Simulating the New Economy*

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Abstract

The IT, the Internet, or the Computing & Communications (C&C) technology revolution has been central to the economic discussion for several decades. Before the mid-1990s the catchword was the "productivity paradox" coined by Robert Solow, who stated in 1987 that "computers are everywhere visible, except in the productivity statistics". Then the New Economy and fast productivity growth fueled by C&C technology suddenly became the catchword of the very late 1990s. Its luster however, faded almost as fast as it arrived with the dot.com deaths of the first years of the new millennium.

With this paper we demonstrate that the two paradoxes above are perfectly compatible within a consistent micro (firm) based macro theoretical framework of endogenous growth. Within the same model framework also a third paradox can be resolved, namely the fact that the previous major New Industry creation, the Industrial Revolution, only involved a handful of Western nations that had got their institutions in order. If the New Economy is a potential reality, one cannot take for granted that all industrial economies will participate successfully in its introduction. It all depends on the local *receiver competence* to build industry on the new technology. We, hence, also demonstrate within the same model the existence of the risk of failing altogether to capture the opportunities of a New Economy.

Key words: Industrial simulation; Innovation and growth; The New Economy; Non-linear dynamics.

JEL code: C45, C63, C81, C99, L16, L63, O14, O31, O33

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1. The problem

The New Economy was a catchword of the very late 1990s (Kelly, 1998). Its luster, however, faded almost as fast as it arrived with the dot.com deaths of the first years of the new millennium. Before that, up to the mid-1990s the catchword was the "productivity paradox" (Berndt and Malone, 1995, Brynjolfsen, 1993) coined by Robert Solow, who stated in 1987 that "computers are everywhere visible, except in the productivity statistics". The paradoxical emergence, on no objective grounds and in the midst of the academic discussion of the productivity paradox, of the shift to fast productivity growth, called the New Economy apparently has something to do with Information Technology (IT) or the Computing & Communications (C&C) technology.

We demonstrate that the two paradoxes above are perfectly compatible within a consistent, micro based macro theoretical framework of endogenous growth. The micro-to-macro model that we use to simulate the New Economy – the MOSES model of the Swedish economy (Eliasson, 1977, 1991a) – approximates, on a simulation format, the theory of the *Experimentally Organized Economy* and of *Competence blocs* (Eliasson, 1987, 1996, Eliasson and Eliasson, 1996, 2002a, Eliasson, 2003a). We use the new version of the model with (Ballot and Taymaz, 1998) endogenous innovative activity and learning and technological diffusion represented by genetic algorithms. Within this model framework also a third paradox can be resolved, namely the fact that the previous major New Industry creation, the Industrial Revolution only involved a handful of Western nations, excluding some of the world's technologically most advanced economies at the time. Only those economies that had got the institutions needed to support a dynamic market economy in order became industrial nations. The others followed the old, slow growth trends in Figures 1A, B (North and

Thomas, 1973, Eliasson, 1991b). We, hence, demonstrate, within the same modeling framework (the third paradox), that even if all the objective requisites, such as technology, are in place no shift onto a faster growth path may follow.

The "first" industrial revolution some 150 years ago, furthermore, suggests patterns of evolution to look for. *First* of all, Figures 1A and B reveal a history with many false starts. *Second*, if the New Economy exists, and there were skeptics (Gordon, 2000a, b) among all enthusiasts, one cannot take for granted that all industrial economies will participate successfully in its introduction. 150 years ago a large part of the world economy did not participate in the new economy creation, and, remembering that experience, among the economies failing to catch the train we might find several technologically very advanced countries. Success in our words, hence, depends on the local *receiver competence* (Eliasson, 1985, 1986, pp. 47 ff, 57 ff, 1990) or absorptive capacity (Cohen and Levinthal, 1990) at the societal level. There is also the worrisome collapse of some of the C&C industry beginning in late 2000 that has not only caused a discontinuation of much of the New Economy hype but also created misgivings about the possibilities of capturing the opportunities of a New Economy. Such collapses among the machine tool builders (Woodbury, 1972) were, however, frequent during the industrial revolution. We will, therefore, also discuss the sustainability of the New Economy in terms of the simulation experiments. Hence, in this paper we demonstrate through simulations on the Swedish micro-to-macro model MOSES that three paradoxes are fully compatible within the same comprehensive modeling framework:

Paradox 1; The long gestation period, before positive circumstances generate the expected upward shift in macroeconomic performance, leads to the premature and mistaken conclusion that investment in new technology has been wasted ("The productivity paradox").

