13	11	2	0.033	0.642	0.048	1.507
VNU	1983	2002	19	19	12	7	0.025	0.825	0.003	0.094
VOPAK	1983	2002	19	19	15	4	0.030	1.005	0.010	0.315
Vredestein	1985	2002	17	17	16	1	0.015	0.771	-0.005	-0.110
Volker-Wessels-Stevin	1983	2002	19	19	17	2	0.009	0.279	-0.014	-0.459
Wegener-Arcade	1983	2002	19	18	17	1	0.030	0.849	-0.006	-0.167
Wessanen	1983	2002	19	19	17	2	-0.029	-1.292	-0.044	-1.519
Wolff	1983	1995	12	12	10	2	-0.001	-0.028	-0.006	-0.156
Wolters-Kluwer	1986	2002	16	16	15	1	0.061	1.280	-0.010	-0.223
Averages			**16**	**16**	**14**	**2**	**0.035**		**0.012**	

Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)

Significance levels are 1-tailed, because the changes in capital-labor and capital-output ratios are expected to be positive.

Significance of the t-test means that the null-hypotheses, i.e., that the mean is equal to the test-value, is rejected. Therefore, significance means that the change in capital-labor or capital-output ratio is different from 0.

Table 9.2: Checks for constancy of the capital-labor and the capital-output ratio for the firm-specific Verdoorn models

Checks for changes in capital-labor and capital-output ratios					T-test for change in capital-labor ratio (test value = 0)		T-test for change in capital-output ratio (test value = 0)	
Industry name	Total number of observations	Valid number of observations	Number of observations in model	Deleted number of observations	Mean of change in capital-labor ratio	T-value	Mean of change in capital-output ratio	T-value
Basic industry	232	232	226	6	0.021 (**)	2.859	0.001	0.066
Food industry	140	140	131	9	0.018 (*)	1.933	-0.004	-0.427
Media	105	104	95	9	0.062 (***)	3.745	0.023	1.439
Engineering industry	241	241	226	15	0.029 (***)	3.241	0.013	1.492
Construction industry	158	158	145	13	0.047 (***)	3.807	0.026 (*)	2.066
Wholesale	215	215	207	8	0.026 (**)	2.411	-0.001	-0.113
Transport	134	134	126	8	0.018	1.514	0.004	0.350
Telecommunications	36	25	17	8	0.076	1.347	0.003	0.084
Financial services	224	217	209	8	0.055 (***)	3.456	-0.003	-0.217
IT services	96	96	83	13	0.019	0.866	-0.006	-0.304
Other business services	120	120	117	3	0.011	0.727	0.016	1.092
Retail	147	147	128	19	0.020 (*)	2.086	0.008	0.834
Electronics industry	99	96	85	11	0.068 (***)	3.998	0.034	1.545
Averages	**150**	**148**	**138**	**10**	**0.036**		**0.009**	

Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)

Significance levels are 1-tailed, because the changes in capital-labor and capital-output ratios are expected to be positive.

Significance of the t-test means that the null-hypotheses, i.e., that the mean is equal to the test-value, is rejected. Therefore, significance means that the change in capital-labor or capital-output ratio is different from 0.

Table 9.3: Checks for constancy of the capital-labor and the capital-output ratio for the industry-specific Verdoorn models

Checks for changes in capital-labor and capital-output ratios					T-test for change in capital-labor ratio (test value = 0)		T-test for change in capital-output ratio (test value = 0)	
	Total number of obser-vations	Valid number of obser-vations	Number of obser-vations in model	Deleted number of observations	Mean of change in capital-labor ratio	T-value	Mean of change in capital-output ratio	T-value
All firms	1947	1925	1860	65	0.036 (***)	8.883	0.015 (*)	3.376
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)								
Significance levels are 1-tailed, because the changes in capital-labor and capital-output ratios are expected to be positive.								
Significance of the t-test means that the null-hypotheses, i.e., that the mean is equal to the test-value, is rejected. Therefore, significance means that the change in capital-labor or capital-output ratio is different from 0.								

Table 9.4: Checks for constancy of the capital-labor and the capital-output ratio for the Verdoorn model on the total population

The necessary corrections can be calculated from the differences between the Verdoorn models in sections 9.2.2 and 9.2.3. The correction *(ϕ)* on the Verdoorn coefficient from the change in capital-labor ratio can be calculated as follows:

$$\phi = \hat{b} - b$$

Where:

$$\hat{b} = 1 - 1/(\alpha\delta + \beta)$$

And:

$$b = (\alpha + \beta - 1)/\beta$$

This gives:

$$\phi = 1 - 1/(\alpha\delta + \beta) - (\alpha + \beta - 1)/\beta$$

The correction *(ζ)* on the constant term from the change in capital-labor ratio can be calculated as follows:

$$\zeta = \hat{a} - a$$

Where:

$$\hat{a} = \lambda / (\alpha\delta + \beta)$$

And:

$$a = \lambda / \beta$$

This gives:

$$\zeta = \lambda / (\alpha\delta + \beta) - \lambda / \beta$$

Or, after some rearranging:

$$\zeta = -\lambda\alpha\delta / ((\alpha\delta + \beta)\beta)$$

The correction *(θ)* on the Verdoorn coefficient from the change in capital-output ratio can be calculated as follows:

$$\theta = \hat{b} - b$$

Where:

$$\hat{b} = (\gamma\alpha + \beta - 1) / \beta$$

And:

$$b = (\alpha + \beta - 1) / \beta$$

This gives:

$$\theta = (\gamma\alpha + \beta - 1) / \beta - (\alpha + \beta - 1) / \beta$$

Or, after some rearranging:

$$\theta = \frac{\alpha}{\beta}(\gamma - 1)$$

To calculate ϕ, ζ and θ, the values of δ and γ had to be calculated from the average growth rates of capital and labor and capital and output, respectively. Further, the values of λ, α and β had to be additionally estimated from the data. We did this by an *Ordinary Least Squares estimation* of the production function that formed the basis of our interpretation of the Verdoorn law:

$$q = \lambda + \alpha k + \beta l$$

These estimations are reported on in *Appendix V*. Note that, because of the data limits, many of the firm-specific estimations of this production function are nonsignificant and that therefore the parameters λ, α and β are often unusable to make the desired corrections. In the same way, corrections on nonsignificant coefficients and nonsignificant constant terms of the Verdoorn estimations are unusable. We therefore only made corrections when the estimations of both the production function parameters and the Verdoorn coefficient and constant term were significant. The values of these corrections are presented in the sections where results of the Verdoorn model estimations are discussed (see section 9.6).

9.5.8 Test for autocorrelation

Autocorrelation means that in the regression the residuals for period *t* are correlated with the residuals of period *t-1*. There can be different reasons for autocorrelation to appear: periodicity of the dependent variable not explained by the model, presence of a time lag between the independent and the dependent variable that has not been included in the model or nonlinearity in the data (Pindyck & Rubinfeld, 1976).

The presence of autocorrelation, both in the Verdoorn model and in the productivity-performance model was checked for by using the *Durbin-Watson test*. For every individual firm model, for every industry model and for the model of the total population it was checked whether, given the number of observations and the number of degrees of freedom of the model, the *Durbin-Watson test value* indicates that there is no autocorrelation, indicates that autocorrelation cannot be decided upon, indicates positive autocorrelation or indicates negative autocorrelation. The outcomes of these tests are reported in the tables summarizing the analyses (see section 9.6). Regarding the firm-specific Verdoorn models, we found *93* firms for which the test showed there was no autocorrelation, *18* firms for which the test on autocorrelation was inconclusive, *5* firms for which the test showed positive autocorrelation and *1* firm for which the test showed negative autocorrelation.[85] Regarding the industry-specific Verdoorn models, we found that for *12* out of *13* industries there was no autocorrelation, and for one industry the test on autocorrelation was inconclusive. For the Verdoorn model on the total population, we also found that the test on autocorrelation was inconclusive.

Regarding the firm-specific productivity-performance models, we found *94* firms for which the test showed there was no autocorrelation, *17* firms for which the test on autocorrelation was inconclusive, *2* firms for which the test showed positive autocorrelation and *3* firms for which the test showed negative autocorrelation.[86] Regarding the industry-specific productivity-performance models, we found that for *12* out of *13* industries there was no autocorrelation, and for one industry the test on autocorrelation was inconclusive. For the productivity-performance model on the total population, the test showed negative autocorrelation.

It is recommended (Pindyck & Rubinfeld, 1976) to try and understand why autocorrelation exists in a model and to subsequently correct the model, e.g. through adding a lagged variable, so that the model does no longer exhibit autocorrelation. We did not do this, for two reasons. First, understanding the presence of autocorrelation in firm-level data over the period of 1983-2002 requires in-depth research into that specific firm's recent business history. Such research falls outside the scope of this thesis. Second, in this thesis we want to compare the Verdoorn and productivity-performance models across firms and across industries. While it is likely that tailoring a model for each individual firm or individual industry will provide a better fit and fewer problems with autocorrelation, we will thereby loose the ability to compare.

In view of these arguments and in view of the statement by Pindyck & Rubinfeld (1976) that autocorrelation will not cause bias in the estimators, we just signaled autocorrelation but we did not correct for it. Still, we are aware that, for a number of the model that we tested, there may be a problem. Further research may shed light on

[85] These numbers add up to 117 instead of 118, because one firm was excluded from the firm-specific Verdoorn analysis.
[86] These numbers add up to 116 instead of 118, because two firms were excluded from the firm-specific productivity-performance analysis.

the causes of autocorrelation in the Verdoorn law and in the productivity-performance models.

9.6 Results

9.6.1 Research model and hypotheses

In this section we present the results of the Verdoorn law analyses and of the analyses of the productivity-performance relationship. The research model for this third empirical study is sketched in figure 9.7. This research model reveals two hypothese. First, the firm's potential for scale and learning effects is hypothesized to have a positive impact on its realization of these effects (H_3). This relationship is measured with the firm-level Verdoorn model. Second, the realization of scale and learning effects is hypothesized to have a positive influence on firm performance (H_5). This relationship was measured with the productivity-performance model. We will subsequently test these hypotheses.

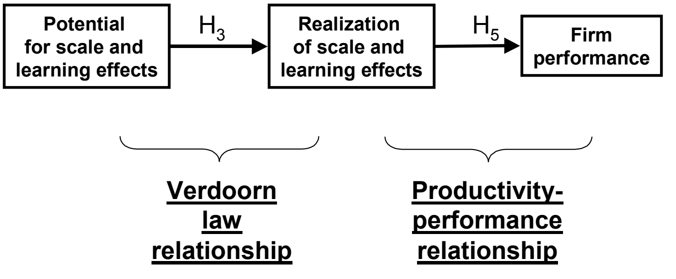

Figure 9-7: Research model and hypotheses of the third empirical study

9.6.2 Estimation method

The relationships between the annual growth in output and the annual growth in productivity and the relationship between the annual growth in productivity and the annual growth in net profit were estimated as *linear regression models using Ordinary Least Squares* as the estimation method. This was done for every firm, for every industry based on pooled firm-level data and for the total population based on pooled firm-level data.

Report third empirical study

The firm-level Verdoorn model and the productivity-performance model were estimated for the *118* firms defined in section 9.4 based on firm-level data consisting of the annual growth rates of output, of productivity and of net profit as discussed in sections 9.3 and 9.4. It was decided during these estimations to exclude one more firm, *Royal Begemann Group*, from the Verdoorn analysis because, on second sight, too many observations had to be deleted from the model as outliers, leaving the model with too few observations to obtain a reliable estimate. It was also decided during these estimations to exclude two more firms, *EVC* and *Royal Begemann Group*, from the productivity-performance analysis because, on second sight, too many observations had to be deleted from these models as outliers, leaving the models with too few observations to obtain a reliable estimate.

The Verdoorn model and the productivity-performance relationship were also estimated for the *13* industry sectors defined in section 9.4 based on pooled firm-level data. For these estimations, the sample consisted of the *131* firms listed on the *Amsterdam Stock Exchange* over the period 1983-2002.[87] No firms had to be deleted from the sample, because the number of data points for each individual firm was only a small proportion of the pooled number of data points for the industry.

Finally, the Verdoorn model and the productivity-performance relationship were estimated for the entire population of firms, based on pooled firm-level data. For these estimations, the sample also consisted of the *131* firms listed on the *Amsterdam Stock Exchange* over the period 1983-2002. As with the industry-specific models, no firms had to be deleted from the sample, because the number of data points for each individual firm was only a small proportion of the pooled number of data points.

The following steps were taken in carrying out the analyses.

1. Graphs were made, setting out the annual growth rate in output against the annual growth rate in productivity and the annual growth rate in productivity against the annual growth rate in net profit for every individual firm, for every industry and for the total population. These graphs were judged visually for outliers and influential points.
2. The regression model including *all* observations was initially estimated for every individual firm, for every industry and for total population. The statistical output indicated among others the observations located over two times the standard residual from this initial regression line and the *Cook distances* of every observation.

[87] See table 9.1 for the distribution of these *131* firms over the different industries.

3. Influential points, distorting the regression, were removed, based on judgment of the *Cook distances* computed from the initial regression model.
4. Statistical outliers, defined as observations that were located over *two* times the standard residual from the initial regression line, were removed from the firm-specific models. In the industry-specific models and in the model of the total population, outliers were defined as observations that were located over *three* times the standard residual from the initial regression line. These were also removed.
5. Every regression model was re-estimated using the remaining observations.

The following figures are reported for each regression model:

- the total number of observations available from the raw data
- the valid number of observations, i.e., the total number of observations minus the observations that were deleted from the raw data due to irregular data definitions (see section 9.5.1), outliers due to extraordinary events (see section 9.5.3) and negative growth rates (see section 9.5.4)
- the number of observations used to estimate the regression model
- the number of observations deleted from the model on statistical grounds
- the unstandardized estimate of the coefficient and its significance; for the Verdoorn model the coefficient is *b*, indicating the extent to which the firm is able to realize scale effects and autonomous learning effects; for the productivity-performance model the coefficient is *d*, indicating the extent to which the firm is able to realize net profit as a consequence of the realization of scale and learning effects
- the *t-value* of the coefficient, indicating its significance
- the estimate of the constant term and its significance; for the Verdoorn model the constant term is *a,* indicating the extent to which the firm is able to realize induced and exogenous learning effects; for the productivity-performance model the constant term is *c*, indicating the extent to which the firm is able to realize net profit from other sources than the realization of scale and learning effects
- the *t-value* of the constant term, indicating its significance
- the value of the *R-square*, indicating the fit of the model, i.e., the explanatory power of the regression model
- the *standard error of the estimate*, indicating the standard distance of the individual observations to the regression line, which serves as an estimator for the error variance of the regression

- the *F-statistic*, testing the equality of variances between the regression and the residual[88]
- the *Durbin-Watson test statistic* for identifying the presence of *autocorrelation* in the model
- the outcome of the *Durbin-Watson test*, indicating the absence, presence and nature of autocorrelation in the model

9.6.3 Estimation of the firm-level Verdoorn model for individual firms

The estimations of the firm-level Verdoorn models for the *118* individual firms in our sample are provided in table 9.5 below. Note that this table is spread over two pages, the left page covering the first eight columns and the right page the last eight columns.

[88] The *F-value* is defined as the mean sum of squares due to the regression divided by the mean sum of square due to the residual (Weinberg & Abramowitz). Mean sum of squares is defined by the total sum of squares divided by the number of degrees of freedom.

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (b)
Aalberts Industries	1983	2002	19	19	18	1	-0.046
ABN-Amro	1983	2002	19	19	18	1	0.765 (***)
Achmea	1993	2002	9	9	8	1	-0.462
AEGON	1983	2002	19	19	18	1	0.734 (***)
Ahold	1983	2002	19	19	18	1	0.277 (*)
Ahrend	1983	2000	17	17	14	3	0.246 (*)
AKZO-Nobel	1983	2002	19	19	16	3	0.913 (***)
Arcadis	1983	2002	19	19	18	1	0.084
ASM International	1994	2002	8	8	7	1	0.922 (***)
ASM Lithography	1993	2002	9	9	7	2	0.597 (***)
ASR Verzekeringsgroep	1984	1999	15	15	14	1	0.998 (***)
Atag	1986	1999	13	13	12	1	-0.040
Athlon	1983	2002	19	19	17	2	0.362 (**)
Ballast-Nedam	1986	2002	16	16	15	1	0.627 (***)
BAM	1983	2002	19	19	17	2	0.172
Batenburg	1985	2002	17	17	15	2	0.428 (**)
Beers	1983	1999	16	16	15	1	0.789 (**)
Begemann	1983	1994	11	11	8	3	0.549 (**)
BE Semiconductor Industries	1994	2002	8	8	8	0	0.669 (**)
Blydenstein-Willink	1983	2002	19	19	17	2	0.603 (**)

T-value of beta (b)	Constant term (a)	T-value of constant term (a)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
-0.596	0.021	0.902	0.022	0.052	0.356	1.209	Inconclusive
6.207	0.000	-0.035	0.707	0.042	38.530	2.675	Inconclusive
-0.501	0.125	0.874	0.040	0.093	0.251	2.232	No
6.318	-0.015	-0.604	0.714	0.084	39.916	2.000	No
2.491	-0.040	-1.888	0.279	0.060	6.204	1.468	No
2.974	0.010	1.315	0.424	0.021	8.843	2.373	No
5.430	0.016	1.353	0.678	0.033	29.482	2.354	No
0.490	0.020	1.179	0.015	0.050	0.241	1.725	No
8.009	-0.079	-0.785	0.928	0.223	64.141	1.890	No
12.348	-0.185 (**)	-5.943	0.968	0.055	152.470	2.538	No
14.070	-0.031 (*)	-2.959	0.943	0.022	197.959	1.789	No
-0.485	-0.013	-0.671	0.023	0.056	0.235	1.220	Inconclusive
3.098	-0.037	-1.533	0.390	0.093	9.596	1.441	No
4.665	-0.029	-1.554	0.626	0.070	21.762	1.523	No
1.899	0.008	0.526	0.194	0.049	3.605	2.464	No
3.239	-0.002	-0.125	0.447	0.032	10.492	2.495	No
3.730	-0.012	-0.425	0.517	0.052	13.914	1.765	No
4.478	-0.017	-0.317	0.770	0.141	20.054	2.079	No
3.954	-0.011	-0.113	0.723	0.262	15.631	1.340	No
3.329	0.009	0.336	0.425	0.113	11.081	2.207	No

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (b)
Boskalis-Westminster	1983	2002	19	19	18	1	0.563 (**)
Brocacef	1983	1999	16	16	15	1	0.743 (**)
Buhrmann	1983	2002	19	19	16	3	0.732 (***)
CAP Gemini	1986	1999	13	13	13	0	0.142
Cindu	1983	1997	14	14	12	2	0.235 (*)
CMG	1993	2002	9	9	6	3	0.393
Content	1985	1997	12	12	10	2	0.908 (***)
Corus	1983	2002	19	19	17	2	0.819 (***)
Crédit Lyonnais Nederland	1983	1997	14	14	13	1	0.812 (***)
CSM	1983	2002	19	19	16	3	0.138
Delft Instruments	1984	2002	18	18	16	2	1.077 (***)
Draka	1988	2002	14	14	13	1	0.045
DSM	1983	2002	19	19	17	2	0.834 (***)
EVC	1993	2002	9	9	6	3	1.094 (***)
Exendis	1985	2002	17	17	14	3	0.463 (*)
Fortis	1983	2002	19	19	14	5	0.429
Frans Maas	1986	2002	16	16	16	0	0.002
Free Record Shop	1989	2001	12	12	11	1	0.418
Fugro	1989	2002	13	13	13	0	0.340
Gamma Holding	1983	2002	19	19	18	1	0.311
Gelderse Papier	1985	1999	14	14	14	0	0.504 (**)

T-value of beta (b)	Constant term (a)	T-value of constant term (a)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
3.336	-0.014	-0.667	0.410	0.077	11.132	2.861	Negative auto-correlation
3.755	0.029	1.341	0.520	0.084	14.101	2.111	No
7.167	-0.019	-1.077	0.786	0.064	51.371	2.250	No
1.270	-0.014	-0.737	0.128	0.050	1.613	1.709	No
2.637	0.007	0.607	0.410	0.031	6.953	2.417	No
2.282	-0.081	-1.324	0.510	0.078	5.209	1.814	No
7.184	-0.085 (**)	-5.010	0.866	0.037	51.608	0.953	Inconclusive
4.977	0.035	1.619	0.623	0.089	24.772	1.274	Inconclusive
7.543	0.041 (**)	4.647	0.838	0.032	56.904	1.754	No
1.233	0.017	1.303	0.098	0.027	1.520	0.668	Positive auto-correlation
8.963	0.035	2.083	0.852	0.068	80.333	1.887	No
0.268	0.005	0.122	0.006	0.089	0.072	2.646	No
12.639	0.034 (**)	3.590	0.914	0.039	159.757	1.792	No
10.953	0.049	1.600	0.968	0.075	119.968	2.161	No
2.484	0.014	0.493	0.340	0.103	6.169	1.866	No
1.931	-0.017	-0.790	0.237	0.053	3.730	2.187	No
0.015	0.012	0.747	0.000	0.053	0.000	1.584	No
2.031	-0.070	-1.836	0.314	0.089	4.123	1.269	Inconclusive
1.939	-0.031	-0.711	0.255	0.092	3.760	2.130	No
1.454	0.001	0.026	0.117	0.082	2.113	2.229	No
4.361	-0.004	-0.104	0.613	0.145	19.018	1.794	No

Firm name	Available data range from/to:		Total number of observations	Valid number of observations	No. of observations in model	Deleted no. of observations	Unstandardized beta (b)
Getronics	1984	2002	18	18	15	3	0.105
Geveke	1984	2001	17	17	15	2	0.121
Van der Giessen	1983	1996	13	13	9	4	0.827 (***)
Gist-Brocades	1983	1997	14	14	13	1	0.806 (**)
Grolsch	1983	2002	19	19	17	2	0.897 (***)
Grontmij	1983	2002	19	19	18	1	0.011
GTI	1983	2000	17	17	17	0	0.405 (**)
Gucci	1993	2002	9	9	6	3	0.817 (**)
Hagemeyer	1983	2002	19	19	19	0	0.171
HBG	1983	2000	17	17	15	2	-0.188
Heijmans	1990	2002	12	12	12	0	-0.138
Heineken	1983	2002	19	19	19	0	0.316
Hunter Douglas	1983	2002	19	19	15	4	1.081 (***)
IHC Caland	1983	2002	19	19	12	7	0.303 (*)
Imtech	1983	2002	19	19	17	2	0.998 (**)
ING Group	1988	2002	14	14	12	2	0.782 (***)
KAS Bank	1983	2002	19	19	18	1	0.853 (***)
KBB	1983	1997	14	14	14	0	0.171
Kempen & Co.	1986	2000	14	14	12	2	0.738 (**)
KLM	1983	2002	19	19	17	2	0.950 (***)
KPN	1983	2002	19	19	13	6	0.913 (**)

T-value of beta (b)	Constant term (a)	T-value of constant term (a)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
1.215	-0.001	-0.017	0.102	0.063	1.477	2.720	Inconclusive
1.258	0.022	1.554	0.108	0.041	1.582	2.026	No
6.160	0.045 (*)	2.950	0.844	0.046	37.947	1.911	No
3.799	-0.008	-0.500	0.568	0.055	14.436	1.707	No
7.860	0.012	1.344	0.805	0.037	61.772	2.020	No
0.061	0.022	1.555	0.000	0.045	0.004	1.447	No
3.381	0.002	0.143	0.432	0.042	11.430	2.196	No
4.788	-0.151	-1.764	0.851	0.139	22.921	1.510	No
1.379	0.004	0.109	0.101	0.120	1.902	1.506	No
-0.874	0.045 (*)	2.696	0.055	0.062	0.763	1.591	No
-0.744	0.061	1.869	0.052	0.048	0.553	1.433	No
1.423	0.012	0.505	0.106	0.065	2.024	1.398	Inconclusive
7.539	-0.048 (**)	-3.658	0.814	0.038	56.835	1.981	No
2.300	-0.018	-0.719	0.346	0.060	5.290	1.554	No
4.292	0.030	1.757	0.551	0.067	18.421	1.528	No
9.234	-0.012	-0.654	0.895	0.049	85.262	2.016	no
9.581	-0.019	-1.385	0.852	0.048	91.795	2.347	No
0.835	0.028	1.813	0.055	0.051	0.696	1.353	No
4.562	-0.061	-1.133	0.675	0.140	20.812	2.713	Inconclusive
13.422	-0.028 (**)	-3.014	0.923	0.039	180.155	1.001	Positive auto-correlation
4.232	0.008	0.592	0.620	0.034	17.913	1.779	No

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (b)
Landré	1983	1998	15	15	11	4	0.235 (*)
Laurus	1986	2002	16	16	11	5	-0.057
LCI	1988	2001	13	13	10	3	0.487 (**)
Van Leer	1983	1998	15	15	14	1	0.577 (**)
Macintosh	1983	2002	19	19	16	3	0.640 (*)
Van Melle	1983	1999	16	16	15	1	0.911 (***)
Bank Mendes Gans	1983	1998	15	13	12	1	0.533 (*)
Van der Moolen	1986	2002	16	16	16	0	0.748 (***)
NBM	1983	2000	17	17	16	1	0.288 (**)
NEDAP	1983	2002	19	19	19	0	0.667 (***)
Nedlloyd	1983	2001	18	16	13	3	0.903 (**)
Neways	1985	2002	17	17	16	1	-0.027
NIB Capital	1983	2002	19	19	16	3	1.067 (***)
NKF	1986	1997	11	11	10	1	0.443 (**)
Norit	1983	2000	17	17	16	1	0.339 (***)
NS	1995	2002	7	7	7	0	1.028 (**)
Numico	1983	2002	19	19	14	5	0.372
Nutreco	1995	2002	7	7	7	0	-0.047
Océ	1983	2002	19	19	16	3	0.427 (*)
Van Ommeren	1983	1998	15	15	11	4	0.408
OPG	1984	2002	18	18	14	4	0.189 (*)

T-value of beta (b)	Constant term (a)	T-value of constant term (a)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
3.199	-0.009	-1.249	0.532	0.023	10.233	1.188	Inconclusive
-0.256	0.034	1.519	0.007	0.050	0.066	1.842	No
4.065	-0.091 (*)	-2.332	0.647	0.110	16.521	1.803	No
3.489	0.024	2.088	0.504	0.042	12.173	1.527	No
2.572	0.003	0.093	0.321	0.098	6.617	1.432	No
6.856	-0.055 (**)	-3.773	0.783	0.035	46.998	1.657	No
2.694	-0.007	-0.340	0.421	0.056	7.258	0.811	Positive auto-correlation
9.728	-0.183 (**)	-3.874	0.871	0.166	94.643	2.373	No
3.810	0.004	0.319	0.509	0.044	14.519	1.785	No
6.150	-0.020	-1.535	0.690	0.041	37.824	1.229	Inconclusive
4.234	0.019	1.191	0.620	0.057	17.930	1.386	No
-0.194	0.041	0.886	0.003	0.137	0.038	2.651	Inconclusive
20.532	-0.061 (***)	-4.819	0.968	0.041	421.552	1.350	Inconclusive
4.820	-0.004	-0.283	0.744	0.044	23.228	1.074	Inconclusive
5.251	-0.006	-0.571	0.663	0.036	27.578	1.836	No
7.350	0.019	0.882	0.915	0.057	54.019	2.421	No
1.298	0.013	0.410	0.123	0.060	1.686	1.771	No
-0.110	0.020	0.276	0.002	0.090	0.012	0.980	Inconclusive
2.548	-0.001	-0.101	0.317	0.042	6.491	1.506	No
1.605	0.025	1.743	0.222	0.046	2.575	2.106	No
2.322	-0.007	-0.553	0.310	0.034	5.391	1.767	No

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (b)
Ordina	1985	2002	17	17	16	1	0.047
Otra	1983	1997	14	14	11	3	0.747 (*)
P&C Group	1983	1997	14	14	13	1	0.926 (**)
Pakhoed	1983	1998	15	15	12	3	-0.145
Philips	1983	2002	19	19	18	1	0.979 (***)
Polygram	1988	1997	9	9	9	0	0.610 (*)
Polynorm	1983	2000	17	17	16	1	0.378 (*)
Randstad	1986	2002	16	16	14	2	0.214
Reed Elsevier	1983	2002	19	19	18	1	0.906 (***)
Rood Testhouse	1986	2002	16	16	16	0	0.623 (**)
Royal Begemann Group	1995	2002	7	3	Ex-cluded from analysis		
Samas	1983	2002	19	19	13	6	0.733 (**)
Schuitema	1983	2002	19	19	16	3	0.820 (**)
Royal Dutch/Shell Group	1983	2002	19	19	16	3	1.134 (***)
Simac	1985	2002	17	17	14	3	0.044
Smit Internationale	1983	2002	19	19	16	3	1.377 (***)
SNS Bank	1990	2002	12	12	11	1	0.661 (***)
Sphinx	1984	1998	14	14	14	0	0.691 (*)
Staal Bankiers	1984	1997	13	13	9	4	0.641
Stork	1983	2002	19	19	19	0	0.412 (***)

T-value of beta (b)	Constant term (a)	T-value of constant term (a)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
1.277	0.000	0.024	0.104	0.044	1.630	2.176	No
3.101	0.006	0.282	0.517	0.050	9.618	1.654	no
4.395	0.031	1.474	0.637	0.074	19.319	1.176	Inconclusive
-0.458	0.040 (*)	2.226	0.021	0.053	0.210	2.050	No
18.160	0.032 (*)	2.730	0.954	0.049	329.773	1.734	No
2.578	-0.024	-0.657	0.487	0.059	6.646	1.570	No
2.213	-0.009	-0.450	0.259	0.045	4.898	1.787	No
1.959	-0.026	-1.254	0.242	0.045	3.839	2.576	No
5.916	-0.011	-0.424	0.686	0.091	34.995	2.092	No
4.270	-0.040	-0.712	0.566	0.220	18.231	1.700	No
3.420	0.014	0.811	0.515	0.055	11.697	1.929	No
4.163	-0.001	-0.060	0.553	0.033	17.331	1.609	No
12.749	0.036 (**)	3.724	0.921	0.039	162.527	1.321	Inconclusive
0.346	0.004	0.129	0.010	0.078	0.120	1.800	No
5.254	0.016	0.706	0.663	0.089	27.603	1.561	No
9.177	-0.015	-1.167	0.903	0.032	84.209	1.599	No
2.940	-0.023	-0.520	0.419	0.144	8.641	2.281	No
3.276	-0.018	-0.332	0.605	0.124	10.730	1.804	No
4.671	-0.002	-0.235	0.562	0.036	21.820	1.675	No

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (b)
Telegraaf	1983	2002	19	19	16	3	0.485 (**)
Ten Cate	1983	2002	19	19	19	0	0.827 (***)
Tulip	1983	2002	19	16	13	3	0.525 (**)
Twentsche Kabel Holding	1983	2002	19	19	16	3	0.584 (*)
Unilever	1983	2002	19	19	16	3	0.737 (***)
Vendex KBB	1990	2002	12	12	9	3	2.451 (**)
Vilenzo	1989	2002	13	13	11	2	0.524
VNU	1983	2002	19	19	12	7	0.288
VOPAK	1983	2002	19	19	15	4	-0.145
Vredestein	1985	2002	17	17	16	1	1.131 (***)
Volker-Wessels-Stevin	1983	2002	19	19	17	2	-0.032
Wegener-Arcade	1983	2002	19	18	17	1	0.083
Wessanen	1983	2002	19	19	17	2	0.599 (**)
Wolff	1983	1995	12	12	10	2	1.690 (***)
Wolters-Kluwer	1986	2002	16	16	15	1	0.663 (**)
Averages			**16**	**16**	**14**	**2**	**0.542**
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)							

The analysis shows that, for individual firms, the average Verdoorn coefficient was *0.542* during the period 1983-2002. This means that every increase in output of *1%* has caused a growth in productivity by *0.542%.* We can therefore say that firms have on average realized scale effects and autonomous learning effects because their output has increased over time. Of the *118* firm-specific models, *81* showed a significant value of the Verdoorn coefficient.

T-value of beta (b)	Constant term (a)	T-value of constant term (a)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
4.335	0.011	1.333	0.573	0.024	18.792	1.652	No
5.298	0.011	0.436	0.623	0.107	28.072	2.336	No
4.064	-0.098	-1.896	0.600	0.161	16.519	1.795	No
2.894	-0.029	-1.084	0.374	0.081	8.376	2.137	No
6.021	0.015	1.618	0.721	0.036	36.253	2.100	No
3.825	0.004	0.169	0.676	0.060	14.632	0.669	Positive auto-correlation
1.761	-0.060	-1.333	0.256	0.124	3.102	0.693	Positive auto-correlation
1.482	0.004	0.170	0.180	0.061	2.197	2.496	No
-0.695	0.026	1.988	0.036	0.044	0.483	2.228	No
13.533	0.011	0.739	0.929	0.056	183.152	1.558	No
-0.275	0.025	1.840	0.005	0.050	0.076	2.021	No
1.157	0.027	1.891	0.082	0.048	1.339	1.796	No
3.337	-0.017	-0.857	0.426	0.062	11.138	2.436	No
9.166	-0.043	-2.176	0.913	0.058	84.011	1.314	Inconclusive
3.117	0.003	0.106	0.428	0.053	9.713	1.816	No
	-0.006		**0.479**				

Table 9.5: Results from the estimation of the firm-specific Verdoorn models

When we only count the significant firm-specific models, the average value of the Verdoorn coefficient is *0.734*. These values are in accordance with the values found in previous research, e.g., with the values found by Verdoorn (1949) himself, by Kaldor (1966), by Kennedy (1971), by Vaciago (1975), by Stoneman (1979) and by De Vries (1985). This provides confidence in the robustness of our measurement model.

It is noteworthy that the Verdoorn coefficients vary greatly across firms: they vary from *–0.462* for *Achmea* to *2.451* for *Vendex KBB*. Again, when we only consider the significant firm-specific models, the Verdoorn coefficients vary from *0.189* for *OPG* to *2.451* for *Vendex KBB*. Lower values of the coefficient have also been found by Cripps & Tarling (1973) and Fase & Van den Heuvel (1988). Cripps & Tarling (1973) also found negative values of the coefficient for parts of their sample. Although extreme values of the coefficient are not in contradiction with the theory, they may be an indication of a possible problem with the validity of the model for that specific firm (see also Fase & Winder, 1999). Still, we should not be surprised to find higher variances at the firm level than at the industry or country level.