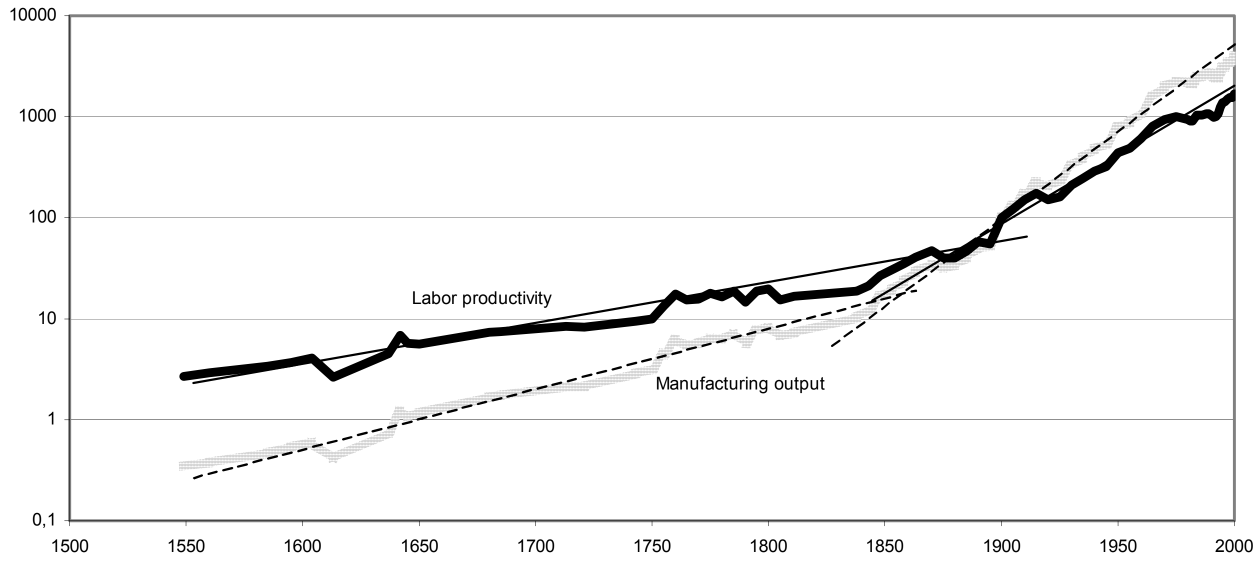
Paradox 2; The dynamics of the sudden surge in macroeconomic performance, cannot be explained in terms of current or near term circumstances.

Paradox 3; A shift to a New Economy development may not occur, even though abundance of technological knowledge is in place locally.

Paradox, or hypothesis 3, means that a sustainable, new and fast growing economy will not appear if the local competence to commercialize the New Technology is lacking (see competence bloc theory in Eliasson and Eliasson, 1996, 2002a) and if the requisite institutions and other supporting circumstances are not in place. The necessary receiver competence of the economy is lacking, a notion discussed already by Abramowitz (1988).

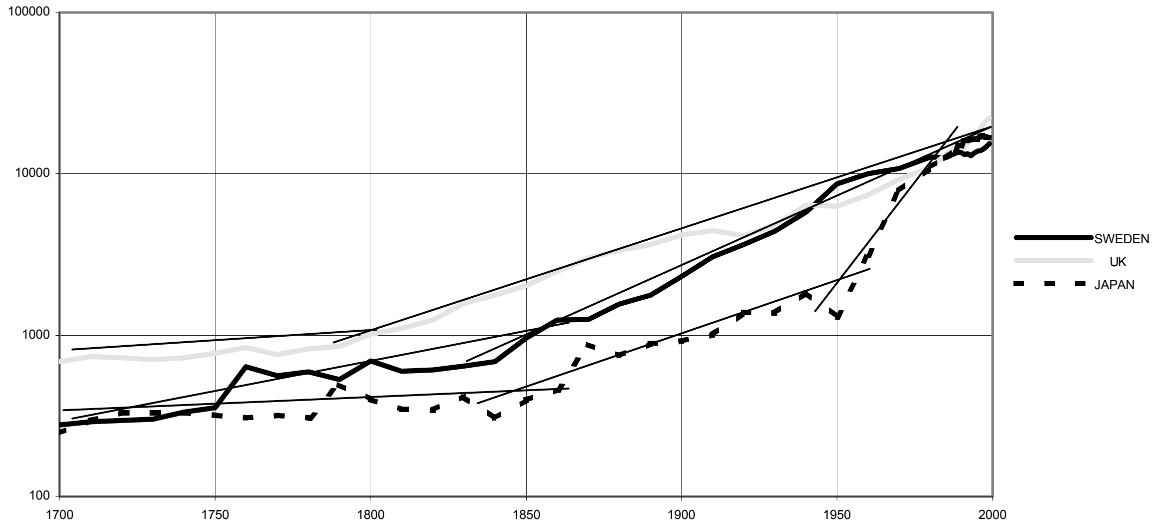
Figures 1A, B, finally, illustrate all three paradoxes as they evolved during the first industrial revolution. The new machine tool technology was developed in the UK during the late 18th century. It revolutionized the organization of production in UK industry and moved the entire UK economy onto a faster growth path, beginning during the last decades of the 18th century. From that time and through the first half of the 19th century the new machine tool technology became increasingly known in other Western European countries and in the US. In fact, the Swedish economist Johan Westerman discussed the new machines in England in a book published already in 1768. But not until the later part of the first half of the 19th century could the upward shift to a new growth trend in output be observed for Sweden (Figure 1A). And it took almost one half of an additional century for a matching shift to a faster growth trend in (labor) productivity to be observed, at about the time the large westward emigration of labor started. Even though technology was internationally available, and successful introductions could be observed along the way, it took considerable time until the then New Economy had been visibly introduced at the macroeconomic level, i.e. until sufficient *receiver competence* had been accumulated for the new technology to make a visible positive cumulative impact on the Swedish growth curve (paradoxes I and II). Atkeson and Kehoe (2001) report that it took several decades before measured productivity growth increased during the second industrial revolution in the US. Even more significant today (third paradox) is that most of the world experienced no shift in their growth curves whatsoever. Most economies of the world never became industrialized and followed the old trend (Figure 1A) to the right. To them belonged the wealthiest economies of the world in the medieval age; China and India. These countries were solidly stuck in their old institutions and traditions.

Figure 1A. Manufacturing production and productivity in Sweden 1549-2000



Source: Eliasson (1988, p. 158) and updatings.

Figure 1B. GNP per capita in Sweden, England and Japan 1700-2000



Source: Eliasson (1986, p. 49) and updatings.

The thicker part of the Swedish curve 1860-1920 provides additional insight into the industrial transformation taking place. During that time two thirds of the firms that became the largest Swedish manufacturing firms during the period 1945-1998 were founded; a "Silicon Valley experience" of gigantic proportions for the small country of Sweden. To be noted is that the burst in industrial activity was distributed geographically over a large part of Sweden demonstrating that geographical proximity was not a necessary condition for the synergies of a competence bloc to become activated even during a period of (by modern standards) primitive information- and communications technology. Most of these firms were founded on the technology of the early industrial revolution developed in England, the machine tools, and some of them (ASEA, Atlas Copco, Electrolux, SKF etc.) later became international engineering giants.

Our base hypothesis is that the technology to open up the potential of a New Economy has been created with the C&C-industry, but that the growth mover will be its introduction in the "old industry" through the establishment of new firms, the reorganization of incumbent firms and through the exit of failing firms, or through the *Schumpeterian Creative Destruction* process of Table 1. The dynamics of this gestation takes decades, not years. This means that the ongoing dynamics will not be captured by standard forecasting or econometric modeling methods.

Digital C&C technology can be said to have been introduced with the invention of the transistor in 1947. For those who are skeptical about the new industrial potential of C&C technology we add that (1) the great industrial potential of C&C technology is exactly its double role of making both tremendous product quality change and a new production organization possible and (2) that several new generic technologies with great industrial potential are also in the pipeline, the technology nearest at hand being biotechnology (Eliasson, 2002a, b). Our task will be to *demonstrate the existence, within our model framework, of all three paradoxes above.*

Table 1. The four mechanisms of Schumpeterian creative destruction and economic growth

1. Innovative entry enforces (through competition)
2. Reorganization
3. Rationalization
or
4. Exit (shut down)

Source: Eliasson (1993, 1996, p. 45).

2. The Swedish Micro-to-Macro model

To capture the three paradoxes within one and the same theoretical structure an entirely new and more general representation of a dynamic economy than the mainstream general equilibrium or new economy models is called for. *First*, our theory has to be micro based, featuring endogenous resource allocation over firms and markets. Distributional characteristics can then be demonstrated to matter for macroeconomic growth (Eliasson, 1984). *Second*, only a complete systems representation of the economy, including complete demand feed back, that endogenizes price and quantity decisions of firms will define a satisfactory platform for dynamic analysis. *Third*, innovative behavior has to be endogenized for macroeconomic growth to be endogenized.

The Swedish micro-to-macro (M-M) model MOSES has these needed dynamic properties. It approximates what we call the *Experimentally Organized Economy* in which growth is endogenized through a Schumpeterian creative destruction process. The New Economy simulations to follow have been made possible with the introduction of the C&C industry in the MOSES model (The new database is presented briefly in the supplement to this paper).

It is hypothesized in this paper that this model possesses the capacity of embodying and explaining the three paradoxes. Our main task is to demonstrate that it does, and explain how.

The M-M model has been documented in detail in a number of publications. For a fast introduction we refer to Albrecht et al. (1989, 1992), Ballot and Taymaz (1998), Eliasson (1977, 1978, 1985, 1991a). The most salient features of the model to be emphasized in the context of the simulations are:

- A Schumpeterian creative destruction model of growth or of the *Experimentally Organized Economy*, see Table 1 and Eliasson (1996, p. 45).
- The creation and selection of new technology (*Competence bloc* theory; Eliasson and Eliasson, 1996, 2002a, Eliasson, 2003a).
- The selection and diffusion of new technology through learning from successful introductions (genetic algorithms, Ballot and Taymaz, 1998).[1]

[1] Currently the competence bloc is crudely represented in the model, mostly through the selective discovery capacity introduced through the genetic learning algorithms. Since we are currently working on improving these modules of the model to obtain a better representation of the competence bloc we want to keep the two theoretical modules apart in the principal presentation, even though they will not be properly separated in the

The dynamic core of the M-M model

The micro-to-macro model has a modular design with well-defined interfaces within the firm/division and between the firm/division and all other firms, or the markets.[2] This modular design has made it easy to improve and update the behavioral specification of the model.[3] The model runs by quarter, which was earlier considered a typical production planning period in large firms (Eliasson, 1976). Products are homogeneous within each market (see below). Hence, currently we only model process innovations. This means that product quality diversification is assumed to be perfectly arbitraged in the markets each period and that product quality change has been fully converted into output volume. Thus, from our point of view the quality issue in the productivity paradox is a measurement problem that we have so handled. We plan to introduce product quality innovations as well, but not in this paper.

The dynamic core that is the source of endogenous growth is represented by the creative destruction process of Table 1. Firms upgrade their performance through investment in new technology, which is stimulated by expected returns and/or by being forced to reorganize internally by competition. Firm behavior - given its production capacity - is governed by an internal short and long term budgeting and production planning process[4] governed in turn by the *Maintain or Improve Profits* (MIP) criterion (Eliasson, 1976, 1977, 1985, 1991a). Firms interact through competition in product, labor and financial markets. The markets are integrated through the internal economies of all firms.