Interestingly, our analysis also shows that, on average, firms were simultaneously confronted with a negative value of the intercept of *-0.006*. This means that over this period firms were confronted with an average decline in productivity by *0.6%.* This decline is caused by the relative inability of firms to realize induced and exogenous learning effects. Of the *118* firms, *16* showed a significant value of the intercept. When we only count the firm-specific models with significant intercepts, the average value of the intercept is *–0.031*. It is noteworthy that the intercepts also vary greatly across firms: the values of the intercept range from *–0.185* for *ASM Lithography* to *0.125* for *Achmea*. Again, when we only consider the firm-specific models with significant intercepts, the values vary from *–0.185* for *ASM Lithography* to *0.045* for *Van der Giessen*.

We present the corrections on the Verdoorn coefficient due to changes in the capital-labor and the capital-output ratios for a number of firms in tables 9.6 and 9.7 below. Note that, although in principle these corrections can be made, the parameter estimates needed to make them were for many firms nonsignificant. Below we only present the corrections for those firms where the necessary parameter estimates were significant.[89]

As can be seen in table 9.6, the rise in capital-labor ratio causes moderate downward corrections of the Verdoorn coefficient for the firms *Athlon* and *KAS Bank*. These corrections do not greatly affect the general results of our firm-specific Verdoorn analysis.

[89] The parameter estimates for making corrections on the constant term for changes in the capital-labor ratio were all nonsignificant and are therefore not presented here. For the complete tables, including the nonsignificant parameter estimates, see *Appendix V*.

Name	initial coefficient (estimated b)	alpha (α) (coefficient of change in capital)	beta (β) (coefficient of change in labor)	average growth of capital input	average growth of labor input	delta (δ)	correction on coefficient: phi (ϕ)	corrected coefficient (b)
Athlon	0.362	0.607	0.551	0.146	0.083	1.767	0.097	0.265
KAS Bank	0.853	0.516	0.960	0.111	0.031	3.566	0.147	0.706

Table 9.6: Corrections on the Verdoorn coefficient for changes in the capital-labor ratio on the firm-specific Verdoorn models, based on significant estimates of the parameters

Name	Initial coefficient (estimated b)	alpha (α) (coefficient of change in capital)	beta (β) (coefficient of change in labor)	average growth of capital input	average growth of output	gamma (γ)	correction on coefficient: thèta (θ)	corrected coefficient (b)
Athlon	0.362	0.607	0.551	0.146	0.071	2.054	1.161	-0.799

Table 9.7: Corrections on the Verdoorn coefficient for changes in the capital-output ratio on the firm-specific Verdoorn models, based on significant estimates of the parameters

As can be seen in table 9.7, the rise in capital-output ratio causes a rather dramatic downward correction on the Verdoorn coefficient for the firm *Athlon*. As there were only a few firms with a non-constant capital-output ratio, this result does not greatly affect the general results of our firm-specific Verdoorn law analysis. It does affect the variance in coefficients, which goes from *0.189* for *OPG* and *2.451* for *Vendex KBB* in the original estimations to *–0.799* for *Athlon* and *2.451* for *Vendex KBB* in the corrected estimations. When both the corrections for change in capital-labor and capital-output ratio are made, the value of the coefficient for Athlon will probably be even lower. Such a strong negative value is an exception, but is not theoretically impossible. As mentioned before, such values may be an indication of a possible problem with the validity of the model for the specific firm (see also Fase & Winder, 1999).

9.6.4 Estimation of the productivity-performance model for individual firms

The estimations of the productivity-performance models for the *118* individual firms in our sample are provided in table 9.8 below. Note that this table is spread over two pages, the left page covering the first eight columns and the right page the last eight columns.

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (d)
Aalberts Industries	1983	2002	19	19	18	1	1.402
ABN-Amro	1983	2002	19	19	18	1	1.903 (***)
Achmea	1993	2002	9	9	8	1	0.345
AEGON	1983	2002	19	19	19	0	0.835 (**)
Ahold	1983	2002	19	19	17	2	1.361 (*)
Ahrend	1983	2000	17	17	13	4	7.352 (*)
AKZO-Nobel	1983	2002	19	19	15	4	1.791 (**)
Arcadis	1983	2002	19	19	18	1	2.810
ASM International	1994	2002	8	6	5	1	7.465
ASM Lithography	1993	2002	9	8	8	0	3.820 (***)
ASR Verzekeringsgroep	1984	1999	15	15	15	0	1.830 (***)
Atag	1986	1999	13	13	12	1	1.273
Athlon	1983	2002	19	19	15	4	2.453 (**)
Ballast-Nedam	1986	2002	16	14	9	5	1.301 (*)
BAM	1983	2002	19	18	16	2	3.922 (*)
Batenburg	1985	2002	17	17	17	0	2.023 (*)
Beers	1983	1999	16	16	14	2	0.546 (**)
Begemann	1983	1994	11	10	9	1	0.068
BE Semiconductor Industries	1994	2002	8	5	5	0	7.967
Blydenstein-Willink	1983	2002	19	12	11	1	4.181

T-value of beta (d)	Constant term (c)	T-value of constant term (c)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
1.453	0.234 (***)	4.773	0.117	0.204	2.111	2.093	No
6.065	0.002	0.061	0.697	0.098	36.783	2.172	No
0.644	0.123	2.319	0.065	0.125	0.415	1.272	Inconclusive
3.473	0.112 (*)	2.627	0.415	0.176	12.062	2.320	No
2.367	0.182 (***)	6.804	0.272	0.107	5.605	1.141	Inconclusive
2.595	-0.078	-0.767	0.380	0.269	6.736	1.633	No
3.477	-0.043	-1.209	0.482	0.133	12.088	2.523	No
1.462	0.075	0.720	0.118	0.393	2.137	2.970	Negative auto-correlation
2.090	0.034	0.021	0.593	3.507	4.367	1.393	No
10.394	0.551 (**)	3.886	0.947	0.401	108.025	2.118	No
14.349	0.021	1.391	0.941	0.043	205.888	1.626	No
0.714	0.120	1.228	0.049	0.320	0.510	2.580	No
3.570	0.047	0.984	0.515	0.177	12.744	1.120	Inconclusive
3.295	0.049	1.137	0.608	0.129	10.854	2.893	Inconclusive
2.784	0.056	0.759	0.356	0.232	7.752	2.041	No
2.704	0.025	0.620	0.328	0.144	7.310	2.468	No
3.543	0.023	1.595	0.511	0.044	12.555	1.983	No
0.063	0.317	1.166	0.001	0.801	0.004	1.599	No
3.086	0.262	0.240	0.760	2.359	9.525	0.585	Inconclusive
1.145	-1.100	-1.575	0.127	2.195	1.310	2.383	No

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (d)
Boskalis-Westminster	1983	2002	19	15	12	3	2.480 (**)
Brocacef	1983	1999	16	15	13	2	2.576 (**)
Buhrmann	1983	2002	19	18	14	4	4.758 (**)
CAP Gemini	1986	1999	13	13	13	0	3.060 (**)
Cindu	1983	1997	14	13	12	1	4.834
CMG	1993	2002	9	8	7	1	2.178
Content	1985	1997	12	11	9	2	1.700 (**)
Corus	1983	2002	19	11	10	1	6.588 (**)
Crédit Lyonnais Nederland	1983	1997	14	8	8	0	1.954
CSM	1983	2002	19	19	16	3	0.954 (**)
Delft Instruments	1984	2002	18	13	12	1	14.969 (***)
Draka	1988	2002	14	14	10	4	0.988 (*)
DSM	1983	2002	19	18	17	1	4.913 (***)
EVC	1993	2002	9	3	Ex-cluded from analysis		
Exendis	1985	2002	17	17	13	4	2.970 (***)
Fortis	1983	2002	19	19	15	4	1.232 (*)
Frans Maas	1986	2002	16	14	13	1	2.518 (*)
Free Record Shop	1989	2001	12	12	11	1	2.665 (*)
Fugro	1989	2002	13	13	13	0	4.125 (***)
Gamma Holding	1983	2002	19	19	19	0	0.552

T-value of beta (d)	Constant term (c)	T-value of constant term (c)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
3.556	0.052	1.005	0.558	0.144	12.642	2.136	No
3.672	-0.085	-1.122	0.551	0.255	13.483	2.368	No
3.200	0.000	-0.002	0.460	0.508	10.241	2.795	Inconclusive
3.582	0.085	2.002	0.538	0.153	12.827	1.368	No
1.556	-0.035	-0.211	0.195	0.431	2.422	1.869	No
1.920	0.315 (*)	2.769	0.381	0.311	3.687	1.332	No
4.044	0.100 (*)	2.516	0.700	0.119	16.357	2.764	Inconclusive
4.541	-0.224	-1.455	0.720	0.484	20.619	1.689	No
1.463	0.021	0.170	0.263	0.299	2.140	2.262	No
3.706	0.098 (***)	9.417	0.495	0.027	13.737	1.611	No
6.818	-0.041	-0.151	0.823	0.939	46.481	2.337	No
2.323	0.154 (***)	5.910	0.403	0.068	5.396	2.033	No
8.837	-0.039	-0.524	0.839	0.278	78.097	2.503	No
4.918	-0.051	-0.881	0.687	0.207	24.182	2.099	No
2.776	0.090 (**)	3.393	0.372	0.101	7.705	1.599	No
2.487	0.075	1.615	0.360	0.165	6.185	1.771	No
2.888	0.094	1.041	0.481	0.297	8.340	1.734	No
5.500	0.130	1.651	0.733	0.266	30.253	1.910	No
0.720	0.105	1.564	0.030	0.293	0.518	2.052	No

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (d)
Gelderse Papier	1985	1999	14	11	10	1	7.341 (**)
Getronics	1984	2002	18	17	14	3	1.507
Geveke	1984	2001	17	15	14	1	3.017
Van der Giessen	1983	1996	13	10	7	3	17.262 (*)
Gist-Brocades	1983	1997	14	14	12	2	3.765 (**)
Grolsch	1983	2002	19	19	17	2	0.664 (*)
Grontmij	1983	2002	19	19	19	0	0.958
GTI	1983	2000	17	17	17	0	1.308
Gucci	1993	2002	9	8	7	1	1.676 (*)
Hagemeyer	1983	2002	19	19	18	1	0.952
HBG	1983	2000	17	17	16	1	-0.332
Heijmans	1990	2002	12	12	12	0	-0.890
Heineken	1983	2002	19	19	19	0	0.675
Hunter Douglas	1983	2002	19	19	19	0	2.856 (***)
IHC Caland	1983	2002	19	16	13	3	2.521 (*)
Imtech	1983	2002	19	18	15	3	5.348 (**)
ING Group	1988	2002	14	14	12	2	2.522 (***)
KAS Bank	1983	2002	19	19	17	2	2.807 (***)
KBB	1983	1997	14	14	13	1	4.838 (**)
Kempen & Co.	1986	2000	14	14	13	1	1.915 (***)
KLM	1983	2002	19	16	14	2	9.880 (**)

T-value of beta (d)	Constant term (c)	T-value of constant term (c)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
5.560	-0.269	-1.235	0.794	0.658	30.918	1.883	No
1.971	0.245 (**)	4.344	0.245	0.182	3.884	1.042	Positive auto-correlation
1.964	0.070	0.829	0.243	0.230	3.857	2.353	No
2.884	-0.524	-1.274	0.625	1.089	8.319	1.463	No
3.835	-0.071	-1.228	0.595	0.180	14.708	1.431	No
2.202	0.059 (*)	3.472	0.244	0.057	4.848	1.939	No
0.362	0.246	1.885	0.008	0.531	0.131	1.826	No
0.724	0.192	1.733	0.034	0.389	0.524	1.482	No
2.973	0.260	2.216	0.639	0.311	8.837	1.386	No
1.063	0.111	1.170	0.066	0.397	1.131	0.852	Positive auto-correlation
-0.808	0.063 (*)	2.160	0.045	0.095	0.653	1.414	No
-0.917	0.311 (***)	5.406	0.078	0.150	0.841	2.383	No
1.933	0.089 (**)	3.439	0.180	0.099	3.735	2.197	No
5.139	0.109	1.874	0.608	0.250	26.406	1.923	No
2.824	0.017	0.277	0.420	0.212	7.974	2.180	No
3.418	-0.049	-0.369	0.473	0.409	11.683	1.850	No
7.403	0.006	0.164	0.846	0.101	54.810	1.588	No
7.986	0.036	0.791	0.810	0.172	63.784	2.741	Inconclusive
4.601	-0.081	-1.260	0.658	0.189	21.169	2.088	No
6.387	0.146	1.927	0.788	0.270	40.796	1.868	No
4.526	0.205	0.726	0.631	1.020	20.488	1.730	No

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (d)
KPN	1983	2002	19	18	12	6	0.197
Landré	1983	1998	15	14	11	3	3.636
Laurus	1986	2002	16	14	11	3	0.537
LCI	1988	2001	13	11	11	0	3.692 (**)
Van Leer	1983	1998	15	15	12	3	0.933
Macintosh	1983	2002	19	18	16	2	3.708 (*)
Van Melle	1983	1999	16	16	16	0	2.586 (**)
Bank Mendes Gans	1983	1998	15	13	10	3	0.321 (*)
Van der Moolen	1986	2002	16	16	13	3	1.326 (***)
NBM	1983	2000	17	17	15	2	4.117 (***)
NEDAP	1983	2002	19	19	19	0	3.762 (***)
Nedlloyd	1983	2001	18	13	9	4	7.534 (*)
Neways	1985	2002	17	16	14	2	1.863 (*)
NIB Capital	1983	2002	19	19	18	1	1.943 (***)
NKF	1986	1997	11	11	9	2	3.716 (***)
Norit	1983	2000	17	17	13	4	3.059 **)
NS	1995	2002	7	7	5	2	6.054
Numico	1983	2002	19	19	18	1	-0.147
Nutreco	1995	2002	7	7	7	0	3.752
Océ	1983	2002	19	19	17	2	1.142
Van Ommeren	1983	1998	15	15	9	6	1.851 (**)

T-value of beta (d)	Constant term (c)	T-value of constant term (c)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
0.467	0.085 (*)	2.786	0.021	0.072	0.218	1.062	Inconclusive
1.492	-0.011	-0.156	0.198	0.241	2.226	2.118	No
0.665	0.058	1.322	0.047	0.122	0.442	2.074	No
3.798	0.214	1.182	0.591	0.625	14.428	1.927	No
1.456	0.117 (*)	2.753	0.175	0.132	2.119	2.451	No
2.944	-0.215	-1.672	0.382	0.509	8.667	1.880	No
3.649	0.075	1.307	0.487	0.212	13.312	2.327	No
3.226	0.063 (***)	7.207	0.565	0.027	10.410	1.060	Inconclusive
4.887	0.166	2.138	0.685	0.247	23.878	2.186	No
4.069	0.146 (*)	2.220	0.560	0.237	16.557	1.130	Inconclusive
7.845	0.015	0.396	0.784	0.145	61.545	2.015	No
3.374	-0.071	-0.386	0.619	0.498	11.383	1.989	No
2.286	0.024	0.233	0.303	0.374	5.224	1.809	No
9.757	0.074	1.396	0.856	0.225	95.198	1.191	Inconclusive
5.417	-0.047	-0.934	0.807	0.131	29.349	1.359	No
3.519	0.070	1.083	0.530	0.182	12.384	1.616	No
2.894	-0.134	-0.997	0.736	0.223	8.376	1.682	No
-0.308	0.192	4.400	0.006	0.182	0.095	2.169	No
1.833	0.281	1.773	0.402	0.414	3.358	1.919	No
0.833	0.099	1.089	0.044	0.302	0.694	2.049	No
3.477	0.165 (**)	5.088	0.633	0.082	12.092	2.488	No

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (d)
OPG	1984	2002	18	18	17	1	3.405 (**)
Ordina	1985	2002	17	17	16	1	2.976
Otra	1983	1997	14	14	14	0	3.622 (*)
P&C Group	1983	1997	14	11	9	2	5.030 (***)
Pakhoed	1983	1998	15	15	12	3	7.622 (**)
Philips	1983	2002	19	15	12	3	4.966 (**)
Polygram	1988	1997	9	9	7	2	1.598 (**)
Polynorm	1983	2000	17	17	16	1	3.450 (**)
Randstad	1986	2002	16	16	15	1	1.902 (*)
Reed Elsevier	1983	2002	19	18	15	3	0.758
Rood Testhouse	1986	2002	16	11	10	1	14.263 (*)
Royal Begemann Group	1995	2002	7	3	Ex-cluded from analysis		
Samas	1983	2002	19	19	17	2	2.057 (**)
Schuitema	1983	2002	19	19	16	3	1.117 (**)
Royal Dutch/Shell Group	1983	2002	19	19	17	2	1.554 (***)
Simac	1985	2002	17	14	12	2	5.102 (**)
Smit Internationale	1983	2002	19	16	12	4	3.152
SNS Bank	1990	2002	12	12	10	2	2.275 (***)
Sphinx	1984	1998	14	12	11	1	2.425 (**)
Staal Bankiers	1984	1997	13	12	11	1	2.154 (***)

T-value of beta (d)	Constant term (c)	T-value of constant term (c)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
3.759	0.113	1.553	0.485	0.300	14.132	2.005	No
1.240	0.226	2.049	0.099	0.419	1.538	1.630	No
2.251	0.155	1.119	0.297	0.451	5.066	1.894	No
7.348	-0.062	-0.730	0.885	0.237	53.992	2.037	No
3.500	-0.049	-0.457	0.551	0.302	12.251	1.382	No
3.811	-0.167	-1.041	0.592	0.552	14.524	2.798	Inconclusive
4.759	0.071 (*)	2.805	0.819	0.049	22.645	1.730	No
3.927	0.036	0.664	0.524	0.193	15.421	2.184	No
2.188	0.198 (**)	3.823	0.269	0.201	4.789	1.262	Inconclusive
1.922	0.177 (*)	2.916	0.221	0.179	3.696	1.690	No
2.973	0.501	0.681	0.525	2.086	8.838	3.167	Negative auto-correlation
2.924	0.154 (*)	2.515	0.363	0.246	8.548	1.952	No
3.468	0.058 (*)	2.458	0.462	0.068	12.028	1.702	No
8.299	-0.014	-0.501	0.821	0.110	68.877	1.586	No
4.505	0.094	1.128	0.670	0.280	20.293	2.466	No
1.770	0.047	0.234	0.239	0.603	3.132	2.609	No
5.860	-0.005	-0.119	0.811	0.081	34.341	1.963	No
3.900	0.150	1.254	0.628	0.383	15.212	1.448	No
6.193	0.048	0.696	0.810	0.220	38.352	2.940	Inconclusive

Firm name	Available data range from/to:		Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta (d)
Stork	1983	2002	19	18	17	1	1.491
Telegraaf	1983	2002	19	18	17	1	1.847 (**)
Ten Cate	1983	2002	19	17	16	1	2.424 (*)
Tulip	1983	2002	19	13	12	1	4.744 (***)
Twentsche Kabel Holding	1983	2002	19	19	18	1	2.632 (***)
Unilever	1983	2002	19	19	15	4	2.179 (***)
Vendex KBB	1990	2002	12	12	10	2	4.916 (***)
Vilenzo	1989	2002	13	13	11	2	0.909
VNU	1983	2002	19	19	18	1	2.689 (***)
VOPAK	1983	2002	19	19	16	3	6.491 (**)
Vredestein	1985	2002	17	13	9	4	5.620 (*)
Volker-Wessels-Stevin	1983	2002	19	18	14	4	0.050
Wegener-Arcade	1983	2002	19	18	15	3	2.575
Wessanen	1983	2002	19	19	17	2	2.150 (***)
Wolff	1983	1995	12	9	7	2	0.602
Wolters-Kluwer	1986	2002	16	16	12	4	0.037
Averages			**16**	**14.9**	**13.2**	**1.8**	**3.083**

Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)

T-value of beta (d)	Constant term (c)	T-value of constant term (c)	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
0.943	0.134	1.694	0.056	0.308	0.890	1.829	No
0.268	0.039	1.136	0.416	0.135	10.682	2.156	No
2.724	-0.077	-0.722	0.346	0.402	7.420	1.568	No
8.442	0.223	1.928	0.877	0.395	71.276	1.760	No
5.075	0.064	1.309	0.617	0.203	25.751	1.423	No
6.001	-0.007	-0.278	0.735	0.093	36.015	1.483	No
3.901	0.184	1.414	0.655	0.407	15.217	1.229	Inconclusive
1.616	0.043	0.579	0.225	0.242	2.611	2.084	No
5.611	0.126	1.430	0.663	0.368	31.48	1.742	No
4.164	-0.072	-0.732	0.553	0.343	17.341	3.009	Negative auto-correlation
3.229	-0.212	-2.113	0.598	0.241	10.426	1.011	Inconclusive
0.153	0.125 (***)	7.663	0.002	0.056	0.023	1.392	No
2.037	0.070	1.184	0.242	0.123	4.148	1.601	No
7.268	0.075 (*)	2.693	0.779	0.115	52.819	2.229	No
0.291	0.169	1.202	0.017	0.255	0.085	2.397	No
0.205	0.197 (***)	11.442	0.004	0.032	0.042	1.390	No
	0.062		**0.459**				

Table 9.8: Results from the estimation of the firm-specific productivity-performance models

The analysis shows that the average coefficient of the firm-specific productivity-performance models was *3.083* during the period 1983-2002. This means that every increase in productivity of *1%* has caused a growth in net profit by *3.083%.* Firms have therefore been able to make strategic use of their productivity increases. Of the *118* firm-specific models, *79* showed a significant value of the productivity-performance coefficient. When we only count the significant firm-specific models, the average value of the productivity-performance coefficient is *3.630*. It is noteworthy that the productivity-performance coefficients vary greatly across firms: the coefficients range from *–0.890* for *Heijmans* to *17.262* (!) for *Van der Giessen*. Again, when we only consider the significant firm-specific models, the productivity-performance coefficients vary from *0.321* for *Bank Mendes Gans* to *17.262* for *Van der Giessen*.

Our analysis also shows that, on average, firms simultaneously realized a positive value of the intercept of *0.062*. This means that over this period firms increased their net profits independent of the rise in their productivity by *6.2%.* Of the *118* firms, *27* showed a significant value of the intercept. When we only count the firm-specific models with significant intercepts, the average value of the intercept is *0.157*. It is noteworthy that the intercepts, too, vary greatly across firms: from a value of *–1.575* for *Blydenstein-Willink* to *0.551* for *ASM Lithography*. Again, when we only consider the firm-specific models with significant intercepts, the values of the intercepts vary from *0.058* for *Schuitema* to *0.551* for *ASM Lithography*.

9.6.5 Estimation of the Verdoorn model for industries

The estimations of the Verdoorn model for the *13* industries in our sample are provided in table 9.9 below. Note that this table is spread over two pages, the left page covering the first seven columns and the right page the last seven columns.

The analysis shows that the average Verdoorn coefficient for the industry models based on pooled firm-level data was *0.399* during the period 1983-2002. This means that every increase in output of *1%* has caused a growth in productivity by *0.399%.* The values found are in accordance with the values found in previous research, e.g., by Verdoorn (1949) himself, by Kaldor (1966), by Kennedy (1971), by Vaciago (1975), by Stoneman (1979) or by De Vries (1985). We can therefore say that firms in these industries have realized scale effects and autonomous learning effects because their output has increased over time. All of the *13* industry models showed a significant value for the Verdoorn coefficient. It is noteworthy that the Verdoorn coefficients vary greatly across industries, though considerably less so than across firms. The industry coefficients range from *0.100* for *IT Services* to *0.672* for *Basic Industry*.

Our analysis also shows that for the industry models based on pooled firm-level data, on average, firms showed a slightly negative value of the intercept of *-0.003*. This means that over the period of analysis firms in these industries were confronted with an average decline in productivity by *0.3%.* This result differs only slightly from our findings on the firm-specific models in section 9.6.3. The difference is probably due to the aggregation of firms into industry-level analysis. The decline is caused by the relative inability of firms to realize induced and exogenous learning effects. Of the *13* industries, *3* showed a significant value of the intercept. When we only count the industry-specific models with significant intercepts, the average value of the intercept is *–0.038*. This result is in line with the findings on the firm-specific models in section 9.6.3. The intercepts vary greatly across industries, ranging from *–0.041* for *Other Business Services* to *0.024* for *Media*. Both values are significant.

In tables 9.10, 9.11 and 9.12 below, we present the corrections on the Verdoorn coefficient and the constant term due to changes in the capital-labor ratio and the corrections on the Verdoorn coefficient due to the changes in the capital-output ratios for a number of industries. Note that, although in principle these corrections can be made, the parameter estimates needed to make them were nonsignificant for some industries. Below we only present those corrections where the necessary parameter estimates were significant.[90]

As can be seen in table 9.10, the rise in capital-labor ratio causes moderate, i.e., *0.072* for *Construction Industry*, to high, i.e., *0.697* for *Basic Industry*, downward corrections on the Verdoorn coefficients of the industries involved. As there were nine industries with a non-constant capital-labor ratio, and for eight of these can we make corrections to the Verdoorn coefficient, this result significantly affects the general results of our industry-specific Verdoorn law analysis. The average Verdoorn coefficient for the industry models based on pooled firm-level data goes from *0.399* in the original estimations to *0.231* in the corrected estimations i.e., from values that are close to those found by Verdoorn (1949), to values that are close to those found by Fase & Van den Heuvel (1988). The variation in coefficients goes from *0.100* for *IT Services* and *0.672* for *Basic Industry* in the original estimations to *–0.304* for *Retail* and *0.652* for *Telecommunications* in the corrected estimations.

[90] For the complete tables, including the nonsignificant parameter estimates, see *Appendix V*.

Industry name	Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta	T-value of beta
Basic industry	232	232	226	6	0.672 (***)	17.268
Food industry	140	140	131	9	0.322 (***)	6.056
Media	105	104	95	9	0.177 (**)	2.719
Engineering industry	241	241	226	15	0.261 (***)	7.468
Construction industry	158	158	145	13	0.234 (***)	5.967
Wholesale	215	215	207	8	0.346 (***)	7.951
Transport	134	134	126	8	0.566 (***)	8.552
Telecommunications	36	25	17	8	0.652 (**)	3.354
Financial services	224	217	209	8	0.606 (***)	16.981
IT services	96	96	83	13	0.100 (**)	2.916
Other business services	120	120	117	3	0.449 (***)	8.313
Retail	147	147	128	19	0.297 (***)	4.024
Electronics industry	99	96	85	11	0.511 (***)	11.600
Averages	**150**	**148**	**138**	**10**	**0.399**	
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

Constant term	T-value of constant term	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for autocorrelation
0.008	1.132	0.571	0.103	298.187	2.059	No
0.003	0.476	0.221	0.067	36.670	1.739	No
0.024 (*)	2.287	0.074	0.079	7.393	2.024	No
-0.002	-0.334	0.199	0.084	55.770	1.953	No
0.004	0.621	0.199	0.064	35.604	2.054	No
0.002	0.189	0.236	0.108	63.223	1.931	No
-0.001	-0.079	0.371	0.101	73.135	2.004	No
0.008	0.291	0.429	0.091	11.252	1.805	No
-0.021 (*)	-1.984	0.582	0.133	288.345	1.884	No
0.000	0.004	0.095	0.086	8.506	2.113	No
-0.041 (**)	-3.217	0.375	0.123	69.101	1.965	No
-0.006	-0.557	0.114	0.095	16.191	1.940	No
-0.018	-1.123	0.619	0.135	134.567	1.657	Inconclusive
-0.003		**0.314**				

Table 9.9: Results from the estimation of the industry-specific Verdoorn models

Name	initial coefficient (estimated b)	alpha (α) (coefficient of change in capital)	beta (β) (coefficient of change in labor)	average growth of capital input	average growth of labor input	delta (δ)	correction on coefficient: phi (ϕ)	corrected coefficient (b)
Basic industry	0.672	0.399	0.484	0.026	0.008	3.386	0.697	-0.025
Media	0.177	0.102	0.618	0.127	0.063	2.009	0.238	-0.061
Engineering industry	0.261	0.202	0.725	0.090	0.065	1.376	0.104	0.157
Construction industry	0.234	0.079	0.871	0.111	0.061	1.822	0.072	0.162
Wholesale	0.346	0.279	0.596	0.081	0.062	1.307	0.169	0.177
Financial services	0.606	0.363	0.600	0.129	0.080	1.619	0.220	0.386
Retail	0.297	0.321	0.352	0.080	0.064	1.250	0.601	-0.304
Electronics industry	0.511	0.476	0.745	0.158	0.087	1.826	0.084	0.427

Table 9.10: Corrections on the Verdoorn coefficient for changes in the capital-labor ratio on the industry-specific Verdoorn models, based on significant estimates of the parameters

Name	initial constant term (estimated a)	lambda (λ) (exogenous techno-logical change)	alpha (α) (coeffi-cient of change in capital)	beta (β) (coeffi-cient of change in labor)	average growth of capital input	average growth of labor input	delta (δ)	correction on constant term: zeta (ζ)	corrected constant term (a)
Basic industry	nonsign.	0.032	0.399	0.484	0.026	0.008	3.386	-0.049	n.a.
Media	0.024	0.052	0.102	0.618	0.127	0.063	2.009	-0.021	0.045
Engineering industry	nonsign.	0.018	0.202	0.725	0.090	0.065	1.376	-0.007	n.a.
Construction industry	nonsign.	0.023	0.079	0.871	0.111	0.061	1.822	-0.004	n.a.
Wholesale	nonsign.	0.032	0.279	0.596	0.081	0.062	1.307	-0.020	n.a.
Financial services	-0.021	0.057	0.363	0.600	0.129	0.080	1.619	-0.047	0.026
Retail	nonsign.	0.027	0.321	0.352	0.080	0.064	1.250	-0.041	n.a.

Table 9.11: Corrections on the constant term for changes in the capital-labor ratio on the industry-specific Verdoorn models, based on significant estimates of the parameters

As can be seen in table 9.11, the rise in capital-labor ratio causes small, i.e., *-0.004* for *Construction Industry*, to substantial, i.e., *-0.049* for *Basic Industry*, upward corrections on the constant term for the industries involved. As there were nine industries with a non-constant capital-labor ratio, for seven of these can we calculate the correction, and for two of these can we present a corrected constant term, this result significantly affects the general results of our industry-specific Verdoorn law analysis. The average value of the constant term for the industry models based on pooled firm-level data goes from *–0.003* in the original estimations to *0.002* in the corrected estimations, which is a change in the sign of the constant term, meaning that firms in these industries were on average able to realize induced and exogenous learning effects. Counting only the significant models, the variation in constant terms goes from *–0.041* for *Other Business Services* and *0.024* for *Media* in the original estimations to *–0.041* for *Other Business Services* and *0.045* for *Media* in the corrected estimations.

Name	initial coefficient (estimated b)	alpha (α) (coefficient of change in capital)	beta (β) (coefficient of change in labor)	average growth of capital input	average growth of output	gamma (γ)	correction on coefficient: thèta (θ)	corrected coefficient (b)
Construction industry	0.234	0.079	0.871	0.111	0.085	1.301	0.027	0.207

Table 9.12: Corrections on the Verdoorn coefficient for changes in the capital-output ratio on the industry-specific Verdoorn models, based on significant estimates of the parameters

As can be seen in table 9.12, the rise in capital-output ratio causes only a small downward correction on the Verdoorn coefficient for the *Construction Industry*. As this was the only industry with a non-constant capital-output ratio, this result does not greatly affect the general results of our industry-specific Verdoorn law analysis.

9.6.6 Estimation of the productivity-performance model for industries

The estimations of the productivity-performance model for the *13* industries in our sample are provided in table 9.13 on the next pages. Note that this table is spread over two pages, the left page covering the first seven columns and the right page the last seven columns.

Industry name	Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta	T-value of beta
Basic industry	232	198	187	11	4.086 (***)	12.811
Food industry	140	140	130	10	1.535 (***)	7.953
Media	105	102	96	6	1.738 (***)	6.952
Engineering industry	241	231	218	13	2.900 (***)	9.575
Construction industry	158	147	136	11	1.221 (**)	3.160
Wholesale	215	204	190	14	3.484 (***)	13.725
Transport	134	121	109	12	4.760 (***)	9.814
Telecommunications	36	22	19	3	0.475	0.682
Financial services	224	211	205	6	1.638 (***)	20.704
IT services	96	89	76	13	2.819 (***)	4.811
Other business services	120	111	97	14	2.496 (***)	4.743
Retail	147	140	124	16	1.983 (***)	7.392
Electronics industry	99	82	66	16	3.812 (***)	9.941
Averages	**149**	**138**	**127**	**11**	**2.534**	
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

Constant term	T-value of constant term	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for autocorrelation
-0.073	-1.776	0.470	0.559	164.128	1.791	No
0.079 (***)	5.316	0.331	0.165	63.244	2.085	No
0.071 (*)	2.469	0.340	0.267	48.326	1.823	No
0.084 (**)	3.145	0.298	0.388	91.686	1.930	No
0.125 (***)	4.778	0.069	0.275	9.985	1.934	No
0.072 (*)	2.511	0.501	0.389	188.380	2.010	No
0.102	1.699	0.474	0.626	96.315	1.920	No
0.164	1.824	0.027	0.331	0.465	1.347	Inconclusive
0.089 (***)	5.150	0.679	0.240	428.636	1.921	No
0.205 (***)	4.686	0.238	0.364	23.141	1.788	No
0.105 (**)	2.783	0.191	0.363	22.500	2.224	No
0.053	1.825	0.309	0.320	54.642	2.083	No
0.019	0.339	0.607	0.457	98.819	2.145	No
0.084		**0.349**				

Table 9.13: Results from the estimation of the industry-specific productivity-performance models

The analysis shows that the average coefficient of the productivity-performance for the industry models based on pooled firm-level data was *2.534* during the period 1983-2002. This means that every increase in productivity by *1%* has caused a growth in net profit by *2.534%.* Firms in these industries have therefore been able to make strategic use of their productivity increases. Of the *13* industries, *12* showed a significant value of the productivity-performance coefficient. When we only count the significant industry-specific models, the average value of the productivity-performance coefficient is *2.706*. It is noteworthy that the productivity-performance coefficients vary greatly across industries, through less so than across firms. The coefficients vary from *–0.475* for *Telecommunications* to *4.086* for *Basic Industry*. Again, when we only consider the significant industry-specific models, the coefficients vary from *1.221* for *Construction Industry* to *4.086* for *Basic Industry*.