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model simulations. The point is that we want to interpret the results of the simulations in terms of this broader theory. See more below.

[2] The original core modular system of behavioral relationships within the firm and between firms is diagrammatically illustrated in Eliasson (1977). Since then this core has been embodied in a larger context.

[3] There is only one area where the original modular systems design has created a problem and that is the interface between firms and individuals/workers. Firms/divisions are being kept track of over their entire life cycles. Individuals are employed out of, and laid off into an anonymous pool of people, the labor force. To study the effects of education and competence development the individuals have to be modeled separately and then linked to the individual firm through a simple aggregation device. See for instance Ballot and Taymaz (1996, 1998) and Ballot et al. (2001).

The firm or the division is defined as a profit oriented production organization with financially defined outer limits. This controlled hierarchy is represented in the model by its internal statistical accounts. Here, the modelers once had the great opportunity in 1975 to specify the questions of the so-called *Planning Survey* of the Swedish Federation of Industries such that they fitted the needs of the M-M model (Albrecht, 1992). This Planning Survey has been repeated annually since then and has served as a unique annual data input in the development of the M-M model. Each incumbent firm makes up investment, production and employment plans under the assumption of reaching a satisfactory ex ante rate of return each period (the MIP criterion), and attempts to realize the plans in competition with other firms, each having its own particular expectations of the market situation. In doing so they climb *ex ante profit hills* and halt search temporarily (for that quarter) when a satisfactory profit level has been reached (for more detail see Eliasson, 1977, 1991a). Technically, total model dynamics can be seen as the first iteration in a gigantic numerical optimization process in which all actors are striving towards their individually perceived profit maxima. Competition (the strategic game; see below) is pushing them. But since the perceived optimum depends both on exogenous and endogenous (to the model) circumstances, including resources used up in the search itself, all perceived optima have to be recomputed for the next step in the iteration, and the nature of the market dynamics is that this recomputation may involve drastic revision and/or dramatic business failure on the part of individual actors. The complexity and multidimensionality of the game as staged within the model is such that there is no way to scan all possible outcomes over a long term (say 50 to 100 year) horizon to make ex post optimization even a theoretical alternative within the M-M modeling framework (Eliasson, 1984, 1992).[5] In the process product and factor prices and the interest rate are endogenously

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[4] crudely modeled. For a detailed presentation, see Eliasson (1978, Section 4.5 and 1985, Section II.7).

[5] This is another way of formulating the assumption of the Experimentally Organized Economy of an immense and for all practical purposes infinite space of business opportunities (Eliasson, 1992, 1996, 2001a).

determined. The dynamics of this highly non-linear model of the Swedish economy means that the profit hills constantly change as a result of individual firm search. Firms constantly make business mistakes and the nature of the "business error correction" process is an important part of the dynamics of economic growth in the MOSES model. This is a typical Austrian – Wicksellian – Stockholm school feature of the MOSES model and of the Experimentally Organized Economy (Eliasson, 1991a, 1992). The ex ante, ex post correction behavior updates the position of incumbent firms on the Salter curves. If a firm fails to meet its profit targets for many periods it eventually exits.

Macroeconomic growth is moved by a constantly ongoing "strategic" competitive game between new and incumbent firms. Each firm faces superior firms that can outbid it in the factor markets and outcompete it in the product market, but also inferior firms subjected to the same competitive pressure that strive to improve their positions. Hence, there is no rest (read "equilibrium") for any firm. The ongoing game forces each firm to constantly strive to improve its performance and this is sufficient to generate *endogenous macroeconomic growth through the Schumpeterian creative destruction process* of Table 1 (see further Eliasson, 1996, Section II.7). The important factor maintaining this competitive dynamic of the model is innovative firm entry. Firm *entry* and turnover, therefore, feature importantly in the MOSES model (item 1 in Table 1).[6] Simply expressed, a new firm enters into a market if it is expected to be able to profitably do so.

When seen "from above" this dynamic core is concealed and the Swedish micro-to-macro model appears as a Leontief – Keynesian 11 sector model, with complete macro demand feed back from a non-linear Stone type consumption expenditure system and a combination of

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[6] See further Eliasson el al. (2001).

neoclassical and financial flow based investment functions, defined and quantified in reality at the micro (firm, division) level on real firm data.

The statistical base of the model

The M-M model is embedded in a complete and consistent micro-to-macro statistical system defined at the Swedish national accounts level (Albrecht et al., 1992). Five manufacturing sectors have been carved out of the national accounts and the input/output matrix and been redefined to correspond to the OECD end use of products classification: raw materials, intermediate goods, non-durable consumption goods, investment goods (consumer and producer) and computing and communications goods and services. The latter market has been added to the model recently (Johansson, 2001, pp. 145, also see supplement). For each initial year (see Supplement) a consistent micro (firm) to macro (National Accounts) database has been constructed in the financial, production (output) and input (labor, purchasing etc.) dimensions. In that context the entire micro-to-macro initial data base was updated to the year 1997 using the firm planning survey of the Federation of Swedish Industries (Albrecht et al., 1992, pp. 181 ff) and a special survey on the same format of the largest 100 firms in the C&C industry. The C&C industry to a great extent covers the private services industry and significant redefinitions of national accounts data have been needed to obtain a consistent micro-to-macro data set.

The macro data of the five market defined segments have been replaced by five sets of firm/division data from the above planning survey and the special survey of the C&C industry. The difference between the national accounts macro data and the five aggregates (in all dimensions; financial, profits, value added etc.) of individual firms have been computed and regarded as “synthetic” firms.[7]

The initial state of the model consists of a complete and consistent set of Salter curves (of all performance variables of firms; see Figures S1 and S2 in Appendix) for each micro defined industry (Salter, 1960, Albrecht et al., 1992). Aggregation is dynamic over markets featuring endogenous prices. This means that each macro trajectory is based on different relative prices. The endogenous micro behavior of firms during a simulation updates the firms and the Salter curves *each quarter* and growth occurs through the Schumpeterian creative destruction process of Table 1.

Technology choice

To understand the simulation experiments in this paper some modules of the model need further clarification. First, the rate of entry of new firms in each year is modeled as a random function of industry profitability. Key characteristics of new entering firms (entry size, technological level, etc.) are also determined as drawings from empirical distributions in such a way that a new firm is about 15% of incumbent firms in terms of (initial) employment. On average, the technological level of a new firm is lower than that of the incumbents, but the spread is much wider. Hence, now and then some new firms (the ”winners”) are significantly more productive than the best incumbent firms (Eliasson, 1991b) and if discovered (see below) carried on to industrial scale production.

Innovations are embodied as new technology in investment. Technology choice, therefore, is part of the investment decision. New technology upgrades firm productivities. Furthermore, disembodied learning-by-doing occurs. There are two types of innovation. An *incremental*

[7] Each “residual aggregate” has been ”chopped up” into several synthetic firms. We have tried, when constructing the ”synthetic firms” to preserve known distributional patterns of the industry/market (Taymaz, 1992).

innovation yields an improvement in the capital and labor productivity (INVEFF and MTEC) variables in the model, within the limits of an optimal technology, which we label the "global technology". The essential point is that firms do not know the global technology and therefore cannot jump to it. Incremental innovation is obtained by discoveries within the firm or by imitation and improvement of another firm's technology. *Radical* innovation reflects a change in the global technology. Global technologies are also ranked by their productivity, and all the technologies that have the same limiting global technology belong to the same technological paradigm. Such a paradigm, also called techno-economic paradigm by Freeman and Perez (1988), corresponds to a cluster of inter-related innovations that affect most of the industries. We have also introduced user-producer learning that stimulates the diffusion of innovations between sectors.

The "technological level" variable in the model refers to the average of technology codes. The average technological level in the model (the technology level index) is an abstraction. The number of patents issued can be used as an empirical proxy, but in the model the technological level represents qualitative differences in technologies.

Technologies are ranked from 1 to 100 and the rank of the technology defines its potential limit. For example, technology 10's potential limit is higher than technology 4's, etc. A firm gets closer to that technological limit by incremental innovation and the closer it gets the more difficult it becomes to improve productivity. Then the firm will try to switch to another technology that is more likely to have a higher potential limit. Therefore, it has to discover/identify a better technology, which takes it outside its own experience range and therefore involves greater risk. The firm allocates part of its R&D budget on incremental innovations, and the rest for radical R&D to discover new technologies. When the firm gets closer to the potential of existing technology, it will be more difficult to increase productivity through incremental innovation, and the firm will allocate increasingly larger parts of its R&D budget to radical R&D.

The ability of the firm to discover winners is improved by appropriate learning where the outcome depends on the firm's accumulated memory for recombination (Ballot and Taymaz, 1998, pp. 312 ff). The firm may have learned the right things by chance, but there is also a possibility that firms with broad based experience to begin with (memory) have a better capacity both to learn and to make the right technological choices. Learning and innovation occur in both incumbent and new firms and contribute to improving their technological performance. Key to success is the capacity of the firm to choose superior project and this capacity depends (Ballot and Taymaz, 1998) on the experience of firms as embodied in their memory. Firms currently update their memory. In the current version of the model their memory is sufficient to remember three technologies at a time. In their technology choices they use the best among those three. They, furthermore, try to improve the memorized technologies by innovation/imitation (experimentation). If they improve any one of them, they update their memory with the better one, and forget about the worse one. Through innovation/imitation they can generate the old, inferior technology again, but they do not adopt it because it is inferior. Even though the firms have learned through experimentation and updated their memories in the MOSES dynamic this is ex post knowledge and no guarantee that they can choose a superior future technology. But in stochastic terms, they are more likely to choose better technologies. Hence, radical, innovative choices are based on learning and experimentation in combination, involving by definition a high-risk level, but also the potential for great rewards. The better firms are at discovering winners the stronger the bias towards macroeconomic growth of the model economy.

Non-linear endogenous growth

The move of the economy towards a new paradigm is supported by decreasing returns to incremental innovations, but its success depends on the willingness of many firms to follow the first firms that have ventured successfully into the new paradigm. There are increasing returns to adoption (Arthur, 1988). This means that radically new paradigms might not develop if the returns to the current paradigm are satisfactory. Several paradigms may then be represented simultaneously in the manufacturing industry for a long time, involving lock-in effects (Ballot and Taymaz, 1998). One not so good paradigm may also block the development of a better paradigm.