Our analysis also shows that, for the industry models based on pooled firm-level data, on average firms realized a positive value of the intercept of *0.084*. This means that over this period firms in these industries increased their net profits independent of the rise in their productivity by *8.4%.* Of the *13* industries, *8* showed a significant value of the intercept. When we only count the industry-specific models with significant intercepts, the average value of the intercept is *0.104*. The intercepts vary across industries, though considerably less so than across firms. The values of the intercept vary from *–0.073* for *Basic Industry* to *0.205* for *IT Services*. Again, when we only consider the models with significant intercepts, the values of the intercept vary from *0.071* for *Media* to *0.205* for *IT Services*.

9.6.7 Estimation of the Verdoorn model for the entire population

The estimation of the Verdoorn model for the entire population is provided in table 9.14 below. Note that this table is spread over two pages, the left page covering the first seven columns and the right page the last seven columns.

	Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta	T-value of beta
All firms	1947	1925	1860	65	0.476 (***)	36.195
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

The analysis shows that the Verdoorn coefficient for the total population model based on pooled firm-level data was *0.476 ($p<0.001$)* during the period 1983-2002. This means that every increase in output of *1%* has caused a growth in productivity by *0.476%*. Firms in the population have therefore realized scale effects and autonomous learning effects because their output has increased over time. The value found is in accordance with previous research (e.g., Verdoorn, 1949; Kaldor, 1966; Kennedy, 1971; Vaciago, 1975; Stoneman, 1979; De Vries, 1985).

Our analysis also shows that, for the total population model based on pooled firm-level data, firms were simultaneously confronted with a negative value of the intercept of *-0.014 ($p<0.001$)*. This means that over this period firms in the population were confronted with an average decline in productivity by *1.4%*. This decline is caused by the relative inability of firms to realize induced and exogenous learning effects.

Constant term	T-value of constant term	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for autocorrelation
-0.014 (***)	-4.279	0.414	0.172	1310.078	1.923	Inconclusive

Table 9.14: Result from the estimation of the Verdoorn model on the total population

We present the corrections on the Verdoorn coefficient and the constant term due to the change in the capital-labor ratio and the correction on the Verdoorn coefficient due to the change in the capital-output ratio for the model on the total population in tables 9.15, 9.16 and 9.17 below.

Name	initial coefficient (estimated b)	alpha (α) (coefficient of change in capital)	beta (β) (coefficient of change in labor)	average growth of capital input	average growth of labor input	delta (δ)	correction on coefficient: phi (ϕ)	corrected coefficient (b)
Total population	0.476	0.257	0.591	0.103	0.071	1.443	0.218	0.258

Table 9.15: Correction on the Verdoorn coefficient for the change in the capital-labor ratio on the Verdoorn model on the total population (based on significant estimates of the parameters)

As can be seen in table 9.15, the rise in capital-labor ratio causes a considerable, i.e., *0.218*, downward correction on the Verdoorn coefficient. The average Verdoorn coefficient for the model on the total population based on pooled firm-level data goes from *0.476* in the original estimation to *0.258* in the corrected estimation, i.e., from a value that is close to that found by Verdoorn (1949), to a value that is closer to that found by Fase & Van den Heuvel (1988).

Name	initial constant term (estimated a)	lambda (λ) (exogenous techno-logical change)	alpha (α) (coeffi-cient of change in capital)	beta (β) (coeffi-cient of change in labor)	average growth of capital input	average growth of labor input	delta (δ)	correction on constant term: zeta (ζ)	corrected constant term (a)
Total population	-0.014	0.036	0.257	0.591	0.103	0.071	1.443	-0.023	0.009

Table 9.16: Correction on the constant term for the change in the capital-labor ratio on the Verdoorn model on the total population (based on significant estimates of the parameters)

As can be seen in table 9.16, the rise of the capital-labor ratio causes a substantial, i.e., *-0.023* upward correction on the constant term. The value of the constant term for total population model based on pooled firm-level data goes from *–0.014* in the original estimations to *0.009* in the corrected estimations, which is a change in the sign of the constant term, meaning that firms were on average able to realize induced and exogenous learning effects.

Name	initial coefficient (estimated b)	alpha (α) (coefficient of change in capital)	beta (β) (coefficient of change in labor)	average growth of capital input	average growth of output	gamma (γ)	correction on coefficient: thèta (θ)	corrected coefficient (b)
Total population	0.476	0.257	0.591	0.103	0.104	0.986	-0.006	0.482

Table 9.17: Correction on the Verdoorn coefficient for the change in the capital-output ratio on the Verdoorn model on the total population (based on significant estimates of the parameters)

As can be seen in table 9.17, the rise in capital-output ratio causes a small upward correction on the Verdoorn coefficient. This result does not greatly affect the general results of the Verdoorn law analysis for the total population.

9.6.8 Estimation of the productivity-performance model for the entire population

The estimations of the productivity-performance relationship for the entire population are provided in table 9.18 below. Note that this table is spread over two pages, the left page covering the first seven columns and the right page the last seven columns.

The analysis shows that the productivity-performance coefficient for the total population model based on pooled firm-level data was *3.493 ($p<0.001$)* during the period 1983-2002. This means that every increase in productivity of *1%* has caused a growth in net profit by *3.493%.* Firms in the population have therefore been able to make strategic use of their productivity increases.

Our analysis also shows that for the total population model based on pooled firm-level data, firms on average realized a positive value of the intercept of *0.028*. This means that over this period firms in the population increased their net profits independent of the rise in their productivity by *2.8%.* This value is nonsignificant, however.

	Total number of obser-vations	Valid number of obser-vations	No. of obser-vations in model	Deleted no. of obser-vations	Unstan-dardized beta	T-value of beta
All firms	1947	1798	1767	31	3.493 (***)	28.250
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

9.6.9 Results of the estimations of the Verdoorn model

The results of the estimation of the Verdoorn model for individual firms provide partial support for hypothesis H_3, because for *68.6%* (*81* out of *118*) of the firms there is a positive and significant relationship between the potential for scale and learning effects and the realization of scale effects and autonomous learning effects. Only for *13.6%* (*16* out of *118*) of the firms is there a significant relationship between the potential for scale and learning effects and the realization of induced and exogenous learning effects, and this relationship is on average negative.

The results of the estimation of the Verdoorn model for industries also provide partial support for hypothesis H_3, because for all industries *(100%)* there is a positive and significant relationship between the potential for scale and learning effects and the realization of scale and autonomous learning effects. For *3* out of *13* industries *(23.1%)* there is a significant relationship between the potential for scale and learning effects and the realization of induced and exogenous learning effects. However, this relationship is on average negative.

The result of the estimation of the Verdoorn model for the entire populations provides support for hypothesis H_3, because there is a positive and significant relationship between the potential for scale and learning effects and the realization of scale and autonomous learning effects. There is a negative and significant relationship, however, between the potential for scale and learning effects and the realization of induced and exogenous learning effects.

Constant term	T-value of constant term	R square	Standard error of estimate	F-statistic	Durbin-Watson coefficient	Result of test for auto-correlation
0.028	1.284	0.311	0.892	798.088	2.120	Negative auto-correlation

Table 9.18: Results from the estimation of the productivity-performance model on the total population

9.6.10 Results of the estimations of the productivity-performance model

The results of the estimation of the productivity-performance model for individual firms provide partial support for hypothesis H_5, because for *66.9%* (*79* out of *118*) of the firms there is a positive and significant relationship between the realization of scale and learning effects and firm performance. The positive values of the intercept, significantly so for *22.9%* or *27* out of *118* firms, provide an indication that net profit is probably co-determined by variables that are not included in our model.

The results of the estimation of the productivity-performance model for industries provide partial support for hypothesis H_5, because for *12* out of *13 (92.3%)* of the industries there is a positive and significant relationship between the realization of scale and learning effects and firm performance. The positive values of the intercept, significantly so for *61.5%* or *8* out of *13* industries, provide an indication that net profit is probably co-determined by variables that are not included in our model.

The result of the estimation of the productivity-performance model for the entire population provides support for hypothesis H_5, because for the model of the entire population there is a positive and significant relationship between the realization of scale and learning effects and firm performance. The positive, but nonsignificant value of the intercept provides a possible indication that net profit is probably co-determined by variables that are not included in our model.

9.7 Conclusions

The following can be concluded from the results of the third empirical study, an analysis of the Verdoorn law and the productivity-performance relationship for *118* firms listed on the *Amsterdam Stock Exchange*.

For our purpose, i.e., investigating the firm-based mechanisms of increasing returns, the Verdoorn law is the most adequate model to measure the extent to which firms are able to realize scale and learning effects from the potential for scale and learning effects.

Analogous to the Verdoorn law, we developed a second model, measuring the extent to which firms are able to exploit the realization of scale and learning effects to realize improvements in their performance.

For our model of the Verdoorn law, the interpretation of the parameter estimates is that the Verdoorn coefficient is the extent to which firms are able to realize scale effects and autonomous learning effects from the potentential for scale and learning effects and the constant term is the extent to which firms are able to realize induced and exogenous learning effects from the potentential for scale and learning effects.

For our model of the productivity-performance relationship, the interpretation of the parameter estimates is that the coefficient is the extent to which firms are able to increase their performance through the realization of scale and learning effects and the constant term is the extent to which firms are able to increase their performance independent of the realization of scale and learning effects.

This empirical study addressed hypotheses H_3 and H_5. Both models, the Verdoorn relationship and the productivity performance relationship, have been estimated for individual firms, for industries and for the entire sample of firms. The results support both hypothesis H_3 and hypothesis H_5. See table 9.19 below.

Research hypotheses:		Result:
H_1	The larger the social interaction effects, the larger the network effects	Not tested
H_{2a}	The larger the network effects, the larger the potential for scale and learning effects	Not tested
H_{2b}	The larger the social interaction effects, the larger the potential for scale and learning effects	Not tested
H_3	The larger the potential for scale and learning effects, the higher the realization of scale and learning effects	Partially supported
H_4	The higher the realization of scale and learning effects, the higher the level of product performance	Not tested
H_5	The higher the realization of scale and learning effects, the higher the level of organizational performance	Partially supported
H_6	The higher the level of product performance, the higher the level of organizational performance	Not tested

Table 9.19: Results on the research hypotheses

The most noticeable results from the firm-level estimation of the Verdoorn law are as follows. First, we found positive values of the Verdoorn coefficient, of, on average, between *0.399* and *0.542*, depending on whether the model was estimated for individual firms, for industries or for the total population. These values are in accordance with values found in previous empirical research into the Verdoorn law at the industry, region or country level. The positive Verdoorn coefficient indicates that firms are in general able to realize scale effects and autonomous learning effects. The average value of the Verdoorn coefficient for firms does not tell the entire story however, because (1) for the firm-specific models, the variance in values between firms seems to be considerable, with values ranging from *–0.799* to *2.451* and (2) for the industry-specific models and the model for the total population substantial corrections for changes in the capital-labor and capital-output ratios have to be made, resulting in substantially *lower* average values of the coefficient of between *0.231* and *0.258*. This means that (1) the variance in values found is rather high, which should not come as a surprise, however, because the variance at the firm level may be expected to be higher than the variance at the industry, regional or country level and, (2) the corrected average values found are somewhat below those generally found in previous research. This may mean that the Verdoorn law has become somewhat weaker in the past twenty years than it was during the 1950's to 1970's, the period that is reported on by, e.g., Kaldor (1966), Kennedy (1971), Vaciago (1975) or De Vries (1985).

A second noticeable result is that we found slightly negative values for the constant term, of, on average, between *–0.003* and *–0.014*, depending on whether the model was estimated for individual firms, for industries or for the entire population. This means that firms listed on the *Amsterdam Stock Exchange* are on average unable to realize induced and exogenous learning effects. Here, too, however, the variance between firms is considerable, with values ranging from *–0.185* to *0.045*, and the corrections due to changes in the capital-labor ratio cause the sign of the average constant term to switch from slightly negative to slightly positive, i.e., to between *0.002* and *0.009*.

The first noticeable result from the estimations of the productivity-performance relationship are the large positive values of the coefficient, of, on average, between *2.534* and *3.493*, depending on whether the model was estimated for individual firms, for industries or for the entire population. The large positive coefficient indicates that firms are generally able to exploit their realization of scale and learning effects to increase their performance. The average value of the coefficient for firms does not tell the entire story, however, because the variance in values between firms seems to be considerable, with values ranging from *0.321* to *17.262* (!). Although extreme values of the coefficient are nowhere in contradiction with the theory, they may be an indication of a possible problem with the validity of the model for that specific firm.

A second noticeable result is that we found, on average, small positive values for the constant term, of between *0.028* and *0.084*, depending on whether the model was estimated for individual firms, for industries or for the entire population. This means that firms listed on the *Amsterdam Stock Exchange* are generally able to increase their net profits partly independent of the rise in their productivity. This means that there are probably other variables, not included in our model, that influence firm performance. Here, too, however, the variance between firms is considerable, with values ranging from *–1.575* to *0.551*.

10. CONCLUSIONS, MANAGEMENT IMPLICATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

In this final chapter, we present the conclusions drawn from the research. In this thesis, we have made four contributions to the existing theory and research on increasing returns.

1. We further developed increasing returns theory from a management perspective, addressing the four mechanisms of increasing returns, i.e., network effects, social interaction effects, scale effects and learning effects, and their interrelations following the *structure-conduct-performance paradigm*, in an integral way.
2. We developed tools allowing us to measure the mechanisms of increasing returns, i.e., we developed a questionnaire with valid constructs for measuring network effects and social interaction effects and we conceptualized the firm-level Verdoorn law to measure scale and learning effects.
3. We performed three empirical studies into the relationships between the different mechanisms of increasing returns and into the relationship between the mechanisms of increasing returns and the performance of firms. The outcomes of these studies provide confidence in the developed measurement tools and in general confirm the hypothesized research framework.
4. In doing the three things listed above, we have provided a reliable framework that can be used to help managers understand the presence of increasing returns in their markets and their firms, allowing them to take conscious management actions based upon the consequences of this presence and to increase the performance of their products and their firms.

We address the conclusions drawn from the research presented in this thesis according to the central problem and the research questions in section one. In section two we address the limitations of the research and we make suggestions for further research to overcome these limitations. Finally, in section three we address the management implications to be drawn from the research and we make suggestions for further research based on these management implications.

10.1 Conclusions from the research

The central problem of this thesis was:

> ***What is the effect of market-based mechanisms of increasing returns on firm-based mechanisms of increasing returns and what is their joint effect on firm performance?***

Drawing conclusions from the research we can provide the following set of answers to this problem. First, we found evidence that the presence of the market-based mechanisms of increasing returns positively and significantly influences the presence of the firm-based mechanisms of increasing returns. Second, we found ample evidence that presence of the firm-based mechanisms of increasing returns positively and significantly influences firm performance. Third, we found no evidence for a *direct* influence of the presence of market-based mechanisms of increasing returns on firm performance. We conclude that, in the presence of market-based mechanisms of increasing returns, better firm performance is *only* achieved through the internalization and exploitation of the firm-based mechanisms of increasing returns.

Below, we discuss these conclusions in more detail following the order of the research questions as presented in section 1.3.

10.1.1 How can market-based and firm-based mechanisms of increasing returns be theoretically specified and defined?

A theoretical specification and definition of increasing returns was given in the theoretical part of this thesis. An introduction to, and a systematic study of, the literature in chapters two and three showed that four generic increasing returns mechanisms can be distinguished: (1) network effects, (2) social interaction effects, (3) scale effects and, (4) learning effects. Of these mechanisms, social interaction effects and network effects are market-based and scale effects and learning effects are firm-based. The common denominator of mechanisms is the possibility of each one to bring about a positive feedback effect. We therefore defined increasing returns as:

> ***Positive feedback effects in markets and firms***

The two market-based increasing returns mechanisms, namely network effects and social interaction effects, were theoretically specified in chapter four. Network effects occur when the economic utility to an economic agent of using a product or technology becomes larger as its network of users grows in size. The network effect may set in motion a positive feedback loop that will cause a product or technology to become more prevalent in the market. Social interaction effects occur when an economic agent's preference for a product or technology is dependent upon the opinions or expectations of other economic agents. The social interaction effect may set in motion a positive feedback loop that will cause agents to expect that a certain product or technology will become more prevalent in the market. Increased prevalence of a product or a technology will result in a market potential, to be exploited by the firms that are best able to internalize this potential.

The two firm-based mechanisms of increasing returns, namely scale effects and learning effects, were specified theoretically in chapter five. Scale effects occur when there is a positive static relationship between the size of output of a firm and its productivity. This is reflected in a downward slope of the firm's average total cost curve. Scale effects may set in motion a positive feedback loop when the firm can convert the cost advantage acquired through large production volumes into increasing sales volumes. Learning effects imply that there is a positive dynamic relationship between the firm's growth of output and its growth of productivity. This is reflected in a downward shift of the firm's average total cost curve. Learning effects may set in motion a positive feedback loop when the firm can convert the cost advantage acquired from productivity growth into further output growth.

The choice of the *positive feedback* definition means that to speak of increasing returns the positive feedback loop has to be closed. For firm-based increasing returns this means that, because of the presence of network effects and social interaction effects there may be a *potential* for scale effects and learning effects in the market but that this potential is not increasing returns as such. It only becomes so when these scale and learning effects are *used* by the firm in such a way that further cost improvements or further productivity growth become possible. According to this theoretical specification, we made an explicit distinction between the *potential* for scale and learning effects and the *realization* of scale and learning effects.

The theoretical specification of increasing returns from a management perspective resulted in the following research model (see figure 10.1).

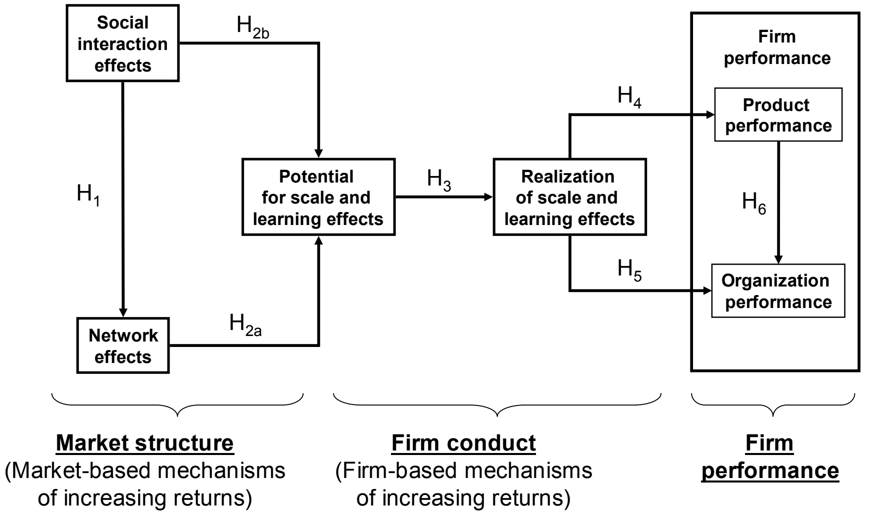

Figure 10-1: Research model

Based on this research model, measurement models were constructed and the hypothesized relationships were studied empirically.

10.1.2 How can market-based and firm-based mechanisms of increasing returns be measured?

In the first, second and third empirical studies, chapters seven, eight and nine, respectively, instruments were developed for measuring the market-based and firm-based mechanisms of increasing returns. In the first empirical study, subjective measures were developed for social interaction effects, for network effects, for the potential and the realization of scale and learning effects and for a number of influencing factors. These measures were developed and validated according to Churchill's (1979) steps 'for developing better measures of marketing constructs.' It was concluded that network effects and social interaction effects can both be conceptualized as second-order constructs, each consisting of two first-order constructs at the product level and the technology level. Regarding scale and learning effects it turned out to be very difficult for respondents to differentiate between those. Therefore, we concluded that scale and learning effects could best be captured in a single construct, albeit distinguishing between the *potential* and the *realization* of scale and learning effects. Firm performance was measured using scales that were adapted from Griffin & Page (1996), Naman & Slevin (1993) and Slater & Narver (1994).

In the second empirical study, subjective and objective measurements were combined. The subjective scales for measuring network effects and social interaction effects were slightly adjusted for capturing the comparative static time frame of the study and were revalidated. The validity of these measures was confirmed and we may therefore conclude that these measures can be applied with confidence to measure network effects and social interaction effects. Objective measurements were developed for measuring the potential and realization of scale and learning effects and for measuring firm performance. We argued in chapter six that *for practical measurement at the firm level* it is almost impossible to differentiate between scale effects and learning effects. The potential for scale and learning effects was measured as the growth in firm output, the realization of scale and learning effects was measured as the growth in the firm's labor productivity and firm performance was measured as the growth in the firm's net profit. The data were closely scrutinized and corrected to ensure the validity of these measures.

In the third empirical study, the objective measures from the second empirical study were further developed and made fit to be applied to the individual firm. To measure the extent to which individual firms are able to realize scale and learning effects from the potential for scale and learning effects, we conceptualized the *Verdoorn law*, a long-term linear relationship between the growth in output and the growth in labor productivity, for the firm level. Analogous to the Verdoorn law, we developed a model relating the growth of productivity to the growth of net profit, reflecting the extent to which firms are able to exploit realization of scale and learning effects to attain better firm performance. The data were closely scrutinized and corrected to ensure the validity of these measures. Corrections were made on the firm-level Verdoorn models for changes in the *capital-labor* and *capital-output* ratios. We conclude that these measures can be applied with confidence to measure the relationship between the potential and the realization of scale and learning effects and the relationship between the realization of scale and learning effects and firm performance, respectively.

10.1.3 What is the effect of market-based mechanisms of increasing returns on firm-based mechanisms of increasing returns?

This relationship was investigated in the first and second empirical studies. First it was established in both these studies that network effects and social interaction effects are present across industries. This is quite a surprising result, because following the increasing returns literature, e.g., Arthur (1996) and Economides (1996), we expected these effects to be much higher in the 'high-tech' or knowledge-intensive industries. A possible explanation for the absence of the expected industry differences is that we are generally inclined to think of technology in terms of the current 'high-tech' industries and we tend to forget that many of the current 'low-tech' industries are also strongly technology driven. For example, in our research, we have found dominant technologies for the pressing of plastic parts, for the extrusion of metal profiles, for the manufacturing of orthopedic shoes or for the configuration of central heating systems. In other words, the distinction between 'high-tech' and 'low-tech', with the connotation that 'high-tech' will be dominated by increasing returns and 'low-tech' will not, may be illusory.

Second, it was established in the first and second empirical studies that, within the market-based mechanisms of increasing returns, network effects are influenced by social interaction effects. The explanation for this may be that we defined, and measured, social interaction effects mainly in terms of expectations about products or technologies and network effects mainly in terms of actual behavior and that it is common sense that expectations will precede and influence actual behavior. It was found in the first empirical study that this relationship between social interaction effects and network effects is influenced by technological substitutability and by product complementarity and compatibility, and is stable for product substitutability, for technological complementarity and compatibility, for knowledge intensity of the product and for lock-in, market predictability and path dependence.

Third, in the first and second empirical studies, we found evidence that social interaction effects and network effects positively and significantly influence the presence of a market potential for scale and learning effects. In the first empirical study we found no significant *direct* relationship between social interaction effects and the potential for scale and learning effects, but we did find a significant *indirect* relationship through the influence of network effects. In the second empirical study we found that the presence of network effects completely mediates the relationship between social interaction effects and the potential for scale and learning effects. It was found in the first empirical study that this relationship between (1) social interaction effects and (2) network effects and the potential for scale and learning effects is stable for product and technological substitutability, for product and technological complementarity and compatibility, for the knowledge intensity of the product and for lock-in, market predictability and path dependence.

With respect to our triangulation approach, we may conclude that the within-method triangulation of the first and second empirical studies increases our confidence in the existence of social interaction effects and network effects across industries, in the existence of a positive relationship between social interaction effects and network effects and in the existence of a positive relationship between (1) social interaction effects and (2) network effects and the potential for scale and learning effects.

10.1.4 What is the joint effect of market-based and firm-based mechanisms of increasing returns on firm performance?

In the first and second empirical studies we investigated the effect of the market-based mechanisms of increasing returns on firm performance. No evidence was found in either study for a *direct* relationship between the presence of social interaction effect and network effects and firm performance. We therefore conclude that when a firm wants to achieve better performance in a market where social interaction effects and/or network effects are present, it can only do so through internalizing the potential for scale and learning effects and subsequently exploiting the realized potential.

The relationships between the potential and the realization of scale and learning effects and between the realization of scale and learning effects and firm performance have been investigated in the first, second and third empirical studies. In every one of those studies we found evidence for significant and positive relationships between the potential and the realization of scale and learning effects and between the realization of scale and learning effects and firm performance. It was found in the first empirical study that this relationship between the potential and the realization of scale and learning effects is stable for product and technological substitutability, for product and technological complementarity and compatibility, and surprisingly, for knowledge intensity of the product.

With respect to our triangulation approach, we may conclude that the within-method triangulation of the first and second empirical studies increases our confidence in the absence of the direct relationship between network and social interaction effects and firm performance and increases our confidence in the existence of a positive relationship between the potential and the realization of scale and learning effects. The between-method triangulation approach of the first, second and third empirical studies also greatly increases our confidence in the existence of this latter relationship and in the positive relationship between the realization of scale and learning effects and firm performance.

10.1.5 Summarizing the conclusions on the hypotheses

The conclusions for the research hypotheses are summarized in table 10.1 below.

Research hypotheses:		First empirical study	Second empirical study	Third empirical study
H_1	The larger the social interaction effects, the larger the network effects	Supported	Supported	Not tested
H_{2a}	The larger the network effects, the larger the potential for scale and learning effects	Supported	Supported	Not tested
H_{2b}	The larger the social interaction effects, the larger the potential for scale and learning effects	Not supported[#]	Supported	Not tested
H_3	The larger the potential for scale and learning effects, the higher the realization of scale and learning effects	Supported	Supported	Partially supported
H_4	The higher the realization of scale and learning effects, the higher the level of product performance	Supported	Not tested	Not tested
H_5	The higher the realization of scale and learning effects, the higher the level of organizational performance	Supported	Supported	Partially supported
H_6	The higher the level of product performance, the higher the level of organizational performance	Supported	Not tested	Not tested
[#] There is, however, an indirect influence of social interaction effects on the potential for scale and learning effects through the support of hypotheses H_1 and H_{2a}				

Table 10.1: Summary of the results for the research hypotheses

10.2 Limitations and suggestions for further research

This thesis is limited by several factors that should be addressed in future research. These factors are discussed according to their relationship with the chosen basic research paradigm, with the chosen measurement tools and methods of analysis or with the results of the research.

10.2.1 Limitations and further research with regard to the choice of the research paradigm – theory of the firm

First, we chose to mold the research around the *structure-conduct-performance paradigm* that was originally developed within *industrial organization theory*. This approach enabled us to focus the research and to root it in a recognized theoretical and empirical tradition, however, it limited the research, because the choice for the *structure-conduct-performance paradigm* implies that we take the developments in the market as the starting point of the analysis. For further research, it would therefore be interesting to study increasing returns and its implications for firm performance from a *resource-based perspective*, i.e., taking the firm as the starting point of the analysis.

Second, we chose to include into the research only the primary relationships of the *structure-conduct-performance paradigm*, i.e., the relationship between market structure and firm conduct, the relationship between firm conduct and firm performance and, in the alternative research models tested in the first and second empirical studies, the relationship between market structure and firm performance. Further research should include the feedback loops between firm conduct and market structure and between firm performance and firm conduct and between firm performance and market structure. This will enable research into how firms can influence the direction and extent of the market-based mechanisms of increasing returns. In further research the dynamic aspects of increasing returns should also be taken into account, enabling more in-depth research into the dynamics of technology battles, of lock-in effects, of excess inertia and excess momentum, of path dependence and of the strategies of individual firms with respect to these issues.

Third, in this thesis we used the *structure-conduct-performance paradigm* in a narrow definition, in the sense that we abstracted from public policy influences on market structure and firm conduct. As the famous legal cases between the United States and the European Union and some of the worlds' largest software firms have shown, the presence of increasing returns mechanisms in markets and the behavior of firms in such markets may evoke strong legal and public reactions. These issues should be addressed in further research.

10.2.2 Limitations and further research with regard to the measurement tools and the methods of analysis

With regard to the developed measurement tools and the methods of analysis chosen, the following limitations can be identified.

First, in this thesis we used several newly developed measures to collect data from firms in different industries to test the hypotheses. In future research, the psychometric properties of the measures and the hypothesized relationships should be tested using other independent samples.

The subjective data for this thesis were collected using the *key informant approach*, which precludes a thorough analysis of measurement error. In future research it would be useful to use *multiple respondents* at different positions within the organization. This will enable us to use more advanced modeling techniques to test the hypotheses.

In the measurement of the subjective data we encountered problems with the validation of the constructs market predictability, product complementarity and compatibility, technological complementarity and compatibility and knowledge intensity of products. In future research the specification and the measurement of these constructs should be further addressed. In the measurement of the constructs of the potential of scale and learning effects and the realization of scale and learning effects we encountered the problem that (1) in the test phase respondents indicated that they were unable to distinguish between scale effects and learning effects, and hence we combined them in a single construct, but that (2) in the final questionnaire respondents nevertheless implicitly differentiated between scale effects and learning effects, through not enough to split them into separate constructs. This problem should be addressed in future research by re-specifying the constructs for measuring scale and learning effects.

In the measurement of the objective data, we were also confronted with the practical difficulties of distinguishing between scale effects and learning effects. Managers participating in our pilot checks indicated an unwillingness to share the detailed financial information needed to perform distinct measurements of scale effects and learning effects, at least for large-scale research. This limitation may be overcome by conducting research on a smaller scale, e.g., through case studies, enabling detailed financial analysis of firms or business units. Such an approach did not fit the aims of this thesis, but might be used in future research.

In the first and second empirical studies, we conducted cross-sectional research based on *static* and *comparative static* research models, respectively. For future research, it would be interesting to follow individual firms or collections of firms longitudinally to address more in-depth the dynamic aspects of increasing returns and its consequences for the strategies of firms and to confirm the causal inferences made in the current empirical studies.

In the third empirical study we chose to measure the relationship between output and productivity, i.e., between the potential and the realization of scale and learning effects, at the firm level. Zegveld (2000) performed a similar analysis using an adaptation of the Solow (1957) model to measure productivity increases at the firm level. For this study, however, we chose not to use the Solow model, but rather a firm-level specification of the Verdoorn law (Verdoorn, 1949; Kaldor, 1966). For future research it would be interesting to investigate the differences between the measurements based on the firm-level Verdoorn law and the firm-level Solow residual.

In the second and third empirical studies we measured the relationships between the growth of output and the growth of productivity and between the growth of productivity and the growth of net profit representing the relationships between the potential and the realization of scale and learning effects and between the realization of scale and learning effects and firm performance. This choice of measurements implies that in our research the firm was considered to be a 'black box'. Further research should enter this 'black box' and test our finding against substantive evidence, e.g., of the buildup of capabilities that enable a firm to internalize the potential for scale and learning effects or to exploit scale and learning effect. Here, too, a longitudinal research design would provide more in-depth insights into the process of how firms adapt to the presence of increasing returns.

In this thesis we made no use of game-theoretic modeling, despite the fact that game theory is widely used in many theoretical contributions to the increasing returns literature. The reason for this was that with our research we aimed to deliver theoretically integrative and empirical contributions, rather than adding to the already extensive game-theoretical body of knowledge on increasing returns. Nevertheless it has been pointed out to us that using game-theoretic models, e.g., to conceptualize the directions of interaction effects between the different mechanisms of increasing returns, might be a challenging goal for future research.[91]

Analogously, we paid limited attention to mathematical-economic analysis or increasing returns. Here, too, the reason was that we chose to focus on the integrative and empirical contribution rather than on delivering a contribution to the already extensive mathematical-economic body of knowledge on increasing returns. Nevertheless, the mathematical-economic aspects could be addressed in further research, especially with regard to further development of the firm-level Verdoorn model and its relationships with other productivity measurements.

10.2.3 Limitations and further research with regard to the research results

With regard to the results of the empirical studies, a number of limitations can be recognized.

First, in this thesis we studied, among others, the following relationships:

- the relationship between (1) social interaction effects and (2) network effects and the potential for scale and learning effects
- the relationship between the potential and the realization of scale and learning effects
- the relationship between the realization of scale and learning effects and firm performance

It became clear from the values found from the estimations of these relationships that there must be other factors at the firm level and at the market level that also influence the potential of scale and learning effects, the realization of scale and learning effects and firm performance. We may think of market-level factors like, e.g., size and growth of the market, the number and size distribution of firms active in this market or the number and size distribution of customers active in this market. We may think of firm-level factors like, e.g., existing firm resources and capabilities, the speed with which firms can build resources and capabilities, existing levels of process efficiency and product differentiation or the quality of the firm's management. Future research should address these factors and incorporate them into the research to achieve better specifications and stronger estimates for these relationships.

[91] We would like to thank an anonymous reviewer of the *Strategic Management Journal* for bringing this to our attention.

Second, in this thesis we only addressed influencing, i.e., moderating effects in the first empirical study by testing the stability of the relationships between social interaction effects and network effects, between (1) social interaction effects and (2) network effects and the potential for scale and learning effects and between the potential and the realization of scale and learning effects. In future research moderating effects these relationships and on other relationships in the model should be addressed more formally and in more detail. In future research, moderating effects should also be addressed for the relationships that were estimated on the basis of the financial measurements, i.e., on relationships studied in the second and third empirical studies.

Third, in this thesis we only addressed a limited number of moderating variables, namely technological substitutability, technological complementarity and compatibility, product substitutability, product complementarity and compatibility, knowledge intensity of the product and lock-in, market predictability and path dependence. In the sections 4.3, 5.4, 5.5 and 5.6 many more variables were addressed that can be expected to moderate the relationships of our general research model. These moderating variables have not been addressed in this thesis, for two different reasons. The first and foremost reason was that addressing all these moderators fell outside the scope of our research, which was primarily aimed at measuring the mechanisms of increasing returns and empirically studying their interrelations and their relationships with firm performance. To do this, we started by studying the main relationships. Moderating relationships, however interesting, were a second priority. Nevertheless, in further research these moderators and their effects should be further explored. Specifically we think of the following variables: marginal gains of network size, conformity and individuality, degree and structure of economic interdependence and nature of the technology, addressed in section 4.3; the factors limiting the extent of scale effects and of learning effects, addressed in section 5.4; the firm's strategies for internalizing the potential for scale and learning effects, addressed in section 5.5; the generic strategies for value creation, addressed in section 5.6. The second reason for not incorporating all possible moderators was that for some of these variables a preliminary analysis of the measurement model (not reported) showed a general lack of validity, specifically the variables with respect to the nature of the product, i.e., industrial or consumer product, product tangibility and product durability. The measurements of these variables should be properly addressed in future research.

10.3 Management implications

Increasing returns is important for managers because it influences market outcomes and firm performance. Managers can not afford to ignore increasing returns; therefore, the research presented in this thesis has important implications for managers.

10.3.1 Management framework

We showed in the research that increasing returns exists in markets, in the forms of network effects and social interaction effects. This is important for managers because it means that their markets will function differently than conventional economic theory predicts: competition shifts from the product level to the technology network level, technology battles will emerge, in which the *winner takes all*, technologies may become locked in, markets may become less predictable, i.e., showing excess inertia or excess momentum, technology diffusion processes may become path dependent and it is not even assured that the best technology or the best firm will win the battle. These are disturbing implications, and firms will have to adjust their behavior to be able to survive.

An important additional finding is that increasing returns is not something only found in the high-tech industries; it is found across industry sectors. Increasing returns is therefore not just a hype to be associated with the 'new economy', but rather something that every firm in every industry sector may encounter and may have to deal with.

In the research we showed that these market-level implications create a market potential for scale and learning effects. It is up to individual firms to realize this potential. To do so, firms first have to *internalize* it, i.e., convert a market-level potential into a firm-level potential. Firms can do so by making the right strategic choices, e.g., by choosing a *shaper* or an *adapter* or a *reserving the right to play strategy*, by learning how to fight technology battles, by learning how to influence market expectations, by learning how to avoid lock-out situations, by competing at the network level and by exploiting their installed base.

It was further shown in the research that firms could only profit from the presence of network effects and social interaction effects in the market by *realizing* scale and learning effects within the firm. Firms only realize scale and learning effects by closing the positive feedback loop, i.e., by using the productivity gains from scale and learning effects to improve their value proposition in the market in such a way that it results in a higher market share, a larger production volume, and therefore a larger potential for scale and learning effects. Firms can do this by further capitalizing on their strategy used to internalize the potential for scale and learning effects and by pursuing generic competitive strategy as described by Porter (1980; 1985), e.g., *cost-leadership*, *differentiation* or *focus*.

Finally, it was shown in the research that the firm's ability to realize scale and learning effects, i.e., increasing productivity, is an important factor influencing firm performance. This performance improvement is part of the feedback loop described above: productivity advantages from scale and learning effects may be used to improve the firm's product proposition in the market, causing higher sales, higher market share and higher contribution margins, i.e., better product performance; and to improve business processes and spread best practices throughout the organization, causing efficiency improvements and higher profitability, i.e., better firm performance.

The implications of the above reasoning for managers are threefold. First, managers will have to understand the relationships between the different mechanisms of increasing returns, their influences on market outcomes and their influences on firm performance. Our research provides the building blocks for a framework that enables managers to do just so (see figure 10.2).

Second, managers have to be able to recognize and identify the increasing returns sensitivity of their markets and their firms.

Third, managers have to be able to act strategically upon the presence of increasing returns in their markets and firms and to exploit opportunities when they arise. Below, we discuss these two management implications and their consequences for further research.

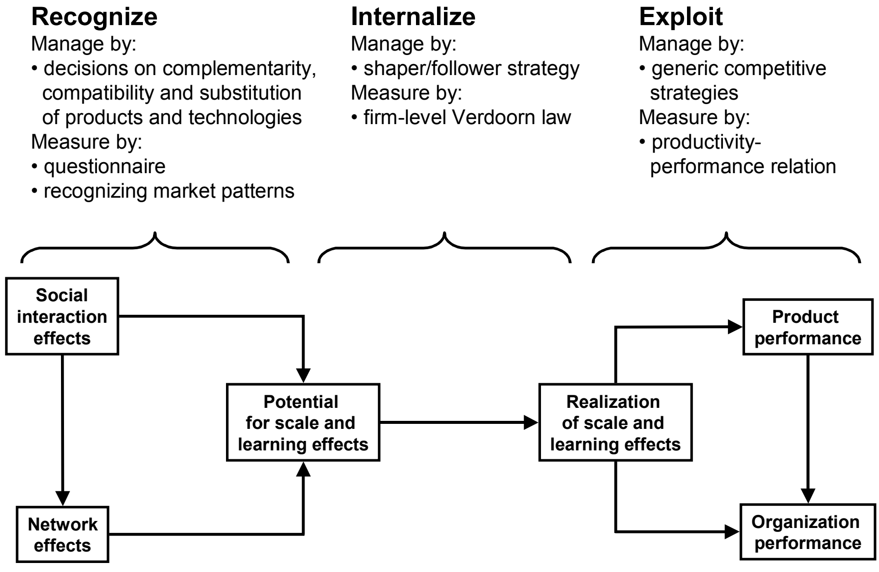

Figure 10-2: Management framework

10.3.2 Management implications and further research

The second management implication is that managers have to be able to recognize and identify the increasing returns sensitivity of their markets and their firms. Our research provides a measurement tool in the form of a questionnaire that can be used to assist managers wit this task. In further research new tools and methods will have to be designed to enable managers to determine the increasing returns sensitivity of their markets and firms.

Besides tools and methods, future research should address the way in which industry characteristics determine the increasing returns sensitivity of markets, i.e., the presence of network effects and social interaction effects. Examples of industry characteristics that may be of influence on the presence of increasing returns in the market are size and growth of the market, the number and size distribution of firms active in this market and the number and size distribution of customers active in this market. Specifically, the influence of the degree and structure of economic interdependence on the extent of network effects and social interaction effects should be addressed in future research. In other words: How does the composition and structure of a business ecosystem, i.e., the collection of suppliers, vendors, partners and customers in the market, influence the presence of increasing returns in the market?

Analogous to industry characteristics, future research should address the way in which firm characteristics determine the increasing returns sensitivity of firms, i.e., the presence of scale effects and learning effects. Examples of firm characteristics that may be of influence on the presence of increasing returns in the firm are existing firm resources and capabilities, the speed with which firms can build resources and capabilities, existing levels of process efficiency and product differentiation and the quality of the firm's management. Our research provides only a limited description of the market patterns that managers can use to recognize increasing returns in their markets. The characterization of such patterns and the management tools needed to detect them should be addressed in future research.

The third management implication is that managers have to be able to act strategically upon the presence of increasing returns in their markets and firms and to exploit opportunities when they arise. They can only do so if the first and second implications have been fulfilled, i.e., if they understand increasing returns and if they are able to recognize and identify them. Our research provides the generic strategic actions firms can take to internalize the potential for scale and learning effects and to exploit scale and learning effects.

Our research also provides measurement tools that managers can use to assess how successful they are in their strategic actions upon the presence of increasing returns, i.e., the firm-level Verdoorn law for measuring the success of internalizing the potential for scale and learning effects and the productivity-performance relationship for measuring the success of exploiting scale and learning effects. In further research, the possible strategic actions that firms can take to internalize the potential for scale and learning effects and to exploit scale and learning effects should be worked out in much more detail. Possible questions to be addressed are: How can firms internalize the market potential that stems from the presence of network and social interaction effects? How can firms optimally realize this potential? How can they convert the realized potential into superior performance and into sustainable competitive advantage? How can such an advantage be used to create a favorable starting position with regard to the next technology generation?

These questions will have to be answered in different ways, depending on the type of strategy the firm chooses, i.e., a *shaper* or an *adapter* strategy. Important questions are therefore why and when the firm should choose a shaper strategy and why and when the firm should choose an adapter strategy. The specific implications of the choice for an adapter strategy require further insight into questions like: How can a firm identify the current state of the market and determine the appropriate adaptation strategy? When does a technology reach sufficient critical mass to become the market standard? When should a firm enter the market? To what technological standard should the firm adapt? What resources should the firm acquire and what capabilities should it build on to ensure success?

The specific implications of the choice for a *shaper strategy* require further insight into questions like: To what extent can the firm influence or set in motion the market-based mechanisms of increasing returns? How can the firm influence the outcomes of these mechanisms and how can these outcomes be converted into firm-specific advantage? What resources should the firm acquire and what capabilities should it build on to ensure success?

Besides these conceptualizations of firm strategies, there is also a need to test whether these strategies are indeed the determinant factors of firm success. Eventually, firms will not be satisfied with strategies to internalize and exploit existing increasing returns. Rather, managers of such firms will want to *manage*, or better: *govern*, the increasing returns mechanisms in the market to their own advantage. In future research therefore questions like: How can a firm influence its market structure in such a way that the diffusion of a new technology maximally enhances the firm's performance? should be addressed. Analogous to this question, public policy makers may ask: How can government agencies or public-private partnerships influence the market structure in such a way that the diffusion of a new technology maximally enhances market efficiency or social welfare?

10.3.3 Concluding

We conclude from the research that increasing returns in markets and firms is an important factor determining firm success and failure. The success stories of firms that have won technology battles in increasing returns markets are well known. Examples are *Microsoft* with *MS-DOS, MS-Windows, MS-Office* and *MS Internet Explorer*, *JVC* with the *VHS* video system, *Sony* with the *Playstation* game console and *Philips* and *Sony* with the Compact Disc: the failures get little publicity. We should recognize that the mechanisms of increasing returns can bring increasing prosperity, but they can also bring increasing misery for firms that lose the technology battle. Examples are *Netscape* with its *Navigator* web browser, *Sony* with its *Betamax* video system, *Sega* with its game console and *Philips* with its *CD-Interactive*. Arthur (1996) even talks about the 'casino of technology', in which the mechanisms of increasing returns plus a large portion of luck and chance determine the very survival of the firm. This may give the impression that competing in increasing returns markets is like playing a game of *Russian roulette*, in which managers and their firms are at the mercy of erratic market forces. We think this is not the whole truth: we think that, provided that managers understand the mechanisms of increasing returns and their consequences, they are certainly capable of dealing with the challenges of competing in increasing returns markets.

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APPENDIX I: ITEMS FROM THE QUESTIONNAIRE USED IN THE FIRST EMPIRICAL STUDY

A star (*) behind an item indicates that this item was not included in the final construct.

Market-based mechanisms of increasing returns

Product-related social interaction effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market the attractiveness of our primary product will increase if:

- it becomes known that opinion leaders among customers use this product
- it becomes known that lead suppliers offer this product
- it is expected that more customers will start to use this product
- it is expected that more suppliers will start to offer this product

Technology-related social interaction effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market the attractiveness of our primary product's technology will increase if:

- it becomes known that opinion leaders among customers use products based on this product technology
- it becomes known that lead suppliers offer products based on this product technology
- it is expected that more customers will start to use products based on this product technology
- it is expected that more suppliers will start to offer products based on this product technology

Product-related network effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market the attractiveness of our product will increase if:

- more customers use this product
- more suppliers offer this product
- more customers use complementary products
- more suppliers offer complementary products

Technology-related network effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market the attractiveness of our primary product's technology will increase if:

- more customers use products based on this product technology
- more suppliers offer products based on this product technology
- more customers use complementary products based on this product technology
- more suppliers offer complementary products based on this product technology

Firm-based mechanisms of increasing returns

Potential for scale and learning effects

Instruction: realization of economies of scale means that through a higher sales volume in units your firm is able to:

- lower the fixed costs per unit volume
- lower the variable costs per unit volume

Appendix I

Realization of economies of learning means that your firm is able to increase efficiency through increasing knowledge and experience. Here: 1 = very low potential, 7 = very high potential.

What is the potential for your primary product to:

- realize economies of scale with regard to fixed costs?
- realize economies of scale with regard to variable costs?
- realize economies of learning?

Realization of scale and learning effects

Instruction: please use the following scale to indicate how well your firm utilizes the potential for economies of scale and learning. Here: 1 = very poor utilization, 7 = very good utilization.

To what extent has your firm been able to utilize the potential for:

- economies of scale with regard to fixed costs?
- economies of scale with regard to variable costs?
- economies of learning?

Firm performance

Product performance

Instruction: please use the following scale to indicate the extent of your agreement about how well your primary product has performed on each of the performance indicators mentioned below. Here: 1 = very poor and 7 = very good.

Product Performance:

- customer acceptance (*)
- customer satisfaction (*)
- unit sales volume
- sales growth
- market share
- contribution margin
- price/quality ratio (*)
- development costs (*)
- integral cost price (*)

- product innovativeness (*)

Organizational performance

Instruction: please use the following scale to indicate the extent of your agreement about how well your firm has performed over the last year relative to competitors on each of the performance indicators mentioned below. Here: 1 = very much poorer and 7 = very much better.

Organizational performance:

- sales growth
- market share
- new product success
- sales share new products, i.e., products introduced last 5 years
- operational cash flow
- profitability
- ROI or IRR

Moderators

Product complementarity and compatibility

Instruction: please use the following scale to indicate the extent of your agreement about the extent to which customers use your primary product and product technology together with complementary products? Here: 1 = very small extent and 7 = very large extent.

To what extent:

- do customers use your primary product together with complementary products?
- is your primary product compatible with complementary products?

Technology complementarity and compatibility

Instruction: please use the following scale to indicate the extent of your agreement about the extent to which your primary product and product technology is compatible with complementary products and product technologies. Here: 1 = very small extent and 7 = very large extent.

To what extent:

- do customers use your product technology together with complementary product technologies?
- is your product technology compatible with complementary product technologies?

Path dependence

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market where our primary product is traded:

- the existing preferences of end users influence the future preferences of end users
- the existing market share of a product influences the future market share of this product
- the existing market share of a supplier influences the future market share of this supplier
- the existing market share of a product technology influences the future market share of this product technology (*)

Lock-in effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market where our primary product is traded:

- it is, in terms of time, money and effort, costly for end users to change between the products of different suppliers (*)
- it is, in terms of time, money and effort, costly for end users to change between suppliers (*)
- it is, in terms of time, money and effort, costly for end users to change between product technologies

- it is, in terms of time, money and effort, costly for suppliers to change between product technologies

Product substitution effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market where our primary product is traded:

- end users consider the different products traded as substitutes, i.e., as equal alternatives
- end users consider the different suppliers as substitutes, i.e., as equal alternatives

Technology substitution effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market where our primary product is traded:

- end users consider the different product technologies as substitutes, i.e., as equal alternatives
- suppliers consider the different product technologies as substitutes, i.e., as equal alternatives

Market predictability

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In the market where our primary product is traded:

- the market situation next year will be different from the market situation today (*)
- the market developments are predictable
- the technological developments are predictable

Labor-capital-knowledge intensity

A 7-point semantic differential scale was used for each of the characteristics.

Instruction: the questions below relate to the primary product of your firm.

One the scale below, where do you position your primary product with respect to the following characteristics:

- labor intensive versus capital intensive product? (*)
- capital intensive versus knowledge intensive product?
- knowledge intensive versus labor intensive product?

APPENDIX II: ITEMS FROM THE QUESTIONNAIRE USED IN THE SECOND EMPIRICAL STUDY

A star (*) behind an item indicates that this item was not included in the analysis.

Market-based mechanisms of increasing returns

Product-related social interaction effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In our market the attractiveness of the primary product has increased in the past 5 to 10 years, because:

- it became known that opinion leaders among customers started using this product
- it became known that lead suppliers started offering this product
- it was expected that more customers would be going to start using this product
- it was expected that more suppliers would be going to start offering this product

Technology-related social interaction effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In our market the attractiveness of the primary product technology has increased in the past 5 to 10 years, because:

- it became known that opinion leaders among customers started using products based on this product technology
- it became known that lead suppliers started offering products based on this product technology

- it was expected that more customers would be going to start using products based on this product technology
- it was expected that more suppliers would be going to start offering products based on this product technology

Product-related network effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In our market the attractiveness of the primary product has increased in the past 5 to 10 years, because:

- more customers started using this product
- more suppliers started offering this product
- more customers started using complementary products
- more suppliers started offering complementary products

Technology-related network effects

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In our market the attractiveness of the primary product technology has increased in the past 5 to 10 years, because:

- more customers started using products based on this product technology
- more suppliers started offering products based on this product technology
- more customers started using complementary products based on this product technology
- more suppliers started offering complementary products based on this product technology

Dependent variables: market dominance

Instruction: please use the following scale to indicate the extent of your agreement about how well each of the following statements is an accurate description of the market that you serve with your primary product. Here: 1 = strongly disagree, 7 = strongly agree.

In our market:

- in the past 5 to 10 years one of the products has become increasingly dominant (*)
- in the past 5 to 10 years one of the suppliers has become increasingly dominant (*)
- in the past 5 to 10 years one of the product technologies has become increasingly dominant

APPENDIX III: LIST OF FIRMS FROM THE SECOND AND THIRD EMPIRICAL STUDIES

Firm name	Corrected sampling frame second empirical study (Chapter 8)	Sample second empirical study (Chapter 8)	Sample third empirical study, individual firm analyses (Chapter 9)	Sample third empirical study, industry analyses (Chapter 9)
Aalberts Industries	1	0	1	1
ABN-Amro	1	1	1	1
Achmea	1	1	1	1
AEGON	1	0	1	1
Ahold	1	0	1	1
Ahrend	1	1	1	1
AKZO-Nobel	1	1	1	1
Amstelland	0	0	0	1
Arcadis	1	1	1	1
ASM International	1	0	1	1
ASM Lithography	1	1	1	1
ASR Verzekerings-groep	0	0	1	1
Atag	0	0	1	1
Athlon	1	1	1	1
Baan Company	0	0	0	1
Ballast-Nedam	1	0	1	1
BAM	1	0	1	1
Batenburg	1	0	1	1
Beers	0	0	1	1
Begemann	0	0	1	1
BE Semiconductor Industries	1	1	1	1
Blydenstein-Willink	1	1	1	1
Boskalis-Westminster	1	0	1	1
Brocacef	0	0	1	1
Buhrmann	1	0	1	1
CAP Gemini	0	0	1	1
Cindu	0	0	1	1
CMG	1	0	1	1
Content	0	0	1	1
Corus	0	0	1	1
Crédit Lyonnais Nederland	0	0	1	1

Firm name	Corrected sampling frame second empirical study (Chapter 8)	Sample second empirical study (Chapter 8)	Sample third empirical study, individual firm analyses (Chapter 9)	Sample third empirical study, industry analyses (Chapter 9)
CSM	1	0	1	1
Delft Instruments	1	1	1	1
Draka	1	0	1	1
DSM	1	0	1	1
Endemol	0	0	0	1
EVC	1	0	1	1
Exendis	1	0	1	1
Fortis	1	1	1	1
Frans Maas	1	0	1	1
Free Record Shop	1	0	1	1
Friesland-Coberco Dairy Foods	0	0	0	1
Fugro	1	1	1	1
Gamma Holding	1	0	1	1
Gelderse Papier	0	0	1	1
Getronics	1	1	1	1
Geveke	1	0	1	1
Van der Giessen	0	0	1	1
Gist-Brocades	0	0	1	1
Grolsch	1	1	1	1
Grontmij	1	0	1	1
GTI	0	0	1	1
Gucci	0	0	1	1
Hagemeyer	1	0	1	1
HBG	1	1	1	1
Heijmans	1	1	1	1
Heineken	1	0	1	1
Hunter Douglas	1	0	1	1
IHC Caland	1	1	1	1
Imtech	1	0	1	1
ING Group	1	0	1	1
KAS Bank	1	1	1	1
KBB	0	0	1	1
Kempen & Co.	1	0	1	1
KLM	1	1	1	1
KPN	1	1	1	1
Landis	0	0	0	1
Landré	0	0	1	1
Laurus	1	0	1	1

Firm name	Corrected sampling frame second empirical study (Chapter 8)	Sample second empirical study (Chapter 8)	Sample third empirical study, individual firm analyses (Chapter 9)	Sample third empirical study, industry analyses (Chapter 9)
LCI	0	0	1	1
Van Leer	0	0	1	1
Libertel	0	0	0	1
Macintosh	1	0	1	1
Van Melle	0	0	1	1
Bank Mendes Gans	0	0	1	1
Van der Moolen	1	0	1	1
NBM	0	0	1	1
NEDAP	1	0	1	1
Nedlloyd	1	0	1	1
Neways	1	1	1	1
NIB Capital	1	0	1	1
NKF	0	0	1	1
Norit	1	0	1	1
NS	0	0	1	1
Numico	1	1	1	1
Nutreco	1	0	1	1
Océ	1	1	1	1
Van Ommeren	0	0	1	1
OPG	1	0	1	1
Ordina	1	0	1	1
Otra	0	0	1	1
P&C Group	0	0	1	1
P&O Nedlloyd	0	0	0	1
Pakhoed	0	0	1	1
Philips	1	0	1	1
Pink Roccade	0	0	0	1
Polygram	0	0	1	1
Polynorm	1	1	1	1
Randstad	1	1	1	1
Reed Elsevier	1	0	1	1
Rood Testhouse	1	0	1	1
Royal Begemann Group	0	0	1	1
Samas	1	1	1	1
Schuitema	1	0	1	1
Royal Dutch/Shell Group	1	1	1	1

Firm name	Corrected sampling frame second empirical study (Chapter 8)	Sample second empirical study (Chapter 8)	Sample third empirical study, individual firm analyses (Chapter 9)	Sample third empirical study, industry analyses (Chapter 9)
Simac	1	1	1	1
Smit Internationale	1	0	1	1
SNS Bank	1	1	1	1
Sphinx	0	0	1	1
Staal Bankiers	0	0	1	1
Stork	1	0	1	1
Telegraaf	1	0	1	1
Ten Cate	1	1	1	1
TPG	0	0	0	1
Tulip	0	0	1	1
Twentsche Kabel Holding	1	0	1	1
Unilever	1	0	1	1
Unit4 Agresso	0	0	0	1
UPC	0	0	0	1
Vedior	0	0	0	1
Vendex KBB	1	1	1	1
Versatel	0	0	0	1
Vilenzo	0	0	1	1
VNU	1	1	1	1
VOPAK	1	1	1	1
Vredestein	1	1	1	1
Volker-Wessels-Stevin	1	1	1	1
Wegener	1	1	1	1
Wessanen	1	0	1	1
Wolff	0	0	1	1
Wolters-Kluwer	1	0	1	1
sum	**83**	**36**	**118**	**131**

Table III.1: List of firms from the second and third empirical studies

APPENDIX IV: DETAILED REPORT ON THE ESTIMATION OF THE VERDOORN LAW AND THE PRODUCTIVITY-PERFORMANCE RELATIONSHIP

The tables below provide the detailed reports on the analyses of the Verdoorn law and the productivity-performance relationship. We address the analyses of the *118* firms in our sample in the first section, the analyses of the *13* different industries in the second section and the analysis of the entire population in the third section.

The following steps were taken in carrying out the analyses.

- Graphs were made, setting out the annual growth rate in output, i.e., added value, against the annual growth rate in productivity, i.e., added value divided by hours worked, and the annual growth rate in productivity against the annual growth rate in net profit, for every individual firm, for every industry and for the total population. These graphs were visually judged for outliers and influential points.
- The regression model including *all* observations was initially estimated for every individual firm, for every industry and for the total population. The statistical output indicated among others the observations located over two times the standard residual from this initial regression line and the *Cook distances* of every observation.
- Influential points, distorting the regression, were removed, based on judgment of these *Cook distances* computed from the initial regression model.
- Statistical outliers, defined as observations that were located over *two* times the standard residual from the initial regression line, were removed from the firm-specific models. In the industry-specific models and in the model of the total population, outliers were defined as observations that were located over *three* times the standard residual from the initial regression line. These were also removed.
- Subsequently, every regression model was re-estimated.

Analyses of the firms

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Aalberts Industries	1983-1984 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.071 to 0.022, beta goes from 0.139 to –0.046, the model remains nonsignificant The test for autocorrelation was inconclusive.	1983-1984 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.648 to 0.117, beta goes from 3.409 to 1.402, the model becomes nonsignificant
ABN-Amro	1997-1998 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.288 to 0.707, beta goes from 0.590 to 0.765, the model remains significant The test for autocorrelation was inconclusive.	1997-1998 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.526 to 0.697, beta goes from 1.341 to 1.903, the model remains significant
Achmea	2001-2002 is an influential point distorting the regression and is therefore removed Cause: financially bad year in 2002 Consequence: R square goes from 0.903 to 0.040, beta goes from 0.896 to –0.462, the model becomes nonsignificant	2001-2002 is an influential point distorting the regression and is therefore removed Cause: financially bad year in 2002 Consequence: R square goes from 0.927 to 0.065, beta goes from 2.614 to 0.345, the model becomes nonsignificant The test for autocorrelation was inconclusive.
AEGON	1991-1992 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.557 to 0.714, beta goes from 0.754 to 0.734, the model remains significant	No remarks

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Ahold	2000-2001 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: the revision of the annual report 2001 due to consolidation problems that emerged in 2003 Consequence: R square goes from 0.179 to 0.279, beta goes from 0.354 to 0.277, the model remains significant	2000-2001 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.184 to 0.272, beta goes from 2.606 to 1.361, the model becomes significant The test for autocorrelation was inconclusive, but on the brink of positive autocorrelation.
Ahrend	1985-1986, 1993-1994 and 1999-2000 are statistical outliers (> 2 times the std residual) and are therefore removed Cause: unknown Consequence: R square goes from 0.125 to 0.424, beta goes from 0.346 to 0.246, the model becomes significant	1983-1984, 1985-1986, 1993-1994 and 1999-2000 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.137 to 0.380, beta goes from 3.793 to 7.352, the model becomes significant
AKZO-Nobel	1997-1998 and 1998-1999 are statistical outliers (> 2 times the std residual) and are therefore removed Cause: unknown Consequence: R square goes from 0.111 to 0.522, beta goes from 0.394 to 0.522, the model becomes significant 1993-1994 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.522 to 0.678, beta goes from 0.522 to 0.913, the model remains significant	1999-2000 is a statistical outlier (> 2 times the std residual) and 1998-1999 is an influential point and are therefore removed Cause: unknown Consequence: R square goes from 0.023 to 0.271, beta goes from –1.435 to 2.748, the model becomes significant After this operation, it turns out that now 1993-1994 is a statistical outlier (> 2 times the std residual) and 198301984 is an influential point. Removing these points gives a better representation of the productivity-performance relationship. Consequence: R square goes from 0.271 to 0.482, beta goes from 2.748 to 1.791, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Arcadis	1991-1992 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.207 to 0.015, beta goes from 0.148 to 0.084, the model becomes nonsignificant	1985-1986 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.291 to 0.118, beta goes from 7.393 to 2.810, the model becomes nonsignificant The model estimated shows negative autocorrelation
ASM International	The average value of the change in capital-output ratio warrants a further analysis of this change. 1996-1997 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.944 to 0.928, beta goes from 0.921 to 0.922, the model remains significant	The observations 1994-1995 and 1997-1998 exhibit missing values and are therefore excluded from the analysis. 1998-1999 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.069 to 0. 593, beta goes from 11.790 to 7.465, the model remains nonsignificant Because of the missing values and the exclusion of one more observation the model is estimated based on the five remaining observations. The value of the standard error of estimate (3.507) casts severe doubts on the quality of the model.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
ASM Lithography	2001-2002 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.636 to 0.967, beta goes from 0.849 to 0.690, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 2000-2001 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.967 to 0.968, beta goes from 0.690 to 0.597, the model remains significant	The observation 2001-2002 exhibits a missing value and is therefore excluded from the analysis.
ASR Verze-keringsgroep	1992-1993 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.879 to 0.943, beta goes from 1.015 to 0.998, the model remains significant	No remarks.
Atag	1998-1999 is a statistical outlier (> 2 times the std residual) and an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.252 to 0.023, beta goes from 0.236 to -0.040, the model remains nonsignificant The test for autocorrelation was inconclusive.	1998-1999 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.811 to 0. 049, beta goes from 11.777 to 1.273, the model becomes nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Athlon	1992-1993 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.454 to 0.533, beta goes from 0.904 to 0.475, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1984-1985 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.533 to 0.390, beta goes from 0.475 to 0.362, the model remains significant The capital-output ratio is constantly increasing, with a annual average of 0.083 (=8.3%)	1984-1985, 1991-1992, 2000-2001 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.378 to 0. 515, beta goes from 3.411 to 2.453, the model remains significant. The test for autocorrelation was inconclusive.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Ballast-Nedam	1986-1987 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.972 to 0.626, beta goes from 1.184 to 0.627, the model becomes nonsignificant	The observations 1986-1987 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 2000-2001 is a statistical outlier (> 2 times the std residual) and 1987-1988 and 1988-1989 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.160 to 0.083, beta goes from 4.694 to 1.330, the model remains nonsignificant After this operation it turns out that 1998-1999 become outliers / influential points distorting the regression. Excluding these gives a better representation of the productivity-performance relation, albeit only representing the era from 1990-1998. Cause: unknown Consequence: R square goes from 0.083 to 0.608, beta goes from 1.330 to 1.301, the model becomes significant The test for autocorrelation was inconclusive.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
BAM	2000-2001 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.145 to 0.214, beta goes from 0.096 to 0.178, the model remains nonsignificant, but is on the brink of significance The average value of the change in capital-output ratio warrants a further analysis of this change. 2001-2002 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.214 to 0.194, beta goes from 0.178 to 0.172, the model remains nonsignificant Alternative models estimated: Removing 1988-1989 as an influential point gives: beta = 0.271, t-value = 2.073, significance = 0.057, R square = 0.235 Removing instead 1985-1986 and 1996-1997 as statistical outliers (> 2 times the std residual) gives: beta = 0.183, t-value = 3.181, significance = 0.007, R square = 0.438	The observation 1996-1997 exhibits a missing value and is therefore excluded from the analysis. 1986-1987 and 1995-1996 are statistical outliers (> 2 times the std residual) and are therefore removed Cause: unknown Consequence: R square goes from 0.365 to 0.356, beta goes from 6.795 to 3.922, the model remains significant
Batenburg	1998-1999 and 1999-2000 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.004 to 0.447, beta goes from 0.043 to 0.428, the model becomes significant	No remarks.

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Beers	1996-1997 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.302 to 0.517, beta goes from 0.717 to 0.789, the model remains significant	1993-1994 is a statistical outlier (> 2 times the std residual) and 1983-1984 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.405 to 0.511, beta goes from 1.442 to 0.546, the model remains significant
Begemann	1985-1986, 1987-1988 and 1988-1989 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.058 to 0.770, beta goes from 0.120 to 0.549, the model becomes significant The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the capital-output ratio is changing in an erratic way during the years 1984-1985, 1985-1986, 1989-1990, 1990-1991 and 1991-1992. There is however no reason to assume that the capital-output ratio would steadily grow or decline when the erratic observations would be removed.	The observation 1985-1986 exhibits a missing value and is therefore excluded from the analysis. 1984-1985 is a statistical outlier (> 2 times the std residual) and an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.207 to 0.001, beta goes from 25.950 to 0.068, the model becomes nonsignificant
BE Semi-conductor Industries	The average value of the change in capital-output ratio warrants a further analysis of this change. The average change in capital-output ratio turns out to be heavily influenced by the large changes in Added value (especially the net profit component). There is however no reason to assume the capital-output ratio would steadily grow or decline when the erratic observations would be removed.	The observations 1995-1996, 1998-1999 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. Because of the missing values the model is estimated based on the five remaining observations. The value of the standard error of estimate (3.507) casts severe doubts on the quality of the model. The test for autocorrelation was inconclusive.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Blydenstein-Willink	1985-1986 and 1987-1988 are statistical outliers (> 2 times the std residual) and are therefore removed Cause: unknown Consequence: R square goes from 0.118 to 0.425, beta goes from 0.605 to 0.603, the model becomes significant	The observations 1987-1988, 1988-1989, 1992-1993, 1995-1996, 1996-1997, 2000-2001 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 1997-1998 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.086 to 0.127, beta goes from 4.616 to 4.181, the model remains nonsignificant
Boskalis-Westminster	1983-1984 is a statistical outlier (> 2 times the std residual) and an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.294 to 0.410, beta goes from -0.618 to 0.563, the model remains significant The model estimated shows negative autocorrelation	The observations 1983-1984, 1985-1986, 1986-1987 and 1987-1988 exhibit missing values and are therefore excluded from the analysis. 1984-1985, 1988-1989 and 1989-1990 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.372 to 0.558, beta goes from 8.572 to 2.480, the model remains significant Because of the missing values and the exclusion of three more observations the model only represents the era from 1990.
Brocacef	1994-1995 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.243 to 0.520, beta goes from 0.552 to 0.743, the model becomes significant	The observation 1989-1990 exhibits a missing value and is therefore excluded from the analysis. 1988-1989 and 1994-1995 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.445 to 0.551, beta goes from 11.011 to 2.576, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Buhrmann	1997-1998 is a statistical outlier (> 2 times the std residual) and 1998-1999 and 1999-2000 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.266 to 0.786, beta goes from 0.405 to 0.732, the model remains significant	The observation 1993-1994 exhibits a missing value and is therefore excluded from the analysis. 1992-1993, 1997-1998, 1998-1999 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.512 to 0.460, beta goes from 26.993 to 4.758, the model remains significant The test for autocorrelation was inconclusive.
Cap Gemini	No remarks	No remarks
Cindu	1989-1990 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.010 to 0.451, beta goes from 0.029 to 0.242, the model becomes significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1996-1997 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.451 to 0.410, beta goes from 0.242 to 0.235, the model remains significant	The observation 1983-1984 exhibits a missing value and is therefore excluded from the analysis. 1993-1994 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.019 to 0.195, beta goes from 1.910 to 4.834, the model remains nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
CMG	2000-2001 and 2001-2002 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.987 to 0.469, beta goes from 0.552 to 0.411, the model becomes nonsignificant (just) The average value of the change in capital-output ratio warrants a further analysis of this change. 1999-2000 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.469 to 0.510, beta goes from 0.411 to 0.393, the model remains nonsignificant	The observation 2001-2002 exhibits a missing value and is therefore excluded from the analysis. 2000-2001 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.943 to 0.381, beta goes from 13.482 to 2.178, the model becomes nonsignificant
Content	1990-1991 is a statistical outlier (> 2 times the std residual) and 1985-1986 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.503 to 0.866, beta goes from 0.634 to 0.908, the model remains significant The test for autocorrelation was inconclusive.	The observation 1986-1987 exhibits a missing value and is therefore excluded from the analysis. 1985-1986 and 1990-1991 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.330 to 0.700, beta goes from –3.389 to 1.700, the model becomes significant The test for autocorrelation was inconclusive.