New technology is introduced through new entering firms and through new investment in incumbent firms. Radically new technology tends to enter more frequently through new firm entry. If through new investment in incumbent firms the impact is reduced because it has to be integrated in old vintages of capital. On the other hand, the new technology, if successfully introduced applies to a much larger capital base, with a much larger (than with the small firm) leverage on total firm productivity growth. One could look at the introduction of new technology in a MOSES firm (through investment) as a strategic acquisition of a new technology firm the capital structure of which is then integrated with the existing capital structure (Eliasson, 1985, pp. 156f, Eliasson and Eliasson, 2002b).

The identification, discovery and technological choice process described above defines the *receiver competence* of the economy at different levels beginning with the firm. The fact that firms make business mistakes and that winners may be lost for ever, tilting the economy on to a slower growth path makes it necessary to model this choice process explicitly. Since the long-term growth outcome depends on the efficiency of this choice process the definition of the *dynamic efficiency of the economy* becomes tricky. We define it as the capacity of the economy to minimize the economic incidence of two types of business mistakes; keeping the losers[8] on for too long and of losing the winners (Eliasson, 2001a, 2003a).

Lack of receiver competence at different levels means that firms are unable to access the pool of globally available technology and/or that good but radical technology choice by firms/entrants do not survive because incompetent financial providers are unable to understand the economic potential of the radically new technology (Eliasson and Eliasson, 1996, Eliasson 2003b). Hence, technology, however advanced, residing in incompetent firms is not sufficient for growth. If downstream commercialization technology is lacking the economy at large may completely miss the train to prosperity that the new technology is promising. We call this the *competence bloc* in which the (technical) innovator is only one of many critical players.

In order not to overdo this explanation (see above) it should be mentioned that the competence bloc is currently very crudely modeled, but we are working on introducing a more elaborate representation of it, notably venture capital competence. We expect, however, that this elaboration will only strengthen the simulation results to be reported on below.

Eliasson and Taymaz (2000) demonstrated that growth in the MOSES economy depended on a balanced firm turnover and labor market process, such that increased labor market mobility gave no growth effects if the potential for positive reallocation of resources was low (read no innovative entry). Similarly an increase in innovative entry gave little positive growth response if resources were not freed from their current allocations through exit of inferior firms and increased labor market mobility. Common to all experiments was that the effects of small parameter changes were very slow in showing up at the macro level. The balancing of all these factors depends on a complex of labor market, firm entry and exit

[8] This problem has been with us for a long time. Thus, for instance (Eliasson and Lindberg, 1981) a clear conclusion from early simulation experiments on the M-M model is that even a big investment mistake need not

parameters in the model, some of which are policy parameters, that have to be set right for " optimal" receiver competence and macro performance. Hence, policy makers can easily be destructive when interfering with the internal dynamics of their economies, and since the gestation period of the macroeconomic effects is so long, it may be impossible to identify and correct policy mistakes in time. The damage to the economy may be permanent.

One important feature of the competence bloc, clearly manifest in the MOSES model, is that it breaks the direct technology – growth drive so typical of postwar growth models in the neoclassical and linear Schumpeterian (1942) traditions. The competence bloc is defined from the demand (customer) side and screens all innovative technological "suggestions" for profitability (the *entrepreneurial* and *venture* capital functions). If the economic circumstances, including institutions and industrially competent actors, are not the right ones, however advanced, technology residing in the economy does not lead to growth. If so, we have the case of lacking receiver competence at the economy wide level that is explicitly represented in the model.

The positive role of business mistakes and dynamic efficiency

The choice of new technology, notably radically new technology involves great business risks. Therefore, business mistakes occur frequently in the Experimentally Organized Economy and in the MOSES model. They should be looked at as a normal cost for economic development and learning. Because no investment venture can be perfectly planned and enacted, as assumed in the static equilibrium setting of the mainstream model, the dominant transactions cost in the Experimentally Organized Economy and in the MOSES model is made up of business mistakes (Eliasson, 1992). All other measured costs are regarded as production costs geared to measured output. Hence, to experience any successes at all – and

be a great disaster, as long as production at the investment is terminated quickly. Early close down of production growth – the economy has to be capable of absorbing a large number of mistaken business experiments. In fact, we have demonstrated elsewhere on the model (Eliasson, 1984, Eliasson et al., 2001) that a certain balancing of firm turnover between entry and exit is necessary for stable macroeconomic growth. Under such "dynamic" circumstances it becomes important that both project creation and selection and the learning process itself be efficient in the sense that the economic consequences of two types of errors are minimized, i.e. of keeping losers on for too long and of losing winners. Competence bloc theory (Eliasson and Eliasson, 1996, 2002a, Eliasson, 2001a) attends to that within the theoretical environment of the Experimentally Organized Economy.

As mentioned, the MOSES model incorporates a very crude version of the competence bloc that has been significantly improved upon by the addition of the genetic innovation and learning mechanisms in Ballot and Taymaz (1998) and the more sophisticated financial services markets in Eliasson and Taymaz (2002). We mention this here only because the efficiency of selection helps us to define Schumpeterian efficiency in a dynamic model where growth is generated through competitive selection and a maximum, exogenously determined, sustainable (or "equilibrium") growth rate cannot be defined as a reference or a bench mark because it requires that the lost winners be identified. For our purposes we only conclude here that Schumpeterian efficiency requires significant exit but that only a minimum of potential winners should belong to the exit flow (Eliasson, 2001a). Receiver competence, hence, has two dimensions in the real world; the ability of the firm (new and incumbent) to pick up the right technology (the winners), and the capacity of the system to select winners and force losers to exit. The latter receiver competence of the economic system is defined by competence bloc theory, and here the industrial competence of venture capitalists figure importantly (Eliasson and Eliasson, 1996, Eliasson 2003b).