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Corus	1998-1999 is a statistical outlier (> 2 times the std residual) and 1999-2000 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.203 to 0.623, beta goes from 0.393 to 0.819, the model becomes significant (from just nonsignificant) The test for autocorrelation was inconclusive.	The observations 1983-1984, 1987-1988, 1991-1992, 1992-1993, 1993-1994, 1999-2000, 2000-2001 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 1998-1999 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.886 to 0.720, beta goes from 6.968 to 6.588, the model remains significant
Crédit Lyonnais Nederland	1987-1988 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.442 to 0.838, beta goes from 0.231 to 0.812, the model becomes significant	The observations 1983-1984, 1984-1985, 1985-1986, 1986-1987, 1987-1988 and 1988-1989 exhibit missing values and are therefore excluded from the analysis. The model is nonsignificant.
CSM	1999-2000 is a statistical outlier (> 2 times the std residual) and 2000-2001 and 2001-2002 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.682 to 0.098, beta goes from 0.444 to 0.138, the model becomes nonsignificant The model estimated show positive autocorrelation	1999-2000, 2000-2001 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.711 to 0.495, beta goes from 4.229 to 0.954, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Delft Instruments	1997-1998 and 1998-1999 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.869 to 0.852, beta goes from 1.165 to 1.077, the model remains significant An analysis of the change in capital-output ratio shows that 1997-1998 and 1998-1999 are also influential points in the average growth in capital-output ratio.	The observations 1986-1987, 1990-1991, 1991-1992, 1992-1993 and 1998-1999 exhibit missing values and are therefore excluded from the analysis. 1993-1994 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.079 to 0.823, beta goes from 39.151 to 14.969, the model becomes significant The value of the standard error of the estimate casts some doubt on the quality of the model, however.
Draka	2001-2002 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.218 to 0.006, beta goes from 0.269 to 0.045, the model remains nonsignificant The test for autocorrelation was inconclusive.	1988-1989, 1992-1993, 1993-1994 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.390 to 0.403, beta goes from 2.341 to 0.988, the model remains significant
DSM	1993-1994 and 1997-1998 are statistical outliers (> 2 times the std residual) and are therefore removed Cause: unknown Consequence: R square goes from 0.734 to 0.914, beta goes from 0.812 to 0.834, the model remains significant	The observation 1993-1994 exhibits a missing value and is therefore excluded from the analysis. 1992-1993 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.776 to 0.839, beta goes from 5.450 to 4.913, the model remains significant

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
EVC	1994-1995 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.998 to 0.987, beta goes from 0.855 to 1.077, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1993-1994 and 1997-1998 are influential points distorting the average change in capital-output ratio and are therefore removed from the analysis. The points are also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.987 to 0.968, beta goes from 1.077 to 1.094, the model remains significant	The observations 1994-1995, 1996-1997, 1998-1999, 1999-2000, 2000-2001 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. This leaves 3 valid observations, which is not sufficient for estimating the model. EVC is therefore excluded from the analysis.
Exendis	1985-1986 is a statistical outlier (> 2 times the std residual) and 1986-1987 and 2000-2001 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.013 to 0.340, beta goes from 0.044 to 0.463, the model becomes significant	1985-1986, 1986-1987, 1993-1994 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.082 to 0.687, beta goes from 1.631 to 2.970, the model becomes significant
Fortis	The Fortis graph gives a fuzzy image. There are five observations that can be qualified as either outliers or influential points. The initial estimated model gives: beta = 0.289, t-value = 4.498, significance = 0.000, R square = 0.543. This model however does not adequately represent the Fortis data. We therefore chose to remove the five observations, i.e., 1989-1990, 1992-1993, 1993-1994, 1997-1998 and 2001-2002. Consequence: R square goes from 0.543 to 0.237, beta goes from 0.289 to 0.429, the model becomes nonsignificant	1989-1990, 1992-1993, 1997-1998 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.618 to 0.372, beta goes from 2.744 to 1.232, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Frans Maas	The model is nonsignificant	The observations 1993-1994 and 1994-1995 exhibit missing values and are therefore excluded from the analysis. 1992-1993 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.396 to 0.360, beta goes from 4.679 to 2.518, the model remains significant
Free Record Shop	1992-1993 is a statistical outlier (> 2 times the std residual) and an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.348 to 0.314, beta goes from 0.828 to 0.418, the model becomes nonsignificant The test for autocorrelation was inconclusive.	1992-1993 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.863 to 0.481, beta goes from 7.009 to 2.665, the model remains significant
Fugro	The model is nonsignificant	No remarks
Gamma Holding	1989-1990 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.020 to 0.117, beta goes from -0.085 to 0.311, the model remains nonsignificant	The model is nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Gelderse Papier	No remarks	The observations 1993-1994, 1995-1996 and 1998-1999 exhibit missing values and are therefore excluded from the analysis. 1996-1997 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.576 to 0.794, beta goes from 9.585 to 7.341, the model remains significant The value of the standard error of the estimate casts some doubt on the quality of the model, however.
Getronics	1998-1999, 2000-2001 and 2001-2002 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.172 to 0.102, beta goes from 0.203 to 0.105, the model remains nonsignificant The test for autocorrelation was inconclusive. The capital-output ratio is constantly declining, with a annual average of -0.075 (= -7.5%)	The observation 2001-2002 exhibits a missing value and is therefore excluded from the analysis. 1985-1986, 1999-2000 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.835 to 0.245, beta goes from 27.658 to 1.507, the model becomes nonsignificant The model estimated shows positive autocorrelation
Geveke	1991-1992 and 1993-1994 are statistical outliers (> 2 times the std residual) and are therefore removed Cause: unknown Consequence: R square goes from 0.034 to 0.108, beta goes from 0.160 to 0.121, the model remains nonsignificant The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the removal of 1991-1992 and 1993-1994 from the regression is the cause of the somewhat high average. As the change in capital-output ratio is nonsignificant, this requires no further action.	The observations 1992-1993 and 1993-1994 exhibit missing values and are therefore excluded from the analysis. 1991-1992 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.783 to 0.243, beta goes from 8.648 to 3.017, the model becomes nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Van der Giessen	1985-1986 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.668 to 0.933, beta goes from 1.013 to 1.092, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1986-1987, 1987-1988 and 1995-1996 are influential points distorting the average change in capital-output ratio and are therefore removed from the analysis. The points are also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.933 to 0.844, beta goes from 1.092 to 0.827, the model remains significant	The observations 1984-1985, 1986-1987 and 1987-1988 exhibit missing values and are therefore excluded from the analysis. 1985-1986, 1991-1992 and 1995-1996 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.052 to 0.625, beta goes from –10.430 to 17.262, the model becomes significant The value of the standard error of the estimate casts some doubt on the quality of the model, however.
Gist-Brocades	1990-1991 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.604 to 0.568, beta goes from 1.076 to 0.806, the model remains significant	1994-1995 is a statistical outlier (> 2 times the std residual) and 1990-1991 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.641 to 0.595, beta goes from 4.616 to 3.765, the model remains significant
Grolsch	1990-1991 and 1993-1994 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.001 to 0.805, beta goes from 0.015 to 0.897, the model becomes significant	1996-1997 and 1997-1998 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.754 to 0.244, beta goes from 3.066 to 0.664, the model remains (just) significant
Grontmij	1990-1991 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.167 to 0.000, beta goes from -0.141 to 0.011, the model remains nonsignificant	The model is nonsignificant

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
GTI	No remarks	The model is nonsignificant
Gucci	1999-2000 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.546 to 0.854, beta goes from 0.960 to 1.123, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1993-1994 and 1998-1999 are influential points distorting the average change in capital-output ratio and are therefore removed from the analysis. The points are also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.854 to 0.851, beta goes from 1.123 to 0.817, the model remains significant	The observation 1993-1994 exhibits a missing value and is therefore excluded from the analysis. 1994-1995 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.819 to 0.639, beta goes from 3.076 to 1.676, the model remains significant
Hagemeyer	The Hagemeyer graph gives a fuzzy image. There are six observations that can be qualified as either outliers or influential points. Removing these six observations, i.e., 1993-1994, 1994-1995, 1995-1996, 1998-1999, 1999-2000 and 2000-2001 and estimating the model gives: beta = 0.231, t-value = 4.306, significance = 0.001, R square = 0.628. This model however does not adequately represent the Hagemeyer data. We therefore stick to the original model. Consequence: R square goes from 0.628 to 0.101, beta goes from 0.231 to 0.171, the model becomes nonsignificant	1999-2000 is a statistical outlier (> 2 times the std residual) and an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.321 to 0.066, beta goes from 6.644 to 0.952, the model becomes nonsignificant The model estimated shows positive autocorrelation
HBG	1996-1997 and 1999-2000 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.029 to 0.055, beta goes from 0.089 to -0.188, the model remains nonsignificant	1999-2000 is a statistical outlier (> 2 times the std residual) and an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.374 to 0.045, beta goes from 4.024 to –0.332, the model becomes nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Heijmans	The model is nonsignificant	The Heijmans graph gives a fuzzy image. Therefore, a number of alternative models have been estimated. Estimating the model based on all observations gives: beta = -0.890, t-value = -0.917, significance = 0.381, R square = 0.078. Removing 1994-1995 as a statistical outlier (> 2 times the std residual) gives: beta = -0.711, t-value = -1.051, significance = 0.321, R square = 0.109. Removing 1995-1996 as an influential point distorting the regression gives: beta = -1.749, t-value = -1.724, significance = 0.119, R square = 0.248. Removing 1991-1992 and 1995-1996 as influential points distorting the regression and 1994-1995 as a statistical outlier (> 2 times the std residual) gives: beta = -0.948, t-value = -2.026, significance = 0.082, R square = 0.370. All of the models are nonsignificant and, moreover, do not seem to give an adequate representation of the Heijmans data. We therefore stick to the (also nonsignificant) model based on all observations. Note however that a negative value of beta, i.e., when productivity rises with x%, net profit falls with x%, is extremely unlikely to occur.
Heineken	The model is nonsignificant The test for autocorrelation was inconclusive.	The model is nonsignificant
Hunter Douglas	1983-1984, 1984-1985, 1985-1986 and 1986-1987 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.052 to 0.814, beta goes from 0.286 to 1.081, the model becomes significant The model only represents the era from 1987	No remarks

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
IHC Caland	1988-1989 and 1989-1990 are statistical outliers (> 2 times the std residual) and 1986-1987 is an influential point and are therefore removed Cause: unknown Consequence: R square goes from 0.988 to 0.912, beta goes from 1.453 to 0.820, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. The period from 1984 to 1989 is characterized by an extreme volatility of the capital-output ratio. All the years previous to 1990 have therefore been removed from the analysis. The points are also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.912 to 0.346, beta goes from 0.820 to 0.303, the model remains significant The model only represents the era from 1990 onwards Still, after these deletions, the average value of the change in capital-output ratio warrants a further analysis of this change. It turns out however, that the capital-output ratio does not significantly differ from 0 (1-tailed significance = 0.071)	The observations 1985-1986, 1986-1987 and 1988-1989 exhibit missing values and are therefore excluded from the analysis. 1984-1985, 1987-1988 and 1989-1990 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.575 to 0.420, beta goes from 13.568 to 2.521, the model remains significant
Imtech	2000-2001 is a statistical outlier (> 2 times the std residual) and 1997-1998 is an influential point and are therefore removed Cause: unknown Consequence: R square goes from 0.259 to 0.551, beta goes from 0.465 to 0.998, the model remains significant	The observation 1991-1992 exhibits a missing value and is therefore excluded from the analysis. 1983-1984, 1990-1991 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.072 to 0.473, beta goes from 25.675 to 5.348, the model becomes significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
ING Group	1997-1998 is a statistical outlier (> 2 times the std residual) and 2000-2001 is an influential point and are therefore removed Cause: unknown Consequence: R square goes from 0.831 to 0.895, beta goes from 0.807 to 0.782, the model remains significant	1999-2000 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.904 to 0.846, beta goes from 2.033 to 2.522, the model remains significant
KAS Bank	2001-2002 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.972 to 0.852, beta goes from 0.977 to 0.853, the model remains significant	1984-1985 is a statistical outlier (> 2 times the std residual) and 2001-2002 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.497 to 0.810, beta goes from 1.767 to 2.807, the model remains significant The test for autocorrelation was inconclusive.
KBB	The model is nonsignificant	1983-1984 is a statistical outlier (> 2 times the std residual) and an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.000 to 0.658, beta goes from –0.375 to 4.838, the model becomes significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Kempen & Co.	1997-1998 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.630 to 0.776, beta goes from 0.630 to 0.772, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1989-1990 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.776 to 0.675, beta goes from 0.772 to 0.738, the model remains significant The test for autocorrelation was inconclusive.	1990-1991 is a statistical outlier (> 2 times the std residual) and an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.370 to 0.788, beta goes from 3.095 to 1.915, the model remains significant
KLM	1990-1991 and 1996-1997 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.951 to 0.923, beta goes from 0.978 to 0.950, the model remains significant The model estimated shows positive autocorrelation The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the relatively high average change is due to the removal of the influential points 1990-1991 and 1996-1997 from the analysis. The change in capital-output ratio does not significantly differ from 0 (1-tailed significance = 0.094)	The observations 1990-1991, 1992-1993 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 1991-1992 is a statistical outlier (> 2 times the std residual) and 1996-1997 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.754 to 0.631, beta goes from 15.093 to 9.880, the model remains significant The value of the standard error of the estimate casts some doubt on the quality of the model, however.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
KPN	The KPN graph gives a fuzzy image. There are six observations that can be qualified as either outliers or influential points. These six observations are 1996-1997, 1997-1998, 1998-1999, 1999-2000, 2000-2001 and 2001-2002, coincidentally the years after the company split into a post and logistics group (i.e., TPG) and a telecommunications group (KPN). These observations were therefore removed from the analysis. Consequence: R square goes from 0.149 to 0.620, beta goes from 0.443 to 0.913, the model becomes significant The model only represents the era until 1996 (i.e., the era when the post and logistics and the telecommunications were combined in one company). From the remaining six observations, covering the era from 1996, no definite conclusion can be drawn as to the Verdoorn relationship.	The observation 2001-2002 exhibits a missing value and is therefore excluded from the analysis. The KPN graph gives a fuzzy image. There are six observations that can be qualified as either outliers or influential points. These six observations are 1988-1989, 1996-1997, 1997-1998, 1998-1999, 1999-2000 and 2000-2001 (2001-2002 exhibits a missing value). Five of those six are from the years after the company split into a post and logistics group (i.e., TPG) and a telecommunications group (KPN). These five observations were therefore removed from the analysis. Consequence: R square goes from 0.321 to 0.126, beta goes from –2.361 to 0.950, the model becomes nonsignificant This model only represents the era until 1996 (i.e., the era when the post and logistics and the telecommunications were combined in one company). In the remaining graph, 1988-1989 is a statistical outlier (> 2 times the std residual) and an influential point distorting the regression and is therefore removed. Consequence: R square goes from 0.126 to 0.021, beta goes from 0.950 to 0.197, the model remains nonsignificant. The test for autocorrelation was inconclusive.

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Landré	1984-1985, 1992-1993, 1993-1994 and 1997-1998 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.053 to 0.532, beta goes from 0.087 to 0.235, the model becomes significant The test for autocorrelation was inconclusive.	The observation 1993-1994 exhibits a missing value and is therefore excluded from the analysis. 1984-1985, 1992-1993 and 1997-1998 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.429 to 0.198, beta goes from 21.472 to 3.636, the model becomes nonsignificant
Laurus	The Laurus graph gives a fuzzy image. There are five observations that can be qualified as either outliers or influential points. These five observations are 1995-1996, 1997-1998, 1999-2000, 2000-2001 and 2001-2002. Removing these observations from the analysis probably gives a more adequate representation of the company as 'going concern' Consequence: R square goes from 0.049 to 0.007, beta goes from 0.186 to -0.057, the model remains nonsignificant The fuzzy image is probably related to the many changes in composition (mergers and acquisitions) of the company over the period analyzed.	The observations 2000-2001 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. The Laurus graph gives a fuzzy image. There are three observations that can be qualified as either outliers or influential points. These five observations are 1995-1996, 1997-1998 and 1999-2000 (note that 2000-2001 and 2001-2002 have already been removed due to missing values). Removing these three observations from the analysis probably gives a more adequate representation of the company as 'going concern'. Consequence: R square goes from 0.033 to 0.047, beta goes from –0.935 to 0.537, the model remains nonsignificant The fuzzy image is probably related to the many changes in composition (mergers and acquisitions) of the company over the period analyzed.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
LCI	1987-1988, 1988-1989 and 1989-1990 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.211 to 0.647, beta goes from 0.207 to 0.487, the model becomes significant The model only represents the era from 1990 onwards The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the relatively high average change is due to the removal of the influential points 1987-1988, 1988-1989 and 1989-1990 from the analysis. The change in capital-output ratio does not significantly differ from 0 (1-tailed significance = 0.199)	The observations 1993-1994 and 1997-1998 exhibit missing values and are therefore excluded from the analysis. No further remarks on the model.
Van Leer	1991-1992 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.166 to 0.504, beta goes from 0.215 to 0.577, the model becomes significant	1990-1991, 1991-1992 and 1992-1993 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.080 to 0.175, beta goes from 1.740 to 0.933, the model remains nonsignificant

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Macintosh	1992-1993, 1996-1997 and 2000-2001are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.005 to 0.321, beta goes from 0.106 to 0.640, the model becomes significant	The observation 2001-2002 exhibits a missing value and is therefore excluded from the analysis. 1992-1993 and 1997-1998 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.004 to 0.382, beta goes from –1.126 to 3.708, the model becomes significant In the remaining graph, 1987-1988 and 2000-2001 can be considered as influential points distorting the regression. Removing these points gives: beta = 4.182, t-value = 4.649, significance = 0.001, R square = 0.643. This model is not so radically different from the previous one as to justify removing these two observations.
Van Melle	1990-1991 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.678 to 0.783, beta goes from 0.936 to 0.911, the model remains significant	No remarks.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Bank Mendes Gans	The observations 1983-1984 and 1984-1985 exhibit missing values and are therefore excluded from the analysis. 1997-1998 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.345 to 0.421, beta goes from 0.621 to 0.533, the model remains significant The model estimated shows positive autocorrelation The average value of the change in capital-output ratio warrants a further analysis of this change. The capital-output ratio is constantly declining, with a annual average of -0.069 (= -6.9%). The removed observation has no influence on this value.	The observations 1983-1984 and 1984-1985 exhibit missing values and are therefore excluded from the analysis. 1985-1986 and 1986-1987 are statistical outliers (> 2 times the std residual) and 1987-1988 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.187 to 0.565, beta goes from 0.400 to 0.321, the model becomes significant The test for autocorrelation was inconclusive.
Van der Moolen	No remarks on the regression. The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the relatively high average change is due to the general volatility of the ratio over the entire period of analysis. The change in capital-output ratio does not significantly differ from 0 (1-tailed significance = 0.203)	1989-1990 is a statistical outlier (> 2 times the std residual) and 1992-1993 and 1996-1997 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.732 to 0.685, beta goes from 2.354 to 1.326, the model remains significant
NBM	1997-1998 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.179 to 0.509, beta goes from 0.071 to 0.288, the model becomes significant	1987-1988 and 1989-1990 are statistical outliers (> 2 times the std residual) and are therefore removed Cause: unknown Consequence: R square goes from 0.248 to 0.560, beta goes from 4.375 to 4.117, the model remains significant The test for autocorrelation was inconclusive.
Nedap	The test for autocorrelation was inconclusive.	No remarks

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Nedlloyd	The observations 1999-2000 and 2000-2001 exhibit missing values and are therefore excluded from the analysis. 1986-1987, 1995-1996 and 1998-1999 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.102 to 0.620, beta goes from 0.596 to 0.903, the model becomes significant	The observations 1983-1984, 1987-1988, 1990-1991, 1992-1993 and 1993-1994 exhibit missing values and are therefore excluded from the analysis. 1986-1987, 1998-1999, 1999-2000 and 2000-2001 influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.004 to 0.619, beta goes from 0.070 to 7.534, the model becomes significant The model only represents the era from 1984 until 1998
Neways	2000-2001 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.057 to 0.003, beta goes from 0.123 to -0.027, the model remains nonsignificant The test for autocorrelation was inconclusive.	The observation 2001-2002 exhibits a missing value and is therefore excluded from the analysis. 1992-1993 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.408 to 0.303, beta goes from 9.646 to 1.863, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
NIB Capital	1999-2000 is an influential point and is therefore removed Cause: unknown Consequence: R square remains 0.974, beta goes from 0.800 to 0.999, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1998-1999 and 2001-2002 are influential points distorting the average change in capital-output ratio and are therefore removed from the analysis. The points are also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.974 to 0.968, beta goes from 0.999 to 1.067, the model remains significant The test for autocorrelation was inconclusive.	1999-2000 is a statistical outlier (> 2 times the std residual) and an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.912 to 0.856, beta goes from 3.132 to 1.943, the model remains significant The test for autocorrelation was inconclusive.
NKF	1994-1995 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.369 to 0.744, beta goes from 0.298 to 0.443, the model remains significant The test for autocorrelation was inconclusive.	1994-1995 is a statistical outlier (> 2 times the std residual) and 1996-1997 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.553 to 0.807, beta goes from 3.614 to 3.716, the model remains significant The test for autocorrelation was inconclusive.
Norit	1987-1988 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.587 to 0.663, beta goes from 0.360 to 0.339, the model remains significant	1990-1991, 1991-1992, 1993-1994 and 1994-1995 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.180 to 0.530, beta goes from 2.664 to 3.059, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
NS	No remarks	1999-2000 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.843 to 0.736, beta goes from 8.448 to 6.054, the model becomes (just) nonsignificant
Numico	2001-2002 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.676 to 0.203, beta goes from 0.699 to -0.247, the model becomes (just) nonsignificant. This model however does not seem to adequately represent the Numico data. Especially observations 1994-1995, 1995-1996, 1998-1999 and 1999-2000 appear to be outliers. Removing these observations gives: beta = 0.372, t-value = 1.298, significance = 0.219, R square = 0.123. Note that the model is nonsignificant. This model seems to represent best the Numico data. An alternative model was estimated that only represents the era until 1994. This gives: beta = 0.500, t-value = 2.076, significance = 0.068, R square = 0.324. This model shows positive autocorrelation.	2001-2002 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.916 to 0.006, beta goes from 5.542 to –0.147, the model becomes nonsignificant
Nutreco	The model is nonsignificant The test for autocorrelation was inconclusive.	The model is nonsignificant
Océ	1987-1988, 1995-1996 and 1996-1997 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.225 to 0.317, beta goes from 0.273 to 0.427, the model remains significant	2000-2001 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.074 to 0.044, beta goes from 10.711 to 1.142, the model remains nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Van Ommeren	1986-1987, 1991-1992, 1994-1995 and 1996-1997 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.225 to 0.222, beta goes from -0.950 to 0.408, the model remains nonsignificant	1986-1987, 1988-1989, 1991-1992, 1992-1993, 1993-1994 and 1994-1995 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.000 to 0.633, beta goes from 0.251 to 1.851, the model becomes significant The large number of influential points casts some doubt on the representativeness of the estimated model for the entire period.
OPG	1994-1995, 1997-1998, 1998-1999 and 1999-2000 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.031 to 0.310, beta goes from 0.171 to 0.189, the model becomes significant	1997-1998 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.742 to 0.485, beta goes from 4.699 to 3.405, the model remains significant
Ordina	1995-1996 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.121 to 0.104, beta goes from 0.079 to 0.047, the model remains nonsignificant	1995-1996 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.067 to 0.099, beta goes from 1.547 to 2.976, the model remains nonsignificant
Otra	1985-1986, 1988-1989 and 1990-1991 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.083 to 0.517, beta goes from 0.211 to 0.747, the model becomes significant	No remarks

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
P&C Group	1996-1997 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.916 to 0.637, beta goes from 1.019 to 0.926, the model remains significant The test for autocorrelation was inconclusive.	The observations 1983-1984, 1994-1995 and 1995-1996 exhibit missing values and are therefore excluded from the analysis. 1993-1994 and 1996-1997 influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.813 to 0.885, beta goes from 127.549 to 5.030, the model remains significant The model only represents the era from 1984-1993.
Pakhoed	1983-1984, 1990-1991 and 1996-1997 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.001 to 0.021, beta goes from -0.019 to -0.145, the model remains nonsignificant	1987-1988, 1990-1991 and 1996-1997 influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.452 to 0.551, beta goes from 4.339 to 7.622, the model remains significant
Philips	The average value of the change in capital-output ratio warrants a further analysis of this change. 2000-2001 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.968 to 0.954, beta goes from 0.978 to 0.979, the model remains significant	The observations 1990-1991, 1992-1993, 1996-1997 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 1989-1990 is a statistical outlier (> 2 times the std residual) and 1999-2000 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.675 to 0.592, beta goes from 5.388 to 4.966, the model remains significant The test for autocorrelation was inconclusive.
Polygram	No remarks	1995-1996 and 1996-1997 influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.767 to 0.819, beta goes from 1.775 to 1.598, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Polynorm	1985-1986 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.452 to 0.259, beta goes from 0.315 to 0.378, the model remains significant	1984-1985 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.388 to 0.524, beta goes from 2.947 to 3.450, the model remains significant
Randstad	1999-2000 and 2000-2001 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.142 to 0.242, beta goes from 0.189 to 0.214, the model remains nonsignificant	2000-2001 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.037 to 0.269, beta goes from 0.995 to 1.902, the model becomes significant The test for autocorrelation was inconclusive.
Reed Elsevier	1992-1993 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.002 to 0.686, beta goes from -0.017 to 0.906, the model becomes significant	The observation 1999-2000 exhibits a missing value and is therefore excluded from the analysis. 1992-1993, 1998-1999 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.002 to 0.221, beta goes from 0.215 to 0.758, the model remains nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Rood Testhouse	No remarks	The observations 1990-1991, 1991-1992, 1992-1993, 1998-1999 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 1997-1998 is a statistical outlier (> 2 times the std residual) and an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.209 to 0.525, beta goes from 126.866 to 14.263, the model becomes significant The model estimated shows negative autocorrelation The value of the standard error of the estimate also casts severe doubt on the quality of the model. Removing further possible influential points does not lead to a satisfactory model.
Royal Begemann Group	The observations 1995-1996, 1999-2000, 2000-2001 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. This leaves 3 valid observations, which is not sufficient for estimating the model. RBG is therefore excluded from the analysis.	The observations 1995-1996, 1999-2000, 2000-2001 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. This leaves 3 valid observations, which is not sufficient for estimating the model. RBG is therefore excluded from the analysis.
Samas	The Samas graph gives a fuzzy image. There are six observations that can be qualified as either outliers or influential points. These six observations are 1986-1987, 1989-1990, 1993-1994, 1994-1995, 1999-2000 and 2001-2002. Removing these observations from the analysis probably gives a more adequate representation of the company as ‘going concern’ Consequence: R square goes from 0.261 to 0.515, beta goes from 0.307 to 0.733, the model remains significant	1999-2000 is a statistical outlier (> 2 times the std residual) and an influential point and 2001-2002 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.687 to 0.363, beta goes from 4.400 to 2.057, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Schuitema	1985-1986, 1999-2000 and 2000-2001 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.043 to 0.553, beta goes from -0.090 to 0.820, the model becomes significant	1983-1984 is a statistical outlier (> 2 times the std residual) and 1999-2000 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.002 to 0.462, beta goes from 0.193 to 1.117, the model becomes significant
Royal Dutch/ Shell Group	1997-1998, 1998-1999 and 2000-2001 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.895 to 0.921, beta goes from 1.087 to 1.134, the model remains significant The test for autocorrelation was inconclusive.	1997-1998 and 1998-1999 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.475 to 0.821, beta goes from 21.594 to 1.554, the model remains significant
Simac	1996-1997, 1999-2000 and 2000-2001 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.196 to 0.010, beta goes from 0.234 to 0.044, the model remains nonsignificant	The observations 1998-1999, 1999-2000 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 2000-2001 is a statistical outlier (> 2 times the std residual) and an influential point distorting the regression and 1997-1998 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.747 to 0.670, beta goes from 53.963 to 5.102, the model remains significant The model only represents the era until 1997.

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Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Smit Inter-nationale	1987-1988 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.997 to 0. 891, beta goes from 1.101 to 1.009, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1986-1987 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.891 to 0.722, beta goes from 1.009 to 1.045, the model remains significant After these adjustments, the observation 1997-1998 becomes an influential point and is therefore removed. Cause: unknown Consequence: R square goes from 0.722 to 0.663, beta goes from 1.045 to 1.377, the model remains significant	The observations 1987-1988, 1988-1989 and 1992-1993 exhibit missing values and are therefore excluded from the analysis. 1986-1987, 1993-1994, 1995-1996 and 1997-1998 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.712 to 0.239, beta goes from 22.928 to 3.152, the model becomes nonsignificant
SNS Bank	1995-1996 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.218 to 0. 903, beta goes from 0.204 to 0.661, the model becomes significant The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the relatively high average change is due to the removal of the influential point 1995-1996 from the analysis. With this observation included, the change in capital-output ratio does not significantly differ from 0 (1-tailed significance = 0.268). With this observation excluded, the change in capital-output ratio does only just not significantly differ from 0 (1-tailed significance = 0.052).	1995-1996 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.396 to 0.811, beta goes from 2.166 to 2.275, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Sphinx	No remarks	The observations 1995-1996 and 1996-1997 exhibit missing values and are therefore excluded from the analysis. 1994-1995 is a statistical outlier (> 2 times the std residual) and an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.528 to 0.628, beta goes from 3.280 to 2.425, the model remains significant
Staal Bankiers	1989-1990 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.894 to 0. 466, beta goes from 0.839 to 0.449, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1988-1989, 1990-1991 and 1995-1996 are influential points distorting the average change in capital-output ratio and are therefore removed from the analysis. The points are also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.466 to 0.605, beta goes from 0.449 to 0.641, the model remains significant	The observation 1990-1991 exhibits a missing value and is therefore excluded from the analysis. 1989-1990 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.966 to 0.810, beta goes from 4.141 to 2.154, the model remains significant The test for autocorrelation was inconclusive.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Stork	No remarks	The observation 2001-2002 exhibits a missing value and is therefore excluded from the analysis. The Stork graph gives a fuzzy image. Excluding 1983-1984, 1988-1989, 1992-1993, 1994-1995, 1995-1996 and 1999-2000 gives: beta = 8.817, t-value = 6.308, significance = 0.000, R square = 0.799. Excluding 1986-1987, 1991-1992, 1998-1999 and 2000-2001 gives: beta = -0.119, t-value = -0.152, significance = 0.882, R square = 0.002. The difference between the two models does not seem to follow a clear pattern, nor is it clearly related to changes in the composition of Stork's business. We therefore decided to remove only 2000-2001, as it is clearly a statistical outlier (> 2 times the std residual) as well as an influential point distorting the regression. Cause: unknown Consequence: R square goes from 0.188 to 0.056, beta goes from 3.581 to 1.491, the model remains nonsignificant
Telegraaf	1992-1993, 1999-2000 and 2000-2001 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.085 to 0.573, beta goes from 0.195 to 0.485, the model becomes significant	The observation 2001-2002 exhibits a missing value and is therefore excluded from the analysis. 2000-2001 is a statistical outlier (> 2 times the std residual) and an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.541 to 0.416, beta goes from 4.419 to 1.847, the model remains significant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Ten Cate	No remarks	The observations 1998-1999 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 1997-1998 is a statistical outlier (> 2 times the std residual) and an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.480 to 0.346, beta goes from 5.704 to 2.424, the model remains significant
Tulip	The observations 1997-1998, 2000-2001 and 2001-2002 exhibit missing values and are therefore excluded. 1996-1997, 1998-1999 and 1999-2000 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 1.000 to 0.600, beta goes from 0.965 to 0.525, the model remains significant The model only represents the era until 1996 The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the relatively high average change is due to the general volatility of the ratio over the entire period of analysis. The change in capital-output ratio does not significantly differ from 0 (1-tailed significance = 0.168)	The observations 1992-1993, 1996-1997, 1997-1998, 1998-1999, 2000-2001 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 1999-2000 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.844 to 0.877, beta goes from 92.152 to 4.744, the model remains significant The model only represents the era until 1996
Twentsche Kabel Holding	1983-1984, 1994-1995 and 2001-2002 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.542 to 0.374, beta goes from 0.544 to 0.584, the model remains significant	2001-2002 is an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.753 to 0.617, beta goes from 9.139 to 2.632, the model remains significant

Appendix IV

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Unilever	1984-1985 is a statistical outlier (> 2 times the std residual) and 1996-1997 is an influential point and are therefore removed Cause: unknown Consequence: R square goes from 0.789 to 0.710, beta goes from 1.068 to 0.749, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. 1999-2000 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.710 to 0.721, beta goes from 0.749 to 0.737, the model remains significant	1984-1985, 1999-2000 and 2000-2001 are statistical outliers (> 2 times the std residual) and 1996-1997 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.698 to 0.735, beta goes from 2.912 to 2.179, the model remains significant
Vendex KBB	1996-1997, 1997-1998 and 1998-1999 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.004 to 0.676, beta goes from 0.062 to 2.451, the model becomes significant The model estimated shows positive autocorrelation The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the removal of 1997-1998 from the regression is the cause of the high average change. Over the period analyzed and with the influential points removed the capital-output ratio is constantly declining, with a annual average of -0.055 (= -5.5%)	2000-2001 is a statistical outlier (> 2 times the std residual) and 1996-1997 is an influential point distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.102 to 0.655, beta goes from 5.873 to 4.916, the model becomes significant The test for autocorrelation was inconclusive.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Vilenzo	2000-2001 and 2001-2002 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.142 to 0.256, beta goes from 0.635 to 0.524, the model remains nonsignificant The model estimated shows positive autocorrelation The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the relatively high average change is an adequate representation of reality. Indeed, without the removal of the influential points 2000-2001 and 2001-2002, the average change in capital-output ratio would be 0.064 (6.4%) and significant (1-tailed significance = 0.027). With the removal of the influential points however, the change in capital-output ratio does not significantly differ from 0 (1-tailed significance = 0.082)	2000-2001 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.101 to 0.225, beta goes from –0.254 to 0.909, the model remains nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
VNU	The VNU graph gives a fuzzy image. There are six observations that can be qualified as either outliers or influential points. These six observations are 1986-1987, 1992-1993, 1998-1999, 1999-2000, 2000-2001 and 2001-2002. Removing these observations from the analysis probably gives a more adequate representation of the company as 'going concern' Consequence: R square goes from 0.223 to 0.203, beta goes from 0.383 to 0.250, the model becomes nonsignificant The average value of the change in capital-output ratio warrants a further analysis of this change. 1997-1998 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.203 to 0.180, beta goes from 0.250 to 0.288, the model remains nonsignificant	1992-1993 is a statistical outlier (> 2 times the std residual) and an influential point distorting the regression and is therefore removed Cause: unknown Consequence: R square goes from 0.547 to 0.663, beta goes from 2.957 to 2.689, the model remains significant
Vopak	1986-1987, 1991-1992, 1996-1997 and 2001-2002 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.373 to 0.036, beta goes from -0.591 to -0.145, the model becomes nonsignificant	1986-1987, 1991-1992 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.201 to 0.553, beta goes from 1.789 to 6.491, the model becomes significant (from just nonsignificant) The model estimated show negative autocorrelation

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Vredestein	1990-1991 is a statistical outlier (> 2 times the std residual) and is therefore removed Cause: unknown Consequence: R square goes from 0.884 to 0.929, beta goes from 1.004 to 1.131, the model remains significant	The observations 1989-1990, 1990-1991, 1991-1992 and 2001-2002 exhibit missing values and are therefore excluded from the analysis. 1988-1989, 1994-1995, 1999-2000 and 2000-2001 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.508 to 0.598, beta goes from 259.115 to 5.620, the model remains significant The test for autocorrelation was inconclusive.
Volker-Wessels-Stevin	1986-1987 and 1987-1988 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.570 to 0.005, beta goes from 0.647 to -0.032, the model becomes nonsignificant	The observation 1987-1988 exhibits a missing value and is therefore excluded from the analysis. 1984-1985, 1986-1987, 1988-1989 and 1995-1996 influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.736 to 0.002, beta goes from 28.514 to 0.050, the model becomes nonsignificant

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Wegener-Arcade	The observation 1983-1984 exhibits missing values and is therefore excluded. The Wegener graph gives a fuzzy image. There are at least five observations that can be qualified as either outliers or influential points. These five observations are 1985-1986, 1986-1987, 1991-1992, 1999-2000 and 2000-2001. Removing these observations from the analysis probably gives again a picture with a number of influential points. The model is therefore based on all observations. Note that the model is nonsignificant. The average value of the change in capital-output ratio warrants a further analysis of this change. 1999-2000 is an influential point distorting the average change in capital-output ratio and is therefore removed from the analysis. The point is also removed from the regression analysis. Cause: unknown Consequence: R square goes from 0.072 to 0.082, beta goes from 0.072 to 0.083, the model remains nonsignificant	The observation 1983-1984 exhibits missing values and is therefore excluded from the analysis. 1985-1986, 2000-2001 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.224 to 0.242, beta goes from 8.153 to 2.575, the model becomes (just) nonsignificant (from just significant). The graph appears more like an inverse quadratic relationship than like a linear relationship.

Firm name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Wessanen	1986-1987 and 1987-1988 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.096 to 0.426, beta goes from 0.259 to 0.599, the model becomes significant The average value of the change in capital-output ratio warrants a further analysis of this change. It turns out that the relatively high average change is due to the removal of the influential points 1986-1987 and 1987-1988 from the analysis. With these observations included, the average change in capital-output ratio is not significantly different from 0 (1-tailed significance = 0.378). With these observation excluded, the change in capital-output ratio also does not significantly differ from 0 (1-tailed significance = 0.074).	2000-2001 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.471 to 0.779, beta goes from 2.835 to 2.150, the model remains significant.
Wolff	1992-1993 and 1993-1994 are influential points and are therefore removed Cause: unknown Consequence: R square goes from 0.759 to 0.913, beta goes from 1.190 to 1.690, the model remains significant The test for autocorrelation was inconclusive.	The observations 1992-1993, 1993-1994 and 1994-1995 exhibit missing values and are therefore excluded from the analysis. 1990-1991 and 1991-1992 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.603 to 0.017, beta goes from 74.621 to 0.602, the model becomes nonsignificant The model only represents the era until 1990
Wolters-Kluwer	1995-1996 is an influential point and is therefore removed Cause: unknown Consequence: R square goes from 0.016 to 0.428, beta goes from -0.114 to 0.663, the model becomes significant	1995-1996, 1999-2000, 2000-2001 and 2001-2002 are influential points distorting the regression and are therefore removed Cause: unknown Consequence: R square goes from 0.344 to 0.004, beta goes from 2.610 to 0.037, the model becomes nonsignificant

Appendix IV

Table IV.1: A detailed report on the firm-specific analyses of the Verdoorn law and the productivity-performance relationship

Analyses of the industries

Industry name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Basic industry	Blydenstein 1985-1986 and 1987-1988, Corus 1998-1999 and Gamma 1989-1990 are statistical outliers (> 3 times the std residual) and are therefore removed. EVC 1993-1994 and 1994-1995 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.931 to 0.571, beta goes from 0.835 to 0.672, the model remains significant	AKZO-Nobel 1999-2000, Blydenstein 1986-1987, 1994-1995, 1997-1998 and 1999-2000, Gelderse Papier 1996-1997 and Vredestein 1988-1989 are statistical outliers (> 3 times the std residual) and are therefore removed. EVC 1993-1994 and 1997-1998, Royal Dutch/Shell Group 1998-1999 and Vredestein 2000-2001 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.075 to 0.470, beta goes from 20.252 to 4.086, the model remains significant
Food industry	Numico 1994-1995 and 1998-1999, Unilever 1996-1997 and Wessanen 1998-1999 are statistical outliers (> 3 times the std residual) and are therefore removed. Grolsch 1990-1991 and 1993-1994 and Numico 1999-2000 and 2001-2002 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.412 to 0.224, beta goes from 0.516 to 0.324, the model remains significant In the data series of the change in capital-output ratio Unilever 1999-2000 is an additional statistical outlier (> 3 times the std deviation from the average) and is therefore removed. Consequence: R square goes from 0.412 to 0.224, beta goes from 0.516 to 0.324, the model remains significant	CSM 2000-2001, Friesland Coberco Dairy Foods 1999-2000, Nutreco 1996-1997, Unilever 1999-2000 and Wessanen 2000-2001 and 2001-2002 are statistical outliers (> 3 times the std residual) and are therefore removed. Grolsch 1997-1998, Numico 1998-1999 and 2001-2002 and Unilever 1996-1997 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.786 to 0.331, beta goes from 4.659to 1.535, the model remains significant

Industry name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Media	Endemol 1998-1999 and VNU 1999-2000 and 2000-2001 are statistical outliers (> 3 times the std residual) and are therefore removed. Elsevier 1992-1993, 1997-1998 and 1998-1999 and VNU 2001-2002 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.015 to 0.044, beta goes from 0.063 to 0.135, the model becomes significant The average value of the change in capital-output ratio warrants a further analysis of this change. In the data series of the change in capital-output ratio VNU 1997-1998 and Wolters 1995-1996 are statistical outliers (> 3 times the std deviation from the average) and are therefore removed. Consequence: R square goes from 0.044 to 0.074, beta goes from 0.135 to 0.177, the model becomes significant	Elsevier 1992-1993 and 2000-2001, VNU 1992-1993 and Wegener 2001-2002 are statistical outliers (> 3 times the std residual) and are therefore removed. Telegraaf 2000-2001 and VNU 1999-2000 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.156 to 0.340, beta goes from 1.985 to 1.738, the model remains significant

Industry name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Engineering industry	Begemann 1985-1986, 1987-1988 and 1988-1989, Delft Instruments 1998-1999, Exendis 1985-1986, 1986-1987 and 2000-2001 and Van der Giessen 1985-1986 and 1987-1988 are statistical outliers (> 3 times the std residual) and are therefore removed. Begemann 1985-1986, 1987-1988 and 1989-1990 and Exendis 2000-2001 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.106 to 0.339, beta goes from 0.167 to 0.368, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. In the data series of the change in capital-output ratio Atag 1998-1999, Begemann 1984-1985, Van der Giessen 1986-1987 and 1995-1996 and Twentsche Kabel Holding 2001-2002 are additional statistical outliers (> 3 times the std deviation from the average) and are therefore removed. Consequence: R square goes from 0.339 to 0.199, beta goes from 0.135 to 0.261, the model remains significant	Begemann 1984-1985, Delft Instruments 1993-1994 and Van der Giessen 1985-1986 and 1991-1992 are extreme statistical outliers (> 3 times the std residual) and are therefore removed. Consequence: R square goes from 0.031 to 0.275, beta goes from 7.442 to 3.991, the model remains significant Atag 1998-1999, Delft Instruments 1987-1988 and 1997-1998, Exendis 1986-1987 and 2001-2002, Van der Giessen 1983-1984 and Twentsche Kabel Holding 2001-2002 are statistical outliers (> 3 times the std residual) and are therefore removed. Begemann 1989-1990 and Exendis 1985-1986 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.275 to 0.298, beta goes from 3.991 to 2.900, the model remains significant

Industry name	**Remarks Verdoorn analysis**	**Remarks productivity-performance analysis**
Construction industry	BAM 2000-2001, Boskalis 1983-1984, IHC Caland 1985-1986, 1986-1987, 1987-1988, 1988-1989 and 1989-1990, NBM 1987-1988 and VWS 1987-1988 are statistical outliers (> 3 times the std residual) and are therefore removed. Ballast-Nedam 1986-1987, IHC Caland 1984-1985 and VWS 1986-1987 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.956 to 0.201, beta goes from 1.400 to 0.234, the model remains significant The average value of the change in capital-output ratio warrants a further analysis of this change. In the data series of the change in capital-output ratio BAM 2001-2002 is an additional statistical outlier (> 3 times the std deviation from the average) and is therefore removed. Consequence: R square goes from 0.201 to 0.199, beta remains 0.234, the model remains significant Over the period analyzed and with the outliers and influential points removed the capital-output ratio is constantly increasing, with a annual average of 0.026 (= 2.6%)	Ballast-Nedam 1988-1989 and 2000-2001, BAM 1995-1996, Boskalis 1984-1985 and 1988-1989, HBG 1999-2000, IHC Caland 1984-1985, 1987-1988 and 1989-1990, NBM 1987-1988 and VWS 1986-1987 are statistical outliers (> 3 times the std residual) and are therefore removed. Consequence: R square goes from 0.467 to 0.069, beta goes from 11.928 to 1.221, the model remains significant

Industry name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Wholesale	Buhrmann 1997-1998 and Wolff 1993-1994 are statistical outliers (> 3 times the std residual) and are therefore removed. Landré 1997-1998, LCI 1988-1989 and 1989-1990 and Samas 2001-2002 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.142 to 0.251, beta goes from 0.239 to 0.356, the model remains significant In the data series of the change in capital-output ratio Buhrmann 1998-1999 and Hagemeyer 1983-1984 are additional statistical outliers (> 3 times the std deviation from the average) and are therefore removed. Consequence: R square goes from 0.251 to 0.236, beta goes from 0.356 to 0.346, the model remains significant	Ahrend 1983-1984, Brocacef 1988-1989 and 1994-1995, Buhrmann 1992-1993, 1997-1998 and 2001-2002, Geveke 1991-1992, Hagemeyer 1998-1999 and 1999-2000, Imtech 1983-1984 and 1990-1991, Landré 1997-1998 Samas 1999-2000 and Wolff 1991-1992 are statistical outliers (> 3 times the std residual) and are therefore removed. Consequence: R square goes from 0.140 to 0.501, beta goes from 14.644 to 3.484, the model remains significant
Transport	Nedlloyd 1998-1999 and 1999-2000, Van Ommeren 1986-1987 and 1991-1992 and Vopak 2001-2002 are statistical outliers (> 3 times the std residual) and are therefore removed. Nedlloyd 2000-2001 and Smit Internationale 1986-1987 and 1987-1988 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.073 to 0.371, beta goes from 0.736 to 0.566, the model remains significant	KLM 1991-1992 and 1996-1997, Nedlloyd 1986-1987, Van Ommeren 1993-1994 and Smit Internationale 1986-1987 and 1993-1994 are statistical outliers (> 3 times the std residual) and are therefore removed. KLM 1989-1990 and 2000-2001, Nedlloyd 1998-1999, 1999-2000 and 2000-2001 and Van Ommeren 1991-1992 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.004 to 0.474, beta goes from 0.148 to 4.760, the model remains significant

Industry name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Telecommu-nications	For this analysis, the data of KPN, Libertel, UPC and Versatel have been pooled. The data of Libertel, UPC and Versatel are characterized by 1) a limited number of observations, 2) a large share of invalid observations and 3) a large number of outliers and influential points. The consequence is that the available data to estimate the industry model for Telecommunications largely reflects the data of KPN. KPN 1997-1998 is a statistical outlier (> 3 times the std residual) and is therefore removed. KPN 2000-2001 and 2001-2002, Libertel 1996-197, 1997-1998 and 1998-1999 and UPC 1996-1997 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.980 to 0.414, beta goes from 0.700 to 0.577, the model remains significant In the data series of the change in capital-output ratio KPN 1999-2000 is an additional statistical outlier (> 3 times the std deviation from the average) and is therefore removed. Consequence: R square goes from 0.414 to 0.429, beta goes from 0.577to 0.652, the model remains significant	For this analysis, the data of Libertel, KPN, UPC and Versatel have been pooled. The data of Libertel, UPC and Versatel are characterized by (1) a limited number of observations, (2) a large share of invalid observations and (3) a large number of outliers and influential points. The consequence is that the available data to estimate the industry model for Telecommunications largely reflects the data of KPN. KPN 1997-1998 and 2000-2001 and Libertel 1997-1998 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.206 to 0.027, beta goes from –2.241 to 0.475, the model becomes nonsignificant The test for autocorrelation was inconclusive.

Industry name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Financial services	RBG 1998-1999 is a statistical outlier (> 3 times the std residual) and is therefore removed. NIB 1999-2000 and Staal Bankiers 1989-1990 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.800 to 0.633, beta goes from 0.805 to 0.652, the model remains significant In the data series of the change in capital-output ratio Achmea 2001-2002, Kempen & Co. 1989-1990, Van der Moolen 1987-1988 and 2000-2001 and NIB 1998-1999 are additional statistical outliers (> 3 times the std deviation from the average) and are therefore removed. Consequence: R square goes from 0.633 to 0.582, beta goes from 0.652 to 0.606, the model remains significant	Kempen & Co. 1990-1991, Van der Moolen 1989-1990, NIB 1999-2000, RBG 1998-1999 and Staal Bankiers 1989-1990 are statistical outliers (> 3 times the std residual) and are therefore removed. Achmea 2001-2002 is an influential point distorting the regression and is therefore removed. Consequence: R square goes from 0.640 to 0.679, beta goes from 2.228 to 1.638, the model remains significant
IT services	Baan Company 1993-1994 and 1997-1998, CMG 2001-2002, Getronics 2001-2002 and Landis 1998-1999 and 1999-2000 are statistical outliers (> 3 times the std residual) and are therefore removed. CMG 2000-2001, Getronics 1998-1999 and 2000-2001, Simac 2000-2001 and Unit4 1997-1998 and 2000-2001 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.658 to 0.094, beta goes from 0.410 to 0.100, the model remains significant In the data series of the change in capital-output ratio CMG 1999-2000 is an additional statistical outlier (> 3 times the std deviation from the average) and is therefore removed. Consequence: R square goes from 0.094 to 0.095, beta remains at 0.100, the model remains significant	Getronics 2000-2001, Pink-Roccade 2000-2001 and Simac 2000-2001 are statistical outliers (> 3 times the std residual) and are therefore removed. Baan Company 1994-1995, 1995-1996, 1996-1997 and 1997-1998, CMG 2000-2001, Landis 1999-2000, Simac 1997-1998 and Unit4 1998-1999, 1999-2000 and 2000-2001 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.366 to 0.238, beta goes from 13.513 to 2.819, the model remains significant

Industry name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Other business services	Athlon 1992-1993 and Vedior 1998-1999 are statistical outliers (> 3 times the std residual) and are therefore removed. Consequence: R square goes from 0.264 to 0.398, beta goes from 0.925 to 0.465, the model remains significant In the data series of the change in capital-output ratio Athlon 1984-1985 is an additional statistical outlier (> 3 times the std deviation from the average) and is therefore removed. Consequence: R square goes from 0.398 to 0.375, beta goes from 0.465 to 0.449, the model remains significant	Rood 1997-1998 is an extreme statistical outlier (> 3 times the std residual) and is therefore removed. Vedior 1998-1999 is an extreme influential point distorting the regression and is therefore removed. Consequence: R square goes from 0.011 to 0.099, beta goes from 3.476 to 2.810, the model becomes significant Content 1985-1986, Grontmij 1995-1996 and Rood 1989-1990, 1993-1994, 1994-1995 and 1999-2000 are statistical outliers (> 3 times the std residual) and are therefore removed. Arcadis 1985-1986, Athlon 1984-1985 and 1991-1992, Content 1990-1991, Rod 2000-2001 and Vedior 1999-2000 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.099 to 0.191, beta goes from 2.810 to 2.496, the model remains significant

Industry name	**Remarks Verdoorn analysis**	**Remarks productivity-performance analysis**
Retail	Gucci 1993-1994, Laurus 1997-1998 and 2001-2002, Macintosh 1992-1993 and Vilenzo 2001-2002 are statistical outliers (> 3 times the std residual) and are therefore removed. Free Record Shop 1992-1993, Gucci 1994-1995, 1995-1996 and 1999-2000, Laurus 1995-1996 and 2000-2001, P&C 1996-1997, Schuitema 1985-1986 and 2000-2001, Vendex 1996-1997, 1997-1998 and 1998-1999 and Vilenzo 2000-2001 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.144 to 0.114, beta goes from 0.364 to 0.288, the model remains significant In the data series of the change in capital-output ratio Gucci 1998-1999 is an additional statistical outlier (> 3 times the std deviation from the average) and is therefore removed. Consequence: R square remains 0.114, beta goes from 0.288 to 0.297, the model remains significant	KBB 1983-1984, Laurus 1995-1996, Macintosh 2000-2001, P&C 1993-1994 and 1996-1997, Schuitema 1983-1984 and Vilenzo 2001-2002 are statistical outliers (> 3 times the std residual) and are therefore removed. Ahold 2001-2002, Free Record Shop 1992-1993, Gucci 1994-1995, Laurus 1997-1998, Macintosh 1992-1993 and 1996-1997, Vendex 1996-1997 and 2001-2002 and Vilenzo 2000-2001 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.106 to 0.309, beta goes from 17.830 to 1.983, the model remains significant

Industry name	Remarks Verdoorn analysis	Remarks productivity-performance analysis
Electronics industry	Tulip 1998-1999 is an extreme influential point distorting the regression and is therefore removed. Consequence: R square goes from 0.999 to 0.784, beta goes from 0.964 to 0.778, the model remains significant ASM Lithography 2001-2002 and Neways 1991-1992 are statistical outliers (> 3 times the std residual) and are therefore removed. ASM International 1997-1998 and Tulip 1996-1997 and 1999-2000 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.784 to 0.672, beta goes from 0.778 to 0.595, the model remains significant In the data series of the change in capital-output ratio ASM International 1996-1997, ASM Lithography 2000-2001, BE Semiconductor Industries 1994-1995 and 2000-2001 and Philips 2000-2001 are additional statistical outliers (> 3 times the std deviation from the average) and are therefore removed. Consequence: R square goes from 0.672 to 0.619, beta goes from 0.595 to 0.511, the model remains significant The test for autocorrelation was inconclusive.	Tulip 1999-2000 is an extreme statistical outlier and is therefore removed. ASM International 1998-1999 is an extreme influential point distorting the regression and is therefore removed. Consequence: R square goes from 0.398 to 0.454, beta goes from 42.329 to 6.195, the model remains significant ASM International 2001-2002, Neways 2000-2001 and Océ 2001-2002 are statistical outliers (> 3 times the std residual) and are therefore removed. ASM International 1996-1997 and 1999-2000, ASM Lithography 1999-2000 and 2000-2001, BE Semiconductor Industries 1994-1995, 1999-2000 and 2000-2001, Neways 1992-1993 and Philips 1989-1990, 1999-2000 and 2000-2001 are influential points distorting the regression and are therefore removed. Consequence: R square goes from 0.454 to 0.607, beta goes from 6.195 to 3.812, the model remains significant

Table IV.2: A detailed report on the industry-specific analyses of the Verdoorn law and the productivity-performance relationship

Analysis of the entire population

	Remarks Verdoorn analysis	Remarks productivity-performance analysis
All firms	IHC Caland 1986-1987, Nedlloyd 1999-2000 and UPC 1996-1997 are extreme statistical outliers and are therefore removed. Tulip 1998-1999 is an extreme influential point distorting the regression and is therefore removed. Consequence: R square goes from 0.949 to 0.606, beta goes from 0.949 to 0.636, the model remains significant Subsequently, 38 statistical outliers (> 3 times the std residual) have been removed. Consequence: R square goes from 0.606 to 0.513, beta goes from 0.636 to 0.558, the model remains significant From the data series of the change in capital-output ratio, 23 additional statistical outliers (> 3 times the std deviation from the average value, i.e., smaller than -1.5143 or larger than 1.6177) have been removed. Consequence: R square goes from 0.513 to 0.414, beta goes from 0.558 to 0.476, the model remains significant The test for autocorrelation was inconclusive. Over the period analyzed and with the outliers and influential points removed the capital-output ratio is constantly increasing, with a annual average of 0.015 (= 1.5%)	Delft Instruments 1993-1994, P&C 1996-1997, Rood 1997-1998, Tulip 1999-2000 and Vredestein 2000-2001 are extreme statistical outliers and are therefore removed. Nedlloyd 1999-2000 is an extreme influential point distorting the regression and is therefore removed. Consequence: R square goes from 0.017 to 0.085, beta goes from 2.328 to 4.471, the model remains significant Subsequently, 24 statistical outliers (> 3 times the std residual) and 2 influential points distorting the regression have been removed. Consequence: R square goes from 0.085 to 0.311, beta goes from 4.471 to 3.493, the model remains significant The model estimated shows negative autocorrelation.

Table IV.3: A detailed report on the analyses of the Verdoorn law and the productivity-performance relationship for the entire population

APPENDIX V: SUPPORTING ESTIMATIONS FOR THE CORRECTIONS ON THE VERDOORN LAW ESTIMATION

The corrections on the estimations of the Verdoorn law for changes in the capital-labor and the capital-output ratios can be calculated from the differences between the Verdoorn models with and without the parameters δ and γ (see section 9.5.7).

To make these calculations, the values of λ, α and β had to be additionally estimated from the data. We did this by an *Ordinary Least Squares estimation* of the production function that formed the basis of our interpretation of the Verdoorn law:

$$q = \lambda + \alpha k + \beta l + \varepsilon$$

Where q represents growth of output, k represents growth of capital input, l represents growth of labor input and ε represents the error term. The results of this estimation are reported in table V.1 (for firms) and V.2 (for industries and for the entire population) below. Note that, because of the data limits, many of the firm-specific estimations of this production function are nonsignificant and that therefore the parameters λ, α and β are often unusable for making the desired corrections.

The *calculated corrections* on the Verdoorn coefficient and the constant term for the change in *capital-labor ratio* are presented in table V.3 (for firms) and V.4 (for industries and for the entire population) below. As only a small number of these calculations were based on significant estimates, the *actual corrections* made are presented in table V.5 (for firms) and V.6 (for industries and for the entire population.

Note that tables V.1 through V.6 are spread over two pages, the left page covering the first columns and the right page the last columns.

The *calculated corrections* made to the Verdoorn coefficient for the change in *capital-output ratio* are presented in table V.7. As only a part of these calculations were based on significant estimates, the *actual corrections* made are presented in table V.8.

Firm name	total number of observations	valid number of observations	number of observations in model	deleted number of observations	lambda (exogenous technological change)	t-value of lambda
ABN-Amro	19	19	18	1	0.061 (*)	2.715
AEGON	19	19	18	1	0.027	0.555
AKZO-Nobel	19	19	16	3	0.011	0.684
ASM Lithography	9	9	7	2	-1.313	-2.128
ASR Verzekeringsgroep	15	15	14	1	0.116	1.557
Athlon	19	19	17	2	-0.063	-2.080
Beers	16	16	15	1	0.086 (**)	3.326
CMG	9	9	6	3	0.218	1.132
Corus	19	19	17	2	0.007	0.221
DSM	19	19	17	2	0.070	1.995
Getronics	18	18	15	3	0.047	1.089
Grolsch	19	19	17	2	0.042	1.914
Grontmij	19	19	18	1	0.034 (*)	2.443
HBG	17	17	15	2	0.035 (*)	2.698
Heijmans	12	12	12	0	0.074 (**)	4.152
Heineken	19	19	19	0	0.022	1.200
IHC Caland	19	19	12	7	-0.002	-0.023
Imtech	19	19	17	2	0.006	0.300
ING Group	14	14	12	2	-0.023	-0.486
KAS Bank	19	19	18	1	0.003	0.110
KPN	19	19	13	6	0.057 (**)	4.007

alpha (coefficient of change in capital)	t-value of alpha	beta (coefficient of change in labor)	t-value of beta	adjusted R-square	standard error of estimate	F-statistic	significance level of model
0.264	0.782	0.321	0.449	0.097	0.079	1.918	0.181
0.374	2.095	0.926 (*)	2.239	0.290	0.148	4.472	0.030
0.154	0.591	0.210	0.473	0.053	0.053	0.362	0.703
0.971	1.374	3.930 (*)	3.247	0.595	0.296	5.413	0.073
0.130	0.206	-0.441	-0.324	-0.170	0.093	0.057	0.945
0.607 (**)	3.371	0.551 (*)	2.480	0.762	0.097	26.677	0.000
0.277	1.340	0.029	0.077	0.041	0.064	1.298	0.309
-0.917	-1.188	1.585	2.426	0.433	0.140	3.295	0.143
0.985 (*)	2.430	-0.156	-0.328	0.295	0.114	4.345	0.034
0.372	1.832	1.872 (*)	2.803	0.407	0.112	6.498	0.010
-0.061	-0.293	1.024 (***)	6.045	0.809	0.086	30.745	0.000
-0.496	-1.467	0.868	1.468	0.068	0.077	1.587	0.239
-0.011	-0.088	0.656 (***)	5.235	0.608	0.037	14.200	0.000
-0.096	-0.520	0.678 (**)	4.617	0.690	0.043	16.561	0.000
0.101	1.174	0.531 (*)	2.953	0.758	0.038	18.220	0.001
0.673 (*)	0.269	0.207	1.109	0.484	0.049	9.435	0.002
0.083	0.420	1.096 (**)	4.250	0.625	0.084	10.170	0.005
0.652 (*)	2.401	-0.321	-0.947	0.202	0.064	3.027	0.081
1.796 (**)	3.698	-0.610	-0.730	0.639	0.106	10.742	0.004
0.516 (***)	4.662	0.960 (*)	2.296	0.578	0.085	12.624	0.001
-0.325	-1.672	0.458	1.016	0.078	0.043	1.506	0.268

Firm name	total number of obser-vations	valid number of obser-vations	number of obser-vations in model	deleted number of obser-vations	lambda (exogenous technological change)	t-value of lambda
Bank Mendes Gans	15	13	12	1	0.033	1.291
Nedap	19	19	19	0	0.055	1.958
NIB Capital	19	19	16	3	0.123	1.185
Otra	14	14	11	3	0.051	1.774
P&C Group	14	14	13	1	-0.029	-0.868
Philips	19	19	18	1	0.026	0.434
Polygram	9	9	9	0	-0.040	-0.513
Polynorm	17	17	16	1	0.032	1.434
Reed Elsevier	19	19	18	1	0.045	1.081
Schuitema	19	19	16	3	0.038 (*)	2.965
SNS Bank	12	12	11	1	-0.011	-0.274
Telegraaf	19	19	16	3	0.033 (*)	2.663
Ten Cate	19	19	19	0	0.060	1.421
Vendex KBB	12	12	9	3	0.014	1.196
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

alpha (coefficient of change in capital)	t-value of alpha	beta (coefficient of change in labor)	t-value of beta	adjusted R-square	standard error of estimate	F-statistic	significance level of model
0.055	0.247	0.689	1.994	0.175	0.077	2.169	0.170
-0.251	-1.249	1.106 (**)	2.951	0.282	0.075	4.531	0.028
0.968	1.633	-1.492	-1.446	0.271	0.175	3.794	0.050
0.098	0.159	0.358	0.524	-0.102	0.069	0.537	0.604
1.240	2.170	-0.238	-0.525	0.201	0.091	2.513	0.131
1.312 (*)	2.463	0.063	0.055	0.246	0.192	3.771	0.047
0.620	1.750	1.058	2.294	0.326	0.072	2.937	0.129
0.185	1.010	0.624 (*)	2.468	0.407	0.052	6.148	0.013
0.474	1.716	-0.141	-0.318	0.064	0.140	1.581	0.238
0.124	1.244	0.313	0.890	0.033	0.042	1.253	0.318
0.233	0.984	1.775 (*)	2.448	0.639	0.085	9.869	0.007
-0.011	-0.069	1.200 (**)	3.618	0.507	0.039	8.719	0.004
-0.142	-0.305	0.508	1.146	-0.035	0.165	0.695	0.514
0.147	0.910	-0.333	-2.256	0.313	0.027	2.824	0.137

Table V.1: OLS estimates of the production function underlying our specification of the Verdoorn law for individual firms

	total number of obser-vations	valid number of obser-vations	number of obser-vations in model	deleted number of obser-vations	lambda (exogenous technological change)	t-value of lambda
Basic industry	232	232	226	6	0.032 (**)	3.151
Food industry	140	140	131	9	0.031 (***)	3.993
Media	105	104	95	9	0.052 (***)	5.408
Engineering industry	241	241	226	15	0.018 (**)	2.653
Construction industry	158	158	145	13	0.023 (***)	3.297
Wholesale	215	215	207	8	0.032 (***)	3.432
Financial services	224	217	209	8	0.057 (***)	3.520
Retail	147	147	128	19	0.027 (**)	3.153
Electronics industry	99	96	85	11	0.019	0.647
Total population	1947	1925	1860	65	0.036 (***)	8.257
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)						

alpha (coefficient of change in capital)	t-value of alpha	beta (coefficient of change in labor)	t-value of beta	adjusted R-square	standard error of estimate	F-statistic	significance level of model
0.399 (***)	4.222	0.484 (***)	4.715	0.286	0.149	46.078	0.000
0.118	1.871	0.736 (***)	10.061	0.517	0.076	70.667	0.000
0.102 (*)	2.438	0.618 (***)	8.740	0.589	0.080	68.424	0.000
0.202 (***)	4.752	0.725 (***)	14.084	0.669	0.092	228.437	0.000
0.079 (*)	2.167	0.871 (***)	13.581	0.704	0.074	171.882	0.000
0.279 (***)	5.526	0.596 (***)	9.727	0.544	0.122	123.998	0.000
0.363 (***)	6.370	0.600 (***)	5.981	0.386	0.203	66.400	0.000
0.321 (***)	4.985	0.352 (***)	5.131	0.486	0.082	61.022	0.000
0.476 (**)	3.393	0.745 (***)	3.903	0.515	0.233	45.664	0.000
0.257 (***)	13.101	0.591 (***)	22.142	0.429	0.169	699.998	0.000

Table V.2: OLS estimates of the production function underlying our specification of the Verdoorn law for industries and for the entire population

Name	initial constant term (estimated a)	initial coefficient (estimated b)	lambda (exo-genous techno-logical change)	alpha (coefficient of change in capital)	beta (coeffi-cient of change in labor)
ABN-Amro	0.000	0.765 (***)	0.061 (*)	0.264	0.321
AEGON	-0.015	0.734 (***)	0.027	0.374	0.926 (*)
AKZO-Nobel	0.016	0.913 (***)	0.011	0.154	0.210
ASM Lithography	-0.185 (**)	0.597 (***)	-1.313	0.971	3.930 (*)
ASR Verzekeringsgroep	-0.031 (*)	0.998 (***)	0.116	0.130	-0.441
Athlon	-0.037	0.362 (**)	-0.063	0.607 (**)	0.551 (*)
Beers	-0.012	0.789 (**)	0.086 (**)	0.277	0.029
CMG	-0.081	0.393	0.218	-0.917	1.585
Corus	0.035	0.819 (***)	0.007	0.985 (*)	-0.156
DSM	0.034 (**)	0.834 (***)	0.070	0.372	1.872 (*)
Getronics	-0.001	0.105	0.047	-0.061	1.024 (***)
Grolsch	0.012	0.897 (***)	0.042	-0.496	0.868
Grontmij	0.022	0.011	0.034 (*)	-0.011	0.656 (***)
HBG	0.045 (*)	-0.188	0.035 (*)	-0.096	0.678 (**)
Heijmans	0.061	-0.138	0.074 (**)	0.101	0.531 (*)
Heineken	0.012	0.316	0.022	0.673 (*)	0.207
IHC Caland	-0.018	0.303 (*)	-0.002	0.083	1.096 (**)
Imtech	0.030	0.998 (**)	0.006	0.652 (*)	-0.321
ING Group	-0.012	0.782 (***)	-0.023	1.796 (**)	-0.610
KAS Bank	-0.019	0.853 (***)	0.003	0.516 (***)	0.960 (*)
KPN	0.008	0.913 (**)	0.057 (**)	-0.325	0.458
Nedap	-0.020	0.667 (***)	0.055	-0.251	1.106 (**)

average growth of capital input	average growth of labor input	delta	correction on constant term (zèta)	correction on coefficient (phi)	corrected constant term (a)	corrected coefficient (b)
0.061	0.019	3.139	-0.137	1.423	0.137	-0.658
0.152	0.046	3.272	-0.017	0.211	0.002	0.523
0.028	-0.010	-2.979	-0.097	8.049	0.113	-7.136
0.516	0.328	1.572	0.093	-0.176	-0.278	0.773
0.118	0.029	4.114	1.500	-12.636	-1.531	13.634
0.146	0.083	1.767	0.076	0.097	-0.113	0.265
0.112	0.036	3.119	-2.864	23.743	2.852	-22.954
0.347	0.258	1.342	0.478	-1.616	-0.559	2.009
0.003	-0.028	-0.101	0.017	3.817	0.018	-2.998
0.037	-0.030	-1.217	0.012	-0.369	0.022	1.203
0.209	0.278	0.750	0.002	0.014	-0.003	0.091
0.024	-0.009	-2.581	-0.029	1.258	0.041	-0.361
0.084	0.032	2.673	0.002	-0.056	0.020	0.067
0.029	-0.012	-2.442	-0.013	0.519	0.058	-0.707
0.218	0.118	1.838	-0.036	0.298	0.097	-0.436
0.072	0.044	1.627	-0.090	0.812	0.102	-0.496
0.225	0.115	1.952	0.000	0.042	-0.018	0.261
0.008	-0.025	-0.313	0.007	0.821	0.023	0.177
0.109	0.039	2.777	-0.044	1.076	0.032	-0.294
0.111	0.031	3.566	-0.002	0.147	-0.017	0.706
0.036	-0.003	-11.188	-0.110	2.649	0.118	-1.736
0.092	0.046	2.009	0.042	-0.531	-0.062	1.198