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activity on grossly mistaken investments, therefore, was part of competent management.

With Ballot and Taymaz (1998) the earlier dependence on historical experience to guide search and luck to be innovative has been improved by a more realistic learning and discovery process modeled through genetic learning mechanisms as described above that can improve upon the selective ability of firms. Firms can learn about rules of resource allocation for imitative activities, and even imitate other more successful firms' rules. The learning modules in Ballot and Taymaz (1998) are modeled using classifier systems.

The MOSES model simulates the complete Swedish economy as defined at the national accounts level. It has been estimated ("calibrated") on macro (national accounts) data for the Swedish economy (Taymaz, 1991b, Albrecht et al., 1992). The simulations to follow should therefore be regarded as "empirical forecasts" on a "Swedish like" economy that are based on facts (data and estimated relationships) and the prior assumptions embodied in the model specifications.

3. The New Economy scenario

For the purpose of this simulation study we accept the stylized facts of the New Economy of the popular economic press, namely that its prime mover is C&C technology and its ultimate manifestation, the *Internet*. We do, however, add two important empirical circumstances; The dominant carriers of the new technology are the users, not the C&C industry itself, and the technology growth relationship is not that of the "linear direct drive" type of the Schumpeter II (1942) school, but features a technology diffusion process that is normally blocked or diverted by economic and institutional factors in more or less deficient competence blocs. We also recognize verbally that a lot more technology than C&C technology is currently in the pipeline of Western industrial economies to make the notion of a new Economy interesting, and as well the risks of missing the train to the New economy an acute policy concern of the same economies (Eliasson, 2002a). The three industrial dimensions of C&C technology are; (1) a "new" generic *technology* that diffuses through the economy being carried by (2) the *industry* producing C&C equipment, software and services to be (3) *used* practically everywhere in products and in production. The interesting industrial dimension of C&C industry is not C&C industry itself but the quality increases achieved in products based on C&C technology and the productivity effects generated when its products are integrated with other forms of production, for instance, in the financial services industry, to create very large positive systemic effects (Eliasson, 1995, 1998a, 1999, Eliasson and Wihlborg, 1998, Eliasson and Taymaz, 2000).

Even though the systemic productivity effects within the firms can only be represented in the model through productivity advance at the " firm aggregation level", we know that the potential productivity effects at that level are very large (Eliasson, 1998a, 2002a). Systems productivity effects at higher levels are, however, captured through the simulations.

This is the sequence of events that we envision in reality and have explicitly represented in the model. *First*, new generic C&C technology is developed within the C&C industry and forms the base for rapid expansion of the C&C industry. The same technology is carried to the incumbent firms in existing industry through their investments in hardware and software produced in the C&C industry. The successful introduction and realization of productivity gains from those investments in user firms, however, require a particular *local receiver competence* (Eliasson, 1990) that is rarely present. *Second*, the early successful introductions are, therefore, preceded by sequences of failed introductions. *Third*, once a winner has been discovered and registered learning sets in among other firms as modeled through genetic algorithms in the model. The diffusion of successful new technology introductions, however, takes a very long time before the opportunities to learn become plentiful and a "spillover source" has been established (Eliasson, 2001b). We register a strongly non-linear introduction process, beginning with the productivity paradox and culminating with a surge in productivity advance as the new technology takes hold of the entire production system, forcing firms that have not been able to accommodate the new opportunities to exit. The fast movers/introducers are the new entrants. *Fourth*, once the new technology has established itself in the form of several successful technology introductions (the technology level index, or the tech level in Figures 3, 4 and 5) other firms will find it easier to learn, and the more firms that have learned the faster other firms can learn and technology diffuses at an accelerating rate. Eventually, the entire economy should have assimilated the new technology and shifted to a higher growth path. This takes care of the first two paradoxes.

The third paradox involves failure on the part of the entire economy to introduce the new technology. Receiver competence from an economy wide perspective has an economic or industrial dimension that is captured by competence bloc theory but also an institutional dimension, including the institutions that support the actors in the competence bloc. If the political spirits of a nation are against the formation of private wealth policies will be enacted that discourage the development of a competent venture capital industry. This will effectively short-circuit the competence bloc. Our analysis will however only demonstrate that simple economic, or economic policy circumstances associated with the institutions of a national economy may be sufficient to prevent the successful transformation of an old economy into a New Economy. From Eliasson and Taymaz (2000), Eliasson et al. (2001) and Johansson (2003) we know that a balanced entry and exit process and a mobile labor market are required for new technology introductions through new entry of firms to be successful. If a viable exit process and a mobile labor market do not facilitate the transfer of resources, notably labor resources to the entering and growing firms the whole growth process might stall. There may not be any New Economy experience.

4. The design of simulation experiments

Experiments have been designed to approximate the New Economy scenario of the previous section and to show how an innovative introduction of C&C technology in some firms (reflected by the technological level curve in the graphs, see above) can be successfully learned by other firms at fast, medium fast and slow rates, or fail to materialize altogether if the needed receiver competence is missing. The experiments are designed to exhibit the three paradoxes referred to historically in Section 1 and hypothetically in Section 3; (1) a long gestation period (the productivity paradox) before (2) a seemingly unexpected surge onto a new growth path occurs, or (3) the absence of a growth outcome altogether. The train to new prosperity has been missed.