Name	initial constant term (estimated a)	initial coefficient (estimated b)	lambda (exo-genous techno-logical change)	alpha (coefficient of change in capital)	beta (coeffi-cient of change in labor)
NIB Capital	-0.061 (***)	1.067 (***)	0.123	0.968	-1.492
Otra	0.006	0.747 (*)	0.051	0.098	0.358
P&C Group	0.031	0.926 (**)	-0.029	1.240	-0.238
Philips	0.032 (*)	0.979 (***)	0.026	1.312 (*)	0.063
Polygram	-0.024	0.610 (*)	-0.040	0.620	1.058
Polynorm	-0.009	0.378 (*)	0.032	0.185	0.624 (*)
Reed Elsevier	-0.011	0.906 (***)	0.045	0.474	-0.141
Schuitema	-0.001	0.820 (**)	0.038 (*)	0.124	0.313
SNS Bank	-0.015	0.661 (***)	-0.011	0.233	1.775 (*)
Telegraaf	0.011	0.485 (**)	0.033 (*)	-0.011	1.200 (**)
Ten Cate	0.011	0.827 (***)	0.060	-0.142	0.508
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)					

average growth of capital input	average growth of labor input	delta	correction on constant term (zeta)	correction on coefficient (phi)	corrected constant term (a)	corrected coefficient (b)
0.099	0.053	1.873	0.465	-3.133	-0.526	4.200
0.039	0.010	4.067	-0.074	1.196	0.080	-0.449
0.025	-0.026	-0.958	-0.102	1.710	0.133	-0.784
0.017	-0.029	-0.583	-0.447	-3.539	0.479	4.518
0.148	0.071	2.103	0.021	-0.064	-0.045	0.674
0.103	0.064	1.592	-0.016	0.217	0.007	0.161
0.100	0.023	4.269	0.341	-4.262	-0.352	5.168
0.069	0.010	6.878	-0.089	1.941	0.088	-1.121
0.176	0.049	3.623	0.002	0.050	-0.017	0.611
0.058	0.014	4.212	0.001	-0.024	0.010	0.509
0.042	0.004	10.424	-0.179	3.277	0.190	-2.450

Table V.3: Calculated corrections on the Verdoorn coefficient and the constant term for changes in the capital-labor ratio for individual firms

	initial constant term (estimated a)	initial coefficient (estimated b)	lambda (exo-genous techno-logical change)	alpha (coefficient of change in capital)	beta (coeffi-cient of change in labor)
Basic industry	0.008	0.672 (***)	0.032 (**)	0.399 (***)	0.484 (***)
Food industry	0.003	0.322 (***)	0.031 (***)	0.118	0.736 (***)
Media	0.024 (*)	0.177 (**)	0.052 (***)	0.102 (*)	0.618 (***)
Engineering industry	-0.002	0.261 (***)	0.018 (**)	0.202 (***)	0.725 (***)
Construction industry	0.004	0.234 (***)	0.023 (***)	0.079 (*)	0.871 (***)
Wholesale	0.002	0.346 (***)	0.032 (***)	0.279 (***)	0.596 (***)
Financial services	-0.021 (*)	0.606 (***)	0.057 (***)	0.363 (***)	0.600 (***)
Retail	-0.006	0.297 (***)	0.027 (**)	0.321 (***)	0.352 (***)
Electronics industry	-0.018	0.511 (***)	0.019	0.476 (**)	0.745 (***)
Total population	-0.014 (***)	0.476	0.036 (***)	0.257 (***)	0.591 (***)
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)					

average growth of capital input	average growth of labor input	delta	correction on constant term (zeta)	correction on coefficient (phi)	corrected constant term (a)	corrected coefficient (b)
0.026	0.008	3.386	-0.049	0.697	0.057	-0.025
0.061	0.047	1.310	-0.007	0.076	0.010	0.246
0.127	0.063	2.009	-0.021	0.238	0.045	-0.061
0.090	0.065	1.376	-0.007	0.104	0.005	0.157
0.111	0.061	1.822	-0.004	0.072	0.008	0.162
0.081	0.062	1.307	-0.020	0.169	0.022	0.177
0.129	0.080	1.619	-0.047	0.220	0.026	0.386
0.080	0.064	1.250	-0.041	0.601	0.035	-0.304
0.158	0.087	1.826	-0.014	0.084	-0.004	0.427
0.103	0.071	1.443	-0.023	0.218	0.009	0.258

Table V.4: Calculated corrections on the Verdoorn coefficient and the constant term for changes in the capital-labor ratio for industries and for the entire population

Name	initial constant term (estimated a)	initial coefficient (estimated b)	lambda (exo-genous techno-logical change)	alpha (coefficient of change in capital)	beta (coefficient of change in labor)
ABN-Amro	nonsign.	0.765 (***)	0.061 (*)	nonsign.	nonsign.
AEGON	nonsign.	0.734 (***)	nonsign.	nonsign.	0.926 (*)
AKZO-Nobel	nonsign.	0.913 (***)	nonsign.	nonsign.	nonsign.
ASM Lithography	-0.185 (**)	0.597 (***)	nonsign.	nonsign.	3.930 (*)
ASR Verzekeringsgroep	-0.031 (*)	0.998 (***)	nonsign.	nonsign.	nonsign.
Athlon	nonsign.	0.362 (**)	nonsign.	0.607 (**)	0.551 (*)
Beers	nonsign.	0.789 (**)	0.086 (**)	nonsign.	nonsign.
CMG	nonsign.	nonsign.	nonsign.	nonsign.	nonsign.
Corus	nonsign.	0.819 (***)	nonsign.	0.985 (*)	nonsign.
DSM	0.034 (**)	0.834 (***)	nonsign.	nonsign.	1.872 (*)
Getronics	nonsign.	nonsign.	nonsign.	nonsign.	1.024 (***)
Grolsch	nonsign.	0.897 (***)	nonsign.	nonsign.	nonsign.
Grontmij	nonsign.	nonsign.	0.034	nonsign.	0.656
HBG	0.045 (*)	nonsign.	0.035 (*)	nonsign.	0.678 (***)
Heijmans	nonsign.	nonsign.	0.074 (**)	nonsign.	0.531 (*)
Heineken	nonsign.	nonsign.	nonsign.	0.673 (*)	nonsign.
IHC Caland	nonsign.	0.303 (*)	nonsign.	nonsign.	1.096 (**)
Imtech	nonsign.	0.998 (**)	nonsign.	0.652 (*)	nonsign.
ING Group	nonsign.	0.782 (***)	nonsign.	1.796 (**)	nonsign.
KAS Bank	nonsign.	0.853 (***)	nonsign.	0.516 (***)	0.960 (*)
KPN	nonsign.	0.913 (**)	0.057 (**)	nonsign.	nonsign.
Nedap	nonsign.	0.667 (***)	nonsign.	nonsign.	1.106 (**)

average growth of capital input	average growth of labor input	delta	correction on constant term (zeta)	correction on coefficient (phi)	corrected constant term (a)	corrected coefficient (b)
0.061	0.019	3.139	n.a.	n.a.	n.a.	n.a.
0.152	0.046	3.272	n.a.	n.a.	n.a.	n.a.
0.028	-0.010	-2.979	n.a.	n.a.	n.a.	n.a.
0.516	0.328	1.572	n.a.	n.a.	n.a.	n.a.
0.118	0.029	4.114	n.a.	n.a.	n.a.	n.a.
0.146	0.083	1.767	n.a.	0.097	n.a.	0.265
0.112	0.036	3.119	n.a.	n.a.	n.a.	n.a.
0.347	0.258	1.342	n.a.	n.a.	n.a.	n.a.
0.003	-0.028	-0.101	n.a.	n.a.	n.a.	n.a.
0.037	-0.030	-1.217	n.a.	n.a.	n.a.	n.a.
0.209	0.278	0.750	n.a.	n.a.	n.a.	n.a.
0.024	-0.009	-2.581	n.a.	n.a.	n.a.	n.a.
0.084	0.032	2.673	n.a.	n.a.	n.a.	n.a.
0.029	-0.012	-2.442	n.a.	n.a.	n.a.	n.a.
0.218	0.118	1.838	n.a.	n.a.	n.a.	n.a.
0.072	0.044	1.627	n.a.	n.a.	n.a.	n.a.
0.225	0.115	1.952	n.a.	n.a.	n.a.	n.a.
0.008	-0.025	-0.313	n.a.	n.a.	n.a.	n.a.
0.109	0.039	2.777	n.a.	n.a.	n.a.	n.a.
0.111	0.031	3.566	n.a.	0.147	n.a.	0.706
0.036	-0.003	-11.188	n.a.	n.a.	n.a.	n.a.
0.092	0.046	2.009	n.a.	n.a.	n.a.	n.a.

Name	initial constant term (estimated a)	initial coefficient (estimated b)	lambda (exo-genous techno-logical change)	alpha (coefficient of change in capital)	beta (coefficient of change in labor)
NIB Capital	-0.061 (***)	1.067 (***)	nonsign.	nonsign.	nonsign.
Otra	nonsign.	0.747 (*)	nonsign.	nonsign.	nonsign.
P&C Group	nonsign.	0.926 (**)	nonsign.	nonsign.	nonsign.
Philips	0.032 (*)	0.979 (***)	nonsign.	1.312 (*)	nonsign.
Polygram	nonsign.	0.610 (*)	nonsign.	nonsign.	nonsign.
Polynorm	nonsign.	0.378 (*)	nonsign.	nonsign.	0.624 (*)
Reed Elsevier	nonsign.	0.906 (***)	nonsign.	nonsign.	nonsign.
Schuitema	nonsign.	0.820 (**)	0.038 (*)	nonsign.	nonsign.
SNS Bank	nonsign.	0.661 (***)	nonsign.	nonsign.	1.775 (*)
Telegraaf	nonsign.	0.485 (**)	0.033 (*)	nonsign.	1.200 (**)
Ten Cate	nonsign.	0.827 (***)	nonsign.	nonsign.	nonsign.
Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)					

average growth of capital input	average growth of labor input	delta	correction on constant term (zeta)	correction on coefficient (phi)	corrected constant term (a)	corrected coefficient (b)
0.099	0.053	1.873	n.a.	n.a.	n.a.	n.a.
0.039	0.010	4.067	n.a.	n.a.	n.a.	n.a.
0.025	-0.026	-0.958	n.a.	n.a.	n.a.	n.a.
0.017	-0.029	-0.583	n.a.	n.a.	n.a.	n.a.
0.148	0.071	2.103	n.a.	n.a.	n.a.	n.a.
0.103	0.064	1.592	n.a.	n.a.	n.a.	n.a.
0.100	0.023	4.269	n.a.	n.a.	n.a.	n.a.
0.069	0.010	6.878	n.a.	n.a.	n.a.	n.a.
0.176	0.049	3.623	n.a.	n.a.	n.a.	n.a.
0.058	0.014	4.212	n.a.	n.a.	n.a.	n.a.
0.042	0.004	10.424	n.a.	n.a.	n.a.	n.a.

Table V.5: Actual corrections on the Verdoorn coefficient and the constant term for changes in the capital-labor ratio for individual firms

Name	initial constant term (estimated a)	initial coefficient (estimated b)	lambda (exo-genous techno-logical change)	alpha (coefficient of change in capital)	beta (coefficient of change in labor)
Basic industry	nonsign.	0.672 (***)	0.032 (**)	0.399 (***)	0.484 (***)
Food industry	nonsign.	0.322 (***)	0.031 (***)	nonsign.	0.736 (***)
Media	0.024 (*)	0.177 (**)	0.052 (***)	0.102 (*)	0.618 (***)
Engineering industry	nonsign.	0.261 (***)	0.018 (**)	0.202 (***)	0.725 (***)
Construction industry	nonsign.	0.234 (***)	0.023 (***)	0.079 (*)	0.871 (***)
Wholesale	nonsign.	0.346 (***)	0.032 (***)	0.279 (***)	0.596 (***)
Financial services	-0.021 (*)	0.606 (***)	0.057 (***)	0.363 (***)	0.600 (***)
Retail	nonsign.	0.297 (***)	0.027 (**)	0.321 (***)	0.352 (***)
Electronics industry	nonsign.	0.511 (***)	nonsign.	0.476 (**)	0.745 (***)
Total population	-0.014 (***)	0.476 (***)	0.036 (***)	0.257 (***)	0.591 (***)

Significance at the 5% level is indicated by (*), at the 1% level by (**) and at the 0.1% level by (***)

average growth of capital input	average growth of labor input	delta	correction on constant term (zeta)	correction on coefficient (phi)	corrected constant term (a)	corrected coefficient (b)
0.026	0.008	3.386	-0.049	0.697	n.a.	-0.025
0.061	0.047	1.310	n.a.	n.a.	n.a.	n.a.
0.127	0.063	2.009	-0.021	0.238	0.045	-0.061
0.090	0.065	1.376	-0.007	0.104	n.a.	0.157
0.111	0.061	1.822	-0.004	0.072	n.a.	0.162
0.081	0.062	1.307	-0.020	0.169	n.a.	0.177
0.129	0.080	1.619	-0.047	0.220	0.026	0.386
0.080	0.064	1.250	-0.041	0.601	n.a.	-0.304
0.158	0.087	1.826	n.a.	0.084	n.a.	0.427
0.103	0.071	1.443	-0.023	0.218	0.009	0.258

Table V.6: Actual corrections on the Verdoorn coefficient and the constant term for changes in the capital-labor ratio for industries and for the entire population

Name	initial coefficient (estimated b)	alpha (coefficient of change in capital)	beta (coefficient of change in labor)	average growth of capital input	average growth of output	gamma	correction on coefficient (theta)	corrected coefficient (b)
Athlon	0.362 (**)	0.607 (**)	0.551 (*)	0.146	0.071	2.054	1.161	-0.799
Getronics	0.105	-0.061	1.024 (***)	0.209	0.319	0.654	0.021	0.084
Bank Mendes Gans	0.553 (*)	0.055	0.689	-0.023	0.054	-0.424	-0.114	0.667
Vendex KBB	2.451 (**)	0.147	-0.333	-0.043	0.013	-3.308	1.902	0.549
Construction industry	0.234 (***)	0.079 (*)	0.871 (***)	0.111	0.085	1.301	0.027	0.207
Total population	0.476 (***)	0.257 (***)	0.591 (***)	0.103	0.104	0.986	-0.006	0.482

Table V.7: Calculated corrections on the Verdoorn coefficient for changes in the capital-output ratio

Name	Initial coefficient (estimated b)	alpha (coefficient of change in capital)	beta (coefficient of change in labor)	average growth of capital input	average growth of output	gamma	correction on coefficient (theta)	corrected coefficient (b)
Athlon	0.362 (**)	0.607 (**)	0.551 (*)	0.146	0.071	2.054	1.161	-0.799
Getronics	nonsign.	nonsign.	1.024 (***)	0.209	0.319	0.654	n.a.	n.a.
Bank Mendes Gans	0.553 (*)	nonsign.	nonsign.	-0.023	0.054	-0.424	n.a.	n.a.
Vendex KBB	2.451 (**)	nonsign.	nonsign.	-0.043	0.013	-3.308	n.a.	n.a.
Construction industry	0.234 (***)	0.079 (*)	0.871 (***)	0.111	0.085	1.301	0.027	0.207
Total population	0.476 (***)	0.257 (***)	0.591 (***)	0.103	0.104	0.986	-0.006	0.482

Table V.8: Actual corrections on the Verdoorn coefficient for changes in the capital-output ratio

EXECUTIVE SUMMARY

What is increasing returns?

This thesis is about *increasing returns, positive feedback effects in markets and firms*. Positive feedback means that success causes further success and failure causes further failure.

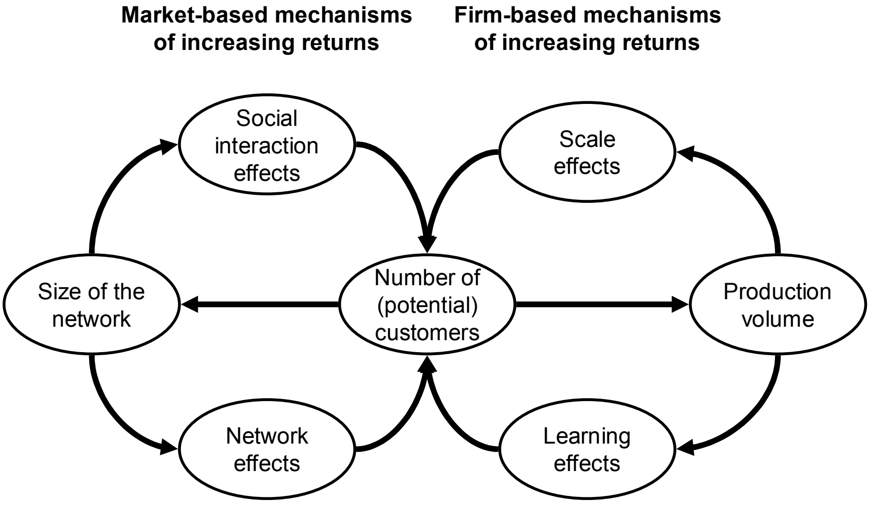
In markets and firms there are four mechanisms of increasing returns: network effects, social interaction effects, scale effects and learning effects. Increasing returns is therefore a broader concept than the traditional increasing returns to scale, which only includes scale effects. Of the four mechanisms, network effects and social interaction effects are market-based and scale effects and learning effects are firm-based.

1. *Network effects* occur when the usefulness of a product becomes larger as its network of users grows in size. Network size is determined by the number of suppliers and users of products based on a common technological standard. The larger the network, the more attractive it becomes for non-users to buy the product, thereby increasing the size of the network. An example is computer operating software: the larger the network of users, the easier it becomes to exchange files worldwide, the more attractive the software, the more it is sold, the larger the network. In other words, there is a positive feedback loop or increasing returns.
2. *Social interaction effects* occur when the opinions or expectations of a customer with regard to a product are dependent on the opinions or expectations of others. The more customers that have a preference for a certain product, or an expectation that a certain technology will become the market standard, the more other customers will copy these preferences and expectations, thus making the product more popular, causing the technology indeed becoming the market standard. Here, we also see a positive feedback loop.
3. *Scale effects* occur when there is a positive relation between the scale at which a firm operates and its productivity. In other words: larger scale production causes lower unit costs. This is a well-known effect that in itself is not yet increasing returns as we define it because there is no positive feedback loop. The firm can create such a positive feedback loop by using the lower unit cost either to lower its product price or to increase its customer value. This will improve the firm's competitive position in the

market, causing more demand for the firm's products, causing a larger scale of production and thus again lower unit costs. This closes the positive feedback loop is closed and thus the firm realizes increasing returns.

4. *Learning effects* occur when there is a positive relation between the cumulative production of the firm and its productivity. In other words: the growth in knowledge and experience, which increases over time, will result in lower unit costs. This can result from conscious training, from technological change or from *learning-by-doing*. For learning effects, the reasoning is the same as for scale effects: they are not increasing returns in themselves. Only when the firm creates a positive feedback loop by investing the acquired cost advantage in lowering product prices or increasing customer value, can we speak of increasing returns.

The four mechanisms of increasing returns, and the ways in which they cause positive feedback effects, are sketched in the figure below.



The mechanisms of increasing returns

Why study increasing returns? Aims and goals

Why would it be interesting to study increasing returns and the four mechanisms described? Almost everyone knows the *law of diminishing returns*, which states that putting in increasing effort will eventually lead to decreasing rise of output. Yet there are reasons to study the opposite, i.e., *increasing returns*. First, increasing returns mechanisms are actually present in markets and firms and have a considerable influence on firm performance. Second, in our current information and knowledge society, with its dense networks of electronic connectivity, increasing returns mechanisms are becoming more important. We need only to look at the ICT industry, and at firms like *Microsoft*, *Cisco* or *Nokia*, to see all four increasing returns mechanisms at work. Third it is an appealing concept: we put effort in and get progressively more out in return! That sounds like a *free lunch*, a compelling yet doubtful concept. Yet, if we look more carefully, the presence of increasing returns mechanisms is a precondition for any system to grow. Fourth, we are in good company as economists since *Adam Smith* have found it worthwhile to study this topic.

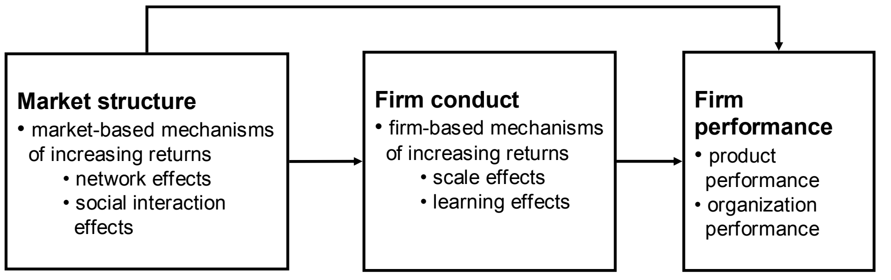
Four goals were set in this thesis:

- Could we, from a management perspective, develop an integral concept of increasing returns?
- Could we create insight into the mechanisms of increasing returns by measuring them?
- Could we empirically, i.e., based on real-world data, analyze the relations between those mechanisms and the consequences of these mechanisms for business performance?
- Could we, using the above knowledge, define a number of building blocks that managers can use to understand the consequences of increasing returns for their market and their firm, enabling them to take strategic action and thereby improve their firms' performance?

To realize these goals we used a well-known framework taken from industrial organization theory, the *structure-conduct-performance paradigm*, following the research of, among others, *Michael Porter*.

Basic reasoning

The basic reasoning underpinning this framework is that what happens in the market influences the performance of firms, through the behavior of these firms. In this thesis, network effects and social interaction effects are indicative of what happens in the market and scale effects and learning effects are indicative of the behavior of the firm, see the figure below.



Basic framework

Reasoning further within this framework, the presence of network effects and social interaction effects causes a battle for the technological standard in the market. The consequences of this battle are that:

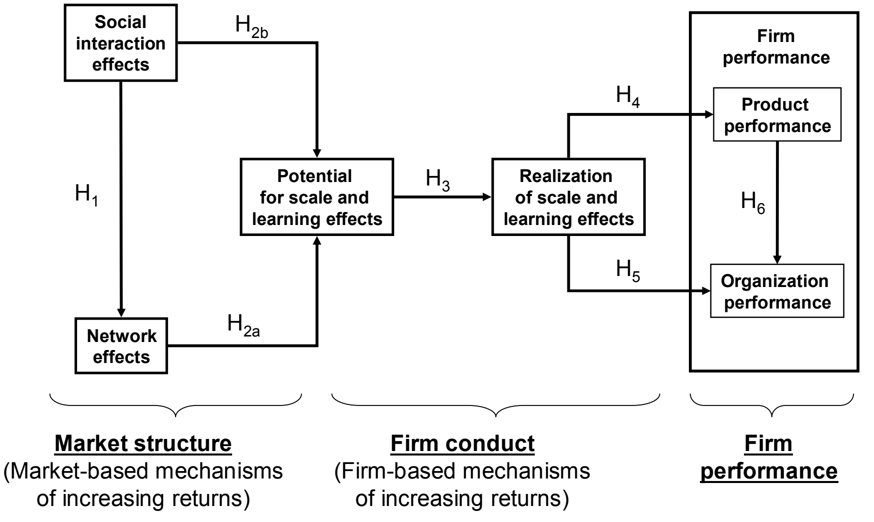
- competition will take place on the network level instead of on the product level: a very high-quality product with a small network of users may easily lose the battle to a good-enough product with a large network of users
- the outcome of the technology battle cannot be predicted in advance: multiple outcomes are possible, usually with one of the technologies taking a dominant position, *winner-takes-all*
- the market may *lock in*, meaning that an existing technology becomes so established that users will find the investments required for a newer or qualitatively better technology prohibitive and therefore will be stuck with the existing technology
- the market may show excessive behavior, either not taking off at all because all the players wait for each other to invest first, or taking off spectacularly fast because all the players imitate each other an do not want to be *last-to-market*
- the market may be *path dependent*, meaning that a small chance event in history, amplified by positive feedback can have a large influence on the market outcome
- the market may be *imperfect* and/or *inefficient*, meaning that the best technology does not necessarily win the technology battle

In this thesis we reason that these market consequences give rise to a potential for individual firms to achieve scale and learning effects. An individual firm could gain, depending on its strategy and management skills, a large part of the potential market. Generic increasing returns strategies that firms could follow are:

- A *shaper strategy*, i.e., a firm sponsoring its own proprietary technology that will generate high returns if it becomes dominant in the market. Firms following such a strategy enjoy the largest potential for scale and learning effects; however, such a strategy is both costly and risky, which means that only a few firms can afford to develop and implement it.
- A *follower strategy*, i.e., a firm joining the dominant technology network by acquiring a license to develop products based on this technology. In a situation where the firm is not a sponsor of the dominant technology, it may nevertheless profit from the potential for scale and learning effects created by the dominant technology, by offering products or technologies that are compatible with, and complementary to, this technology.
- *Reserving the right to play*, i.e., a firm can postpone the decision to commit itself to a technology network until it becomes clear which technology network will dominate the market; doing all that is necessary to create or keep open opportunities in order to acquire a strong position at a later stage.

Whether an individual firm is also able to exploit any advantage from an increasing returns strategy is dependent on the generic competitive strategy it follows. Following a *cost-leadership strategy*, the firm will lower its product prices and acquire a competitive advantage by being the cheapest in the market. Following a *differentiation strategy*, the firm will increase its customer value and acquire a competitive advantage by offering unique value in the market.

This reasoning led us to construct the following research model.



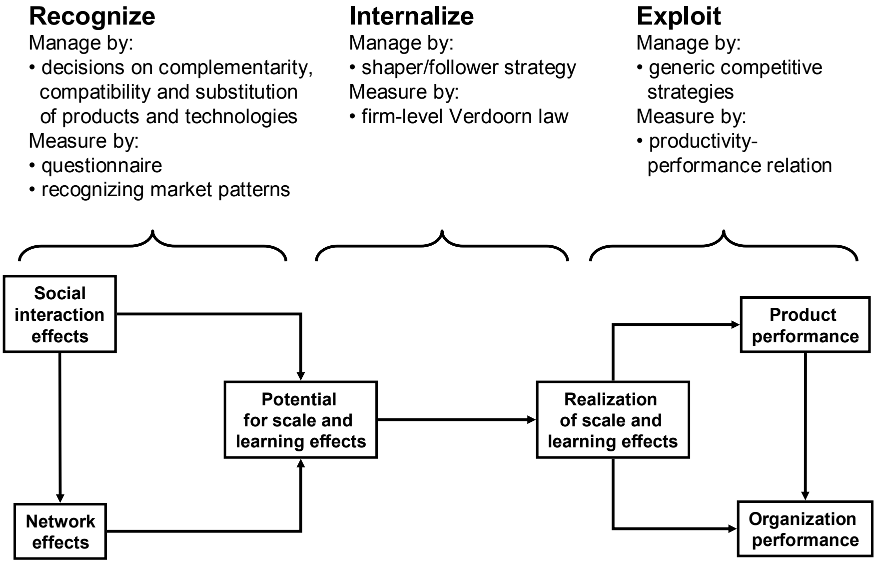
Research model

Research and results

Three empirical studies were conducted for which new measurement models were constructed and tested and for which primary and secondary data was collected and analyzed. The first and second empirical studies were survey studies; the third was an analysis of the developments in firms' productivity over time, based on financial data. The results of all three studies support the presented research model, which means that the presence of network effects and social interaction effects in the market influence firm performance, but always through the realization of scale and learning effects in the firm. This means that in an increasing returns market the management of the firm is an important factor for determining firm performance.

Management implications

The implications for management presented in this thesis are threefold. First, it is important for managers to understand the mechanisms of increasing returns in their markets and their firms, the relations between those mechanisms and the consequences for business performance. A number of building blocks are presented in this thesis that can be used to assist managers to understand their firms' situations. See the figure below.



Management implications

Second, managers will need to recognize and estimate the increasing returns sensitivity of their market and their firm. A number of measurement instruments are presented in this thesis that can be used to support managers to do so. The questionnaire used for measuring network effects and social interaction effects in the market was tested thoroughly and was found to be a reliable and valid measurement instrument for this goal. A measurement instrument was developed of the relation between output and productivity for measuring scale and learning effects. This relation is known as *Verdoorn's law* at the country and industry level and in this thesis *Verdoorn's law* has been applied at the firm level for the first time. An equivalent model was developed to measure the relation between productivity and business performance. These analyses have been made, and are available from the author, for larger Dutch firms listed on the *Amsterdam Stock Exchange (AEX).* Such analyses can also be made for all other firms, provided the necessary financial data are made available.

Third, managers should be able to fathom the strategic implications of the presence of increasing returns in their markets and firms. This will enable them to take strategic actions to exploit business opportunities arising from increasing returns and to avoid pitfalls, resulting in better business performance.

In summary, competing in increasing returns markets is certainly more risky and it requires different management skills than competing in traditional markets. This might give the impression that it is like playing a game of *Russian roulette*, in which managers and their firms are at the mercy of erratic market forces. We think this is not the whole truth: we think that, provided that managers understand the mechanisms of increasing returns and their consequences, they are certainly capable of dealing with the challenges of competing in increasing returns markets.

SAMENVATTING (SUMMARY IN DUTCH)

Wat is increasing returns?

Dit proefschrift gaat over *increasing returns*[92]*, positieve feedback effecten in markten en bedrijven*.[93] Positieve feedback betekent dat de outputs van een systeem, dus een markt of een bedrijf, een positieve invloed hebben op de inputs ervan. Hierdoor zullen toenemende inputs leiden tot progressief toenemende outputs. In managementtermen betekent dit dat succes leidt tot vermeerderd succes en falen tot vermeerderd falen.

Uit de literatuurstudie die voor dit proefschrift is uitgevoerd, blijkt dat er in markten en bedrijven vier mechanismen van positieve feedback zijn, de *mechanismen van increasing returns*: netwerkeffecten, sociale interactie-effecten, schaaleffecten en leereffecten. Van deze mechanismen zijn netwerkeffecten en sociale interactie-effecten gerelateerd aan de markt en schaaleffecten en leereffecten gerelateerd aan het bedrijf.

1. Netwerkeffecten treden op als de gebruiksmogelijkheden van een product toenemen naarmate het gebruikersnetwerk groter wordt. Het gebruikersnetwerk bestaat uit alle gebruikers en aanbieders van het product. Door het groter worden van dit netwerk wordt het aantrekkelijker voor niet-gebruikers om het product eveneens aan te schaffen, waardoor het netwerk weer wordt vergroot. Op deze wijze ontstaat dus een positieve feedback loop. We spreken hier van *directe netwerkeffecten*. Een voorbeeld is de besturingssoftware van een computer: hoe groter het netwerk van gebruikers, hoe gemakkelijker het wordt om wereldwijd bestanden uit te wisselen, hoe aantrekkelijker weer het product, hoe meer verkocht, hoe groter het netwerk. De gebruiksmogelijkheden van een product nemen eveneens toe als het netwerk van complementaire producten groter wordt, dat wil zeggen, wanneer er meer producten op de markt komen die samen met dit product te gebruiken zijn. We spreken hier van *indirecte netwerkeffecten*.

Een voorbeeld is het gebruik van besturingssoftware van een computer samen met de toepassingsprogramma's: hoe meer toepassingsprogramma's er beschikbaar zijn, hoe

[92] In het Nederlands kan increasing returns worden vertaald als *toenemende meeropbrengsten*. Ik geef echter de voorkeur aan het gebruik van *increasing returns*.

[93] Let op! Deze definitie wijkt af van de gebruikelijke economische definitie van increasing returns.

aantrekkelijker het besturingsprogramma, hoe aantrekkelijker het voor aanbieders wordt om nieuwe toepassingsprogramma's te ontwikkelen.

2. Sociale interactie-effecten treden op als de voorkeuren of verwachtingen van een gebruiker ten aanzien van een product afhankelijk zijn van de voorkeuren of verwachtingen van andere gebruikers. Bij afhankelijkheid van voorkeuren spreken we van *informatie-uitwisseling*, bij afhankelijkheid van verwachtingen spreken we van *zelfversterkende verwachtingen*. Voorbeelden van informatie-uitwisseling zijn hypes en modeverschijnselen waarbij gebruikers elkaars voorkeuren overnemen en vaak ook elkaars gedrag kopiëren. Hoe meer gebruikers een voorkeuren voor een bepaald product hebben, hoe meer andere gebruikers deze voorkeur zullen overnemen. Op deze wijze ontstaat een positieve feedback loop.

Een voorbeeld van zelfversterkende verwachtingen bij nieuw op de markt komende technologieën is het volgende: wanneer veel gebruikers verwachten dat technologie A de marktstandaard zal worden, zullen andere gebruikers hiermee in hun aanschafgedrag rekening houden, door producten gebaseerd op technologie *A* te kopen en producten gebaseerd op technologie *B* juist niet te kopen, waardoor technologie *A* ook inderdaad de marktstandaard wordt. Ook in dit geval is er sprake van een positieve feedback loop.

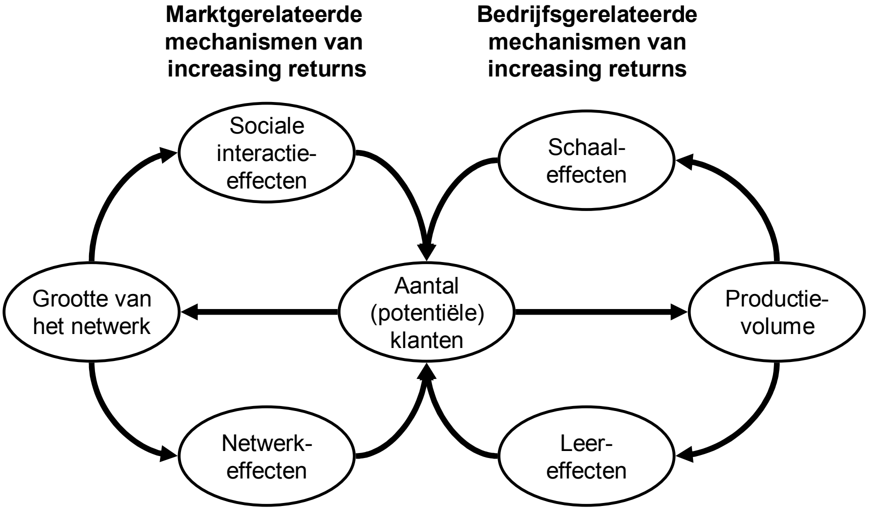
3. Schaaleffecten treden op als er een positieve relatie is tussen de schaal waarop een bedrijf opereert en de productiviteit van het bedrijf. Met andere woorden: een grotere schaal van produceren leidt tot lagere kosten per eenheid product. Dit kan te maken hebben met de vaste kosten: als de schaal van productie groter wordt, kunnen de vaste kosten over een groter aantal producten worden uitgesmeerd, waardoor de vaste kosten per eenheid product lager zullen worden. Het kan ook te maken hebben met de variabele kosten: als de schaal van productie groter wordt kan er voordeliger in grotere hoeveelheden worden ingekocht, waardoor de variabele kosten per eenheid product lager zullen worden.

Het is van groot belang te onderkennen dat het optreden van schaaleffecten als hierboven beschreven nog niet betekent dat er ook sprake is van increasing returns. Hiervoor moet in onze defnitie immers sprake zijn van een positieve feedback loop. Een dergelijke loop ontstaat pas waneer het bedrijf de lagere kosten per eenheid product gebruikt om ófwel de prijs van het product in de markt te verlagen, ófwel de waarde van het product voor de klant te verhogen. Onder voorwaarden dat (1) er voldoende vraag is in de markt, (2) de prijs-elasticiteit voldoende hoog is en (3) het bedrijf met het verlagen van de prijs of het verhogen van de klantwaarde in staat is de positie ten opzichte van concurrenten te verbeteren, zal de vraag naar de producten van dit bedrijf toenemen, waardoor de kosten per eenheid lager zullen worden. Alleen als dit het geval is, is de positieve feedback loop gesloten en spreken we van increasing returns.

4. Leereffecten treden op als er een positieve relatie is tussen de cumulatieve productiegrootte tot nu toe en de productiviteit van een bedrijf. Met andere woorden: de groeiende kennis en ervaring die in de loop van de tijd door het bedrijf wordt opgebouwd zal leiden tot lagere kosten per eenheid product. Zulke groeiende kennis en ervaring kan het resultaat zijn van een drietal onderscheiden processen. Ten eerste, het proces van *gepland leren*, het verhogen van kennis door bewuste actie van het management. Voorbeelden hiervan zijn trainingen, bewust doorgevoerde procesverbeteringen of het inhuren van beter gekwalificeerde medewerkers. Ten tweede, het proces van *exogeen leren*: het verhogen van kennis door oorzaken die buiten het bedrijf liggen. Voorbeelden hiervan zijn verbeterde kwalificaties van de beroepsbevolking, kennis-spillovers tussen bedrijven of tussen bedrijven en universiteiten, of exogene technologische veranderingen. Ten derde, het proces van *autonoom leren*, ofwel *learning-by-doing*. Voorbeelden hiervan zijn verbetering van efficiency door een bepaalde taak vaker uit te voeren, de *leercurve*, en het door toepassing van bestaande kennis of technologie verkrijgen van nieuwe kennis of technologie, *endogene technologische verandering*.

Ten aanzien van leereffecten en increasing returns geldt eenzelfde redenering als bij schaaleffecten: leereffecten op zich zijn nog geen increasing returns. Zij worden dit pas wanneer het door leereffecten verkregen kostenvoordeel wordt gebruikt om prijzen te verlagen of klantwaarde te verhogen, waardoor de vraag naar de producten van het bedrijf toeneemt. Met andere woorden, ook leereffecten zijn pas increasing returns wanneer de positieve feedback loop gesloten is.

De vier mechanismen van increasing returns, en de wijze waarop ze tot positieve feedback leiden, zijn in de onderstaande figuur weergegeven.



De mechanismen van increasing returns

Waarom increasing returns bestuderen?

Waarom is het nu interessant om het verschijnsel increasing returns, en de vier beschreven mechanismen in het bijzonder, te bestuderen? Tenslotte kent bijna iedereen de *wet van de afnemende meeropbrengsten*, een wet die keer op keer is bewezen en die stelt dat toenemende inspanningen uiteindelijk tot minder stijging van output zullen leiden. Er is een viertal redenen te geven waarom het toch interessant is om naar het tegenovergestelde, *toenemende meeropbrengsten, ofwel naar increasing returns* te kijken. De eerste is dat increasing returns daadwerkelijk binnen markten en bedrijven aanwezig lijkt te zijn en een belangrijke invloed lijkt te hebben op de prestaties van bedrijven. Een tweede is dat increasing returns in onze huidige informatie- en kennismaatschappij met zijn sterk verknoopte elektronische netwerken aan belang lijkt te winnen. We hoeven maar naar de ICT-sector en naar bedrijven als *Microsoft*, *Cisco* of *Nokia* te kijken om alle vier de increasing returns mechanismen aan het werk te zien. Een derde reden is dat increasing returns een zeer aansprekend, maar tegelijkertijd zeer verdacht concept is: inputs die leiden tot progressief toenemende outputs, succes dat leidt tot meer succes? Dat ruikt naar ‘zelfrijzend bakmeel’ en piramidespelen. Toch is, bij nader inzien, increasing returns een essentiële voorwaarde voor economische groei, op landenniveau zowel als op bedrijfsniveau: waar zou groei immers vandaan moeten komen als dergelijke mechanismen niet ergens in het economisch systeem aanwezig zouden zijn? Een vierde reden voor het bestuderen van increasing returns is dat we ons in goed gezelschap bevinden: economen sinds *Adam Smith* hebben het de moeite waarde gevonden om zich met het onderwerp bezig te houden.

Doelstellingen van het proefschrift

De centrale doelstellingen van dit proefschrift zijn afgeleid van de eerste bovengenoemde reden:

1. Kunnen we, vanuit een managementperspectief, bijdragen aan de ontwikkeling van een integraal concept van increasing returns, dus een concept waarin alle vier de genoemde mechanismen, de marktgerelateerde zowel als de bedrijfsgerelateerde, verenigd zijn?
2. Kunnen we het optreden van deze mechanismen in markten en bedrijven inzichtelijk maken door ze te meten?
3. Kunnen we empirisch analyseren wat de relaties tussen deze mechanismen zijn en wat de consequenties zijn van het optreden van deze mechanismen voor de prestaties van bedrijven?
4. Kunnen we, als we deze kennis hebben, een aantal bouwblokken definiëren die managers kunnen gebruiken om de consequenties van increasing returns voor hun markt en bedrijf te begrijpen, zodat ze op die basis strategische acties kunnen ondernemen om de prestaties van hun bedrijf te verbeteren?

Om deze doelstellingen te verwezenlijken is gebruik gemaakt van een bekend framework uit de managementwetenschappen, namelijk het structure-conduct-performance paradigma uit de *industrial organization theory of the firm*. Om precies te zijn hebben we hierbij een *gedragsbenadering* gevolgd, omdat we van mening zijn dat de gedragingen van bedrijven een wezenlijke invloed hebben, en volgden we de *Harvard-traditie*, gebruik makend van en voortbouwend op het werk van onder andere *Michael Porter*, omdat we van mening zijn dat marktimperfecties een wezenlijke rol spelen bij de te bestuderen materie.

Literatuurstudie

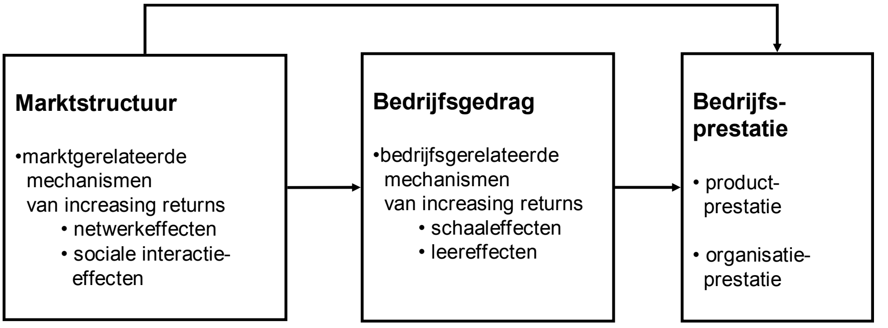
Op basis van dit framework is allereerst een uitgebreide literatuurstudie verricht. Deze bestaat uit twee delen. Het eerste deel is een uitgebreide kwalitatieve beschrijving van de geschiedenis van het economisch denken over increasing returns, beginnend in het tijdperk voor *Adam Smith* en via nieuwe benaderingen zoals *endogene groeitheorie*, *complexity science* en *social economics* eindigend bij de hedendaagse managementwetenschappen.

Het tweede deel is een gedetailleerde analyse van *96* historische en hedendaagse publicaties op het gebied van increasing returns. De belangrijkste bevindingen van deze literatuurstudie zijn dat:

- de literatuur geclassificeerd kan worden volgens de vier mechanismen van increasing returns
- netwerkeffecten en sociale interactie-effecten gezien kunnen worden als deel van marktstructuur (structure in ons framework) en schaaleffecten en leereffecten als deel van bedrijfsgedrag (conduct in ons framework)
- empirische studies naar increasing returns, studies met integrale benaderingen van increasing returns en studies naar de impact van increasing returns op bedrijfsprestaties schaars zijn

Daarmee zijn het de in dit proefschrift verrichte onderzoeken en de gekozen benadering gelegitimeerd.

Vervolgens is het gebruikte *structure-conduct-performance paradigma* vertaald naar onze onderzoeksdoelen. In dit paradigma is de basisredenering dat de marktstructuur de prestaties van bedrijven in de markt beïnvloedt *via de gedragingen van die bedrijven*. Vertaald naar ons onderzoeksveld beschouwen we de marktgerelateerde mechanismen van increasing returns, dus netwerkeffecten en sociale interactie-effecten, als determinanten van marktstructuur (*structure*). De bedrijfsgerelateerde mechanismen van increasing returns beschouwen we als determinanten van het gedrag van bedrijven (*conduct*). We nemen hierbij aan dat de marktgerelateerde mechanismen van increasing returns de bedrijfsprestatie zullen beïnvloeden ten minste gedeeltelijk via de bedrijfsgerelateerde mechanismen van increasing returns.



Basismodel

Uit het verrichte literatuuronderzoek blijkt dat kan worden aangenomen dat de aanwezigheid van netwerkeffecten en sociale interactie-effecten in de markt zal leiden tot een strijd tussen technologieën in de markt, en dus tussen de producten die op deze technologieën zijn gebaseerd. Hierbij treden diverse effecten op, die specifiek zijn voor een increasing returns markt:

- concurrentie vindt plaats op netwerkniveau en niet op het niveau van het individuele product, dus een technisch superieur product dat een klein gebruikersnetwerk heeft of waarvoor weing complementaire producten beschikbaar zijn zal de strijd verliezen van een product dat een groter netwerk heeft en/of waarvoor veel complementaire producten beschikbaar zijn
- de uitkomst van de strijd tussen technologieën ligt niet op voorhand vast; in economische termen zijn er meerdere evenwichten mogelijk, vaak evenwichten waarbij één van de technologieën een dominante positie in de markt verovert: *winner-takes-all*
- *lock-in effecten* kunnen optreden, waarbij een bestaande technologie zodanig is ingeburgerd dat de overgang naar een andere, kwalitatief betere, technologie zoveel investeringen kost dat de gebruikers er niet aan beginnen en dus als het ware vastzitten in de bestaande technologie
- er kan sprake zijn van extreme marktontwikkelingen, in de vorm van excessieve inertie, waarbij de markt klein blijft en er geen technologiestandaard ontstaat doordat alle partijen op elkaar wachten met het doen van investeringen, of juist excessief momentum, waarbij de markt in zeer korte tijd zeer snel groeit en er snel een technologiestandaard ontstaat doordat alle partijen elkaar imiteren en zeker niet de last mover willen zijn
- er kan sprake zijn van *padafhankelijkheid* in de markt, wat betekent dat het verleden en/of de bestaande situatie een grote invloed hebben op de toekomst omdat een kleine toevallige gebeurtenis, versterkt door positieve feedback, grote invloed kan hebben op de einduitkomst
- er zijn marktimperfecties of marktinefficiënties mogelijk, hetgeen betekent dat door toevalligheden de beste technologie niet altijd de marktstandaard hoeft te worden[94]

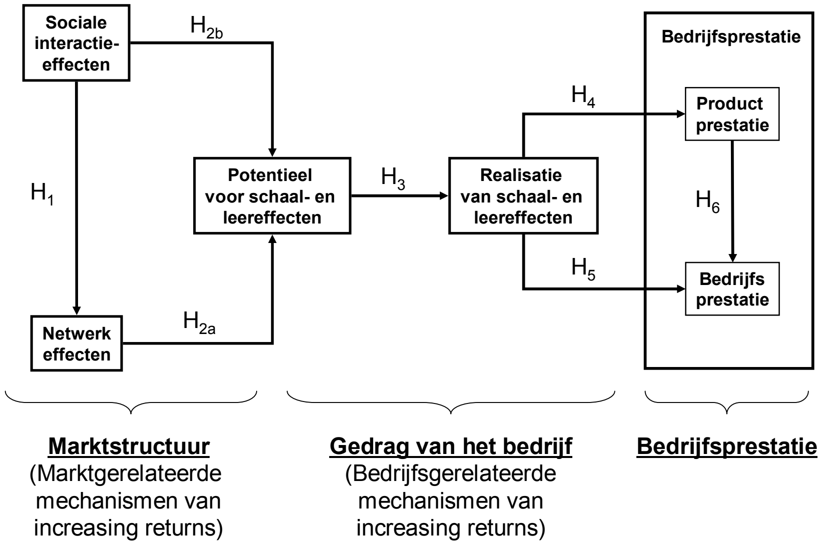
[94] Met name dit laatste aspect is onderwerp van heftig debat tussen economen van verschillende stromingen, omdat dit, als het klopt, de standaard economische theorie onderuit haalt. Dit debat is echter in het proefschrift niet gevoerd.

De redenering in het proefschrift is dat deze effecten ertoe leiden dat er voor individuele bedrijven een *marktpotentieel* ontstaat, dat wil zeggen een potentiële vraag naar de producten van het bedrijf en dus een potentieel om schaaleffecten en leereffecten te behalen. Zoals hierboven al beredeneerd betekent dit nog lang niet dat er ook sprake is van bedrijfsgerelateerde increasing returns. Dit hangt immers af van het vermogen van het bedrijf om het potentieel ook daadwerkelijk te realiseren en het vervolgens te exploiteren, namelijk door de prijzen verlagen en/of de klantwaarde verhogen. Of het bedrijf hiertoe in staat is, zelfs indien aan de randvoorwaarden is voldaan[95], hangt onder meer af van de door het bedrijf gevolgde *increasing returns-strategie*: een bedrijf kan acteren als *shaper*, waarbij het zelfstandig een technologie op de markt zet die, indien succesvol, hoge inkomsten zal opleveren, of als *follower*, waarbij het producten of technologieën op de markt brengt die compatible met en/of complementair zijn aan een dominante technologie. Een bedrijf kan ook besluiten te wachten – *reserving the right to play* – totdat de markt zich verder uitkristalliseert en er een betere keuze gemaakt kan worden. Indien het bedrijf vervolgens ook in staat is de gerealiseerde schaal- en leereffecten te exploiteren zal hiermee de bedrijfsprestatie verbeteren. Dit hangt onder meer af van de door het bedrijf gevolgde *generieke concurrentie-strategie*, bijvoorbeeld, *cost-leadership*, *differentiatie* of *focus*.

Onderzoeksmodel en hypothesen

De bovenstaande redenering heeft geleid tot een onderzoeksmodel (zie de onderstaande figuur. In dit model vinden we een zevental hypothesen. Het empirische onderzoek van dit proefschrift is opgezet in drie afzonderlijke studies, waarmee deze hypothesen zijn getoetst (zie de onderstaande tabel).

[95] Recapitulerend: (1) voldoende vraag in de markt, (2) voldoende hoge prijs-elasticiteit en (3) het bedrijf moet met het verlagen van prijzen en/of verhogen van klantwaarde in staat zijn de positie ten opzichte van concurrenten te verbeteren.



Onderzoeksmodel

Onderzoekshypothesen:	Studie:	Eerste empirische studie (hfdst. 7)	Tweede empirische studie (hfdst. 8)	Derde empirische studie (hfdst. 9)
H_1	Hoe groter de sociale interactie-effecten, hoe groter de netwerkeffecten	**X**	**X**	
H_{2a}	Hoe groter de netwerkeffecten, hoe groter het potentieel voor schaal- en leereffecten	**X**	**X**	
H_{2b}	Hoe groter de sociale interctie-effecten, hoe groter het potentieel voor schaal- en leereffecten	**X**	**X**	
H_3	Hoe groter het potentieel voor schaal- en leereffecten, hoe groter de realisatie van schaal- en leereffecten	**X**	**X**	**X**
H_4	Hoe groter de realisatie van schaal- en leereffecten, hoe hoger de productprestatie	**X**		
H_5	Hoe groter de realisatie van schaal- en leereffecten, hoe hoger de bedrijfsprestatie	**X**	**X**	**X**
H_6	Hoe hoger de productprestatie, hoe hoger de bedrijfsprestatie	**X**		

Overzicht van de onderzoekshypothesen en de empirische studies waarin deze worden getoetst

Eerste empirische studie

De eerste empirische studie is een cross-sectionele survey onder *257* managers van Nederlandse industriële bedrijven. Voor deze studie is een vragenlijst ontwikkeld die telefonisch bij de respondenten is afgenomen. Aangezien er in de literatuur geen bestaande constructen (vragen, meetinstrumenten) te vinden waren om increasing returns op deze wijze bij bedrijven te meten, zijn deze constructen door ons nieuw ontwikkeld en getest. Het gaat hierbij om constructen voor het meten van de mechanismen van increasing returns, te weten netwerkeffecten, sociale interactie-effecten en schaal- en leereffecten, alsmede om een aantal aanvullende constructen. Voor het testen hiervan is gebruik gemaakt van meetmodellen in *LISREL 8.3*. De tests wijzen uit dat de constructen voor het meten van netwerkeffecten en sociale interactie-effecten in alle opzichten zowel betrouwbaar als valide zijn en dus bruikbaar om de geformuleerde hypothesen te toetsen.

Voor het toetsen van de hypothesen is gebruik gemaakt van causale modellen, eveneens in *LISREL 8.3*. De toetsing wijst uit dat, op hypothese H_{2b} na, alle hypothesen ondersteund worden.[96] Schatting van een alternatief causaal model, waarbij ter aanvulling directe relaties zijn opgenomen tussen enerzijds netwerkeffecten en sociale interactie-effecten en anderzijds productprestatie en ondernemingsprestatie, levert geen betere resultaten op dan het oorspronkelijke onderzoeksmodel. Dit betekent dat het oorspronkelijke onderzoeksmodel het best met de empirische gegevens overeenkomt. Tests voor de stabiliteit van het onderzoeksmodel wijzen uit dat, op de relatie tussen sociale interactie-effecten en netwerkeffecten na, het model stabiel is voor variaties in mogelijk beïnvloedende variabelen. Ook dit draagt bij aan het vertrouwen in de juistheid van het onderzoeksmodel.

Tweede empirische studie

De tweede empirische studie is eveneens een cross-sectionele survey, dit keer schriftelijk gehouden onder managers van *36* grote Nederlandse bedrijven genoteerd aan de *Amsterdam Stock Exchange (AEX).* In deze studie zijn de martkgerelateerde en de bedrijfsgerelateerde mechanismen van increasing returns, alsook de ondernemingsprestatie gemeten over een periode van vijf jaar, zodat sprake is van een comparatief statisch onderzoeksontwerp. In de survey zijn alleen data verzameld over de marktgerelateerde mechanismen van increasing returns. Dit is gedaan met de

96 Hypothese H_{2b} wordt weliswaar niet direct ondersteund, maar wel indirect via de ondersteuning van hypothesen H_1 en H_{2a}.

in de eerste empirische studie ontwikkelde en geteste constructen voor het meten van netwerkeffecten en sociale interactie-effecten. Deze constructen zijn licht aangepast om een mening van de respondenten over een periode van vijf jaar te verkrijgen. Voor het testen van deze gewijzigde constructen is opnieuw gebruik gemaakt van meetmodellen in *LISREL 8.3*. Het resultaat van deze test is dat de betreffende constructen wederom in alle opzichten betrouwbaar en valide zijn. De bedrijfsgerelateerde mechanismen van increasing returns en de bedrijfsprestatie zijn in deze studie gemeten met de financiële gegevens uit de jaarverslagen van de betreffende bedrijven. Deze metingen zijn eveneens verricht over een periode van vijf jaar. De financiële bedrijfsgegevens zijn gevalideerd door minutieuze bedrijfsspecifieke checks op dataconsistentie en door correcties voor inflatie, voor outliers en voor negatieve groeipercentages.

De hypothesen zijn in deze studie getoetst middels lineaire regressiemodellen. Wegens het geringe aantal waarnemingen *(36)* kon geen gebruik gemaakt worden van causale modellen in *LISREL 8.3*. De uitkomst van deze toetsing is dat alle getoetste hypothesen worden ondersteund.[97] In deze studie zijn aanvullende tests uitgevoerd voor *mediërende* effecten. De uitkomst van de eerste test is dat netwerkeffecten de relatie tussen sociale interactie-effecten en het potentieel voor schaal- en leereffecten volledig mediëren, wat betekent dat de invloed van sociale interactie-effecten op het potentieel voor schaal- en leereffecten *altijd* verloopt via netwerkeffecten.

Derde empirische studie

De derde empirische studie is een analyse van (1) de *Wet van Verdoorn*, dat is de relatie tussen groei van output en groei van productiviteit, en (2) de relatie tussen groei van productiviteit en groei van bedrijfsprestatie. Deze studie is uitgevoerd voor *118* grote Nederlandse bedrijven genoteerd aan de *Amsterdam Stock Exchange (AEX)*. In deze studie zijn de bedrijfsgerelateerde mechanismen van increasing returns en de bedrijfsprestatie gemeten met de financiële gegevens uit de jaarverslagen van de betreffende bedrijven. Deze metingen zijn verricht over een zo lang mogelijke periode, die per bedrijf verschilt, afhankelijk van de beschikbare bedrijfsdata. Voor de beste beste bedrijven waren financiële data van 1983 tot en met 2002 beschikbaar. Hiermee is sprake van een dynamisch onderzoeksontwerp. De financiële bedrijfsgegevens zijn hier eveneens gevalideerd door minutieuze

[97] Aangezien in deze studie productprestatie en bedrijfsprestatie niet afzonderlijk zijn gemeten, komen hypothesen H_4 en H_6 te vervallen.

bedrijfsspecifieke checks op dataconsistentie en door het aanbrengen van correcties voor inflatie, voor outliers en voor negatieve groeipercentages.

De relatie tussen de groei van output en de groei van productiviteit staat in de literatuur bekend als de *Wet van Verdoorn*. *Verdoorn* vond in 1949 dat er op sectorniveau een lineair verband bestond tussen de groei van output en de groei van productiviteit, met een coëfficiënt van tussen de *0.41* en *0.57*. De betekenis hiervan is dat elk procent outputgroei leidt tot tussen de *0.41* en *0.57* procent productiviteitsgroei, en dat er dus sprake is van increasing returns, namelijk van de realisatie van schaal- en leereffecten. Deze wetmatigheid is in de literatuur veelvuldig getest en aangetoond, overigens met verschillende uitkomsten, op landenniveau, op regioniveau en op sectorniveau. In dit proefschrift wordt de *Wet van Verdoorn* voor het eerst toegepast en getoetst op bedrijfsniveau. De *Wet van Verdoorn* is in deze studie gebruikt als meting van de relatie tussen het potentieel en de realisatie van schaal- en leereffecten (onderzoekshypothese 3). De output is immers gerelateerd aan het potentieel om schaal- en leereffecten te benutten, de productiviteit is het resultaat daarvan: het realiseren van schaal- en leereffecten. Analoog hieraan is de relatie tussen de groei van productiviteit en de groei van bedrijfsprestatie gebruikt als meting van de relatie tussen de realisatie van schaal- en leereffecten en de bedrijfsprestatie (onderzoekshypothese 5).

De hypothesen zijn in deze studie getoetst middels lineaire regressiemodellen. De regressies zijn uitgevoerd voor de *118* individuele bedrijven, voor *13* sectoren op basis van gepoolde bedrijfsdata en voor de *AEX* als geheel, eveneens op basis van gepoolde bedrijfsdata. Deze regressies leiden tot gedeeltelijke onderstening van de hypothesen. De *Wet van Verdoorn* houdt stand voor *68.8%* van de bedrijven, voor alle *13* sectoren en voor de gehele *AEX*, waarbij de gemiddelde coëfficiënten variëren van *0.399* tot *0.542*, waarden die redelijk overeenstemmen met de in de literatuur gerapporteerde waarden op landenniveau, sectorniveau en regioniveau. Aanvullende modellen zijn gebouwd en analyses uitgevoerd waamee op deze waarden nog correcties kunnen worden uitgevoerd. De relatie tussen de groei van productiviteit en de groei van bedrijfsprestatie houdt stand voor *66.9%* van de bedrijven, voor *8* van de *13* sectoren en voor de gehele *AEX*, waarbij de gemiddelde coëfficiënten variëren tussen de *2.534* en *3.493*. Met andere woorden: de invloed van productiviteitsgroei op groei van de bedrijfsprestatie is aanzienlijk.

Conclusies

De in dit proefschrift uitgevoerde onderzoeken hebben een aantal bevindingen opgeleverd die het geformuleerde onderzoeksmodel ondersteunen. Ten eerste zijn de marktgerelateerde mechanismen van increasing returns positief en significant van invloed op de bedrijfsgerelateerde mechanismen van increasing returns. Ten tweede zijn de bedrijfsgerelateerde mechanismen van increasing returns positief en significant van invoed op de bedrijfsprestatie. Ten derde is er geen bewijs gevonden voor een directe relatie tussen de marktgerelateerde mechanismen van increasing returns en de bedrijfsprestatie. We kunnen dus concluderen dat, in aanwezigheid van de marktgerelateerde mechanismen van increasing returns, een betere bedrijfsprestatie *alleen* gerealiseerd wordt door het exploiteren van de bedrijfsgerelateerde mechanismen van increasing returns. De conclusies ten aanzien van de afzonderlijke hypothesen worden samengevat in de onderstaande tabel.

Onderzoekshypothesen:	**Studie:**	**Eerste empiri-sche studie (hfdst. 7)**	**Tweede empiri-sche studie (hfdst. 8)**	**Derde empiri-sche studie (hfdst. 9)**
H_1	Hoe groter de sociale interactie-effecten, hoe groter de netwerkeffecten	Onder-steund	Onder-steund	Niet getest
H_{2a}	Hoe groter de netwerkeffecten, hoe groter het potentieel voor schaal- en leereffecten	Onder-steund	Onder-steund	Niet getest
H_{2b}	Hoe groter de sociale interctie-effecten, hoe groter het potentieel voor schaal- en leereffecten	Niet onder-steund [#]	Onder-steund	Niet getest
H_3	Hoe groter het potentieel voor schaal- en leereffecten, hoe groter de realisatie van schaal- en leereffecten	Onder-steund	Onder-steund	Gedeeltelijk onder-steund
H_4	Hoe groter de realisatie van schaal- en leereffecten, hoe hoger de productprestatie	Onder-steund	Niet getest	Niet getest
H_5	Hoe groter de realisatie van schaal- en leereffecten, hoe hoger de bedrijfsprestatie	Onder-steund	Onder-steund	Gedeeltelijk onder-steund
H_6	Hoe hoger de productprestatie, hoe hoger de bedrijfsprestatie	Onder-steund	Niet getest	Niet getest

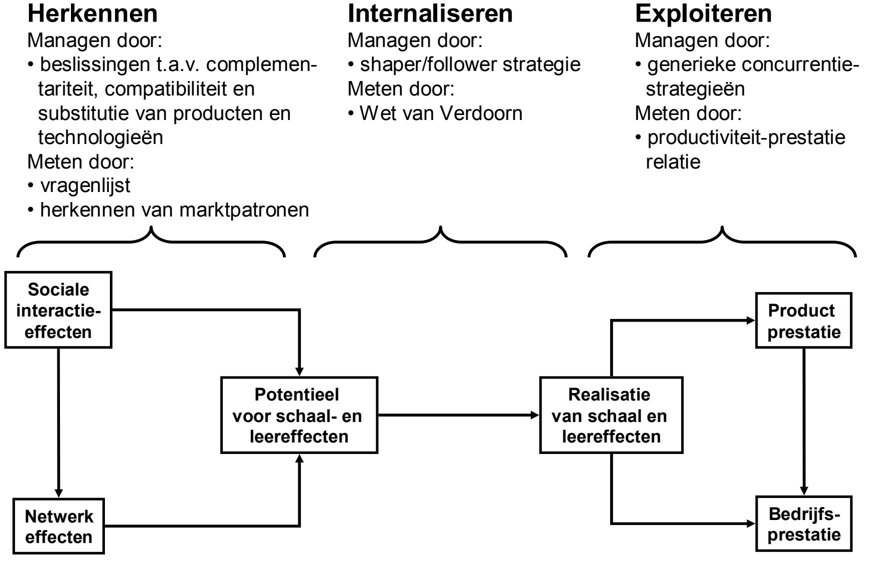
[#] *Er is wel een indirecte invloed van sociale interactie-effecten op the potentieel vor schaal- en leereffecten door de ondersteuning van hypothsen H_1 en H_{2a}*

Samenvatting van de toetsingresultaten van de onderzoekshypothesen

Dit onderzoek kent een groot aantal beperkingen ten aanzien van het gehanteerde framework, de gehanteerde methoden en samples en de onderzochte relaties. Wegens de schaarste aan bestaand empirisch onderzoek naar increasing returns is voor dit proefschrift in eerste instantie gekozen voor het onderzoeken van de hoofdrelaties, op basis van een bestaand en bekend framework en met behulp van bestaande, eenvoudige methoden. Dit betekent dat er legio mogelijkheden zijn om op basis van het huidige proefschrift het onderzoek naar increasing returns voort te zetten en uit te breiden.

Managementimplicaties

De implicaties van het verrichte onderzoek voor managers die te maken hebben met increasing returns mechanismen in hun markten en bedrijven zijn drievoudig: ten eerste zullen managers de relaties tussen de verschillende mechanismen van increasing returns, de gevolgen van deze mechanismen voor de werking van de markt en de gevolgen voor de prestatie van hun bedrijf moeten leren begrijpen. Dit onderzoek levert hiertoe een aantal theoretisch en empirisch ondersteunde bouwblokken (zie onderstaande figuur).



Managementimplicaties

Ten tweede zullen managers in staat moeten zijn om de increasing returns-gevoeligheid van hun markt en hun bedrijf te herkennen en de hoogte ervan in te schatten. Dit proefschrift levert een aantal meetinstrumenten aan, die hiervoor gebruikt kunnen worden. De constructen voor het meten van netwerkeffecten en sociale interactie-effecten komen als betrouwbaar en valide uit de tests en kunnen dus voor dit doel worden ingezet. Voor het meten van schaal- en leereffecten en de impact op bedrijfsprestaties is de analyse van de *Wet van Verdoorn* en van de relatie tussen productiviteit en prestatie beschikbaar. Voor de grotere beursgenoteerde bedrijven is deze ondernemingsspecifieke analyse reeds verricht (opvraagbaar bij de auteur); voor alle andere bedrijven kan een dergelijke analyse gemaakt worden wanneer de benodigde financiële gegevens beschikbaar zijn.

Ten derde zullen managers in staat moeten zijn om de strategische implicaties van de aanwezigheid van increasing returns mechanismen in hun markten en bedrijven te doorgronden. Op basis daavan kunnen zij actie ondernemen om ontstane mogelijkheden te exploiteren en valkuilen te vermijden. Dit proefschrift levert een aanzet tot de strategieën die hierbij gevolgd kunnen worden. Verder onderzoek is echter nodig om op dit gebied valide uitspraken te kunnen doen.

Samenvattend: concurreren in een increasing returns markt is zeker meer risicovol en vergt andere managementvaardigheden dan concurreren in een meer traditionele markt. Dit zou de indruk kunnen wekken dat concurreren in een increasing returns markt een soort *Russiche roulette* is, waarbij het management vrijwel machteloos staat tegenover de krachten van de markt. Toch is dit niet het geval. Indien managers een goed inzicht hebben in de mechanismen van increasing returns en de consequenties ervan, zullen zij wel degelijk in staat zijn de uitdagingen van het concurreren in increasing returns markten aan te gaan.

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Increasing Returns and Firm Performance

An Empirical Study

This thesis is about increasing returns: *positive feedback effects in markets and firms*. Positive feedback means that success causes further success and failure causes further failure. There are two market-based mechanisms of increasing returns, network effects and social interaction effects, and two firm-based mechanisms of increasing returns, scale effects and learning effects.

Empirical research into the relations between these mechanisms and into the consequences of increasing returns for firm performance is relatively scarce. The aim of the researcher with this thesis is to fill part of this gap. Concepts taken from economics and management sciences are used, building on the *industrial organization theory of the firm*.

Three empirical studies were conducted for which new measurement models were constructed and tested and for which primary and secondary data was collected and analyzed. The results show that the presence of increasing returns in the market influences firm performance, but always through the realization of increasing returns in the firm. This means that in an increasing returns market, management is an important factor determining firm performance.

It is therefore essential for managers to understand the mechanisms of increasing returns in their markets and firms and for them to be able to act strategically upon those mechanisms. This will enable managers to exploit business opportunities arising from increasing returns and to avoid pitfalls, which should result in better firm performance.

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