Technology introductions occur through firm investments, in which we vary the share of C&C investments exogenously. Two things now occur. *First*, C&C industry investment increases the probability of successfully innovating and initiating new technology in the C&C industry firms. *Second*, productivity of new investments in the firms using C&C industry products increase strongly.[9]

The experiments also distinguish between fast and slow innovative entry, and fast and slow exit. In this model setting, a (a) low technology level, and a slow rate of growth in the same level, and (b) a slow introduction of C&C technology are taken to reflect a low receiver competence on the part of the firm population of the economy. A slow increase in successful new and innovative C&C technology introductions can also be caused by a badly functioning competence bloc in the sense that radically new and innovative technologies or products are not identified and supported commercially, e.g., because of lack of sophisticated customers or

[9] That is labor and capital productivities (INVEF and MTEC respectively) in new investment vintages increase, and the more so the larger the share of C&C investment in total firm investments.

competent venture capitalists. The genetic learning mechanisms of the model capture some of that in a stylized way. Similarly, the whole economic system can be more or less adopted for facilitating the introduction of new technology through new entry etc. In our simulation experiments this is crudely represented by the speed of entry that can be varied by setting the parameters that determine how new firms react differently to profit opportunities in the market. The other side of the receiver competence of the economy at large is a more or less speedy exit process that releases resources more or less early for fast growing new entrants and incumbents. In the slow case, firms exit when they have used up their equity. In the fast case they exit after so and so many years of below market interest rates of return. One problem should, however, be mentioned right away. The successful introduction of new C&C technology (the technology level curve) is all endogenous. We cannot keep that factor constant and vary other parameters to see how fast technology diffusion occurs.

5. Simulation experiments

The Figures 2A, 3A and 5 show cumulative developments over a 50 year period of (1) the C&C technology level, (2) C&C industry output, (3) total manufacturing output and (4) (labor) productivity. In the first round of experiments exit is fast, releasing resources fast (fast exit).

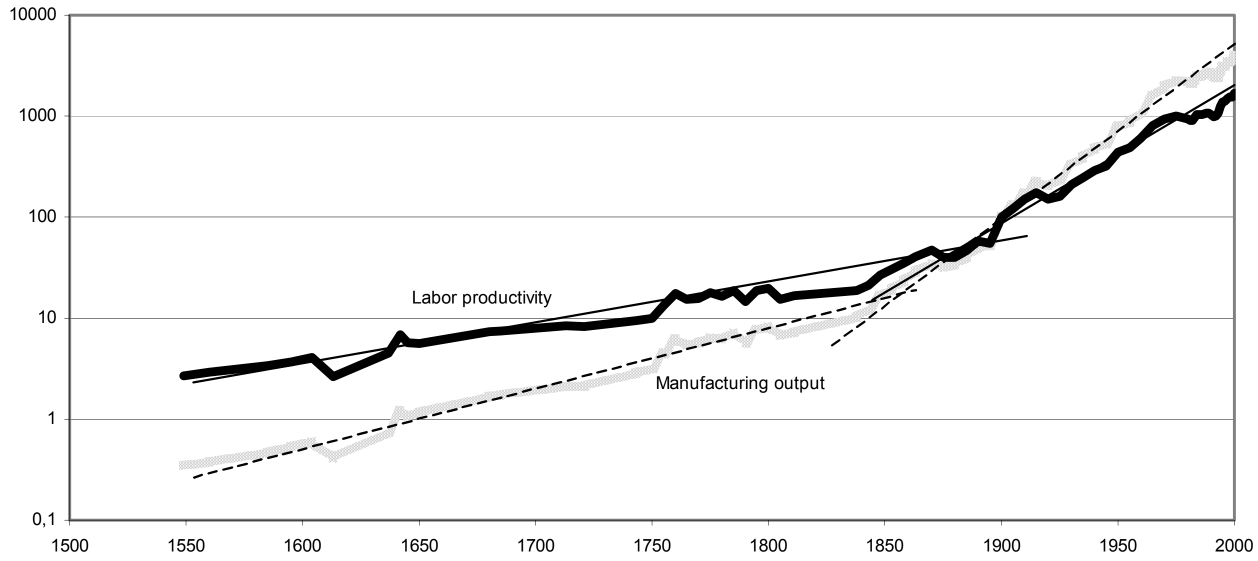
The reader should, however, note one particular thing. Towards the end of the simulations productivity growth is quite fast and total demand does not keep pace with growth in potential output. Unemployment reaches fairly high levels in most experiments. This means that the experimental design is not that of a full employment economy. Unemployment is all endogenous in the model and a growing unemployment will eventually be self-correcting through endogenous downward adjustments in real wage growth, if not prevented by policy determined stickiness of wages (not in these experiments). This has consequences for the interpretation of the simulation results that were not anticipated when designing the experiments (see below).

Table 2. Key end of 60 year simulated data

	(a) worst growth case	(b) best sustainable	c) best 60 year growth case
GNP	100	152	175
Manufacturing output	100	141	171
Entry	0	242	114
Exit	191	225	69
Technology level	100	212	160
Unemployment	100	158	89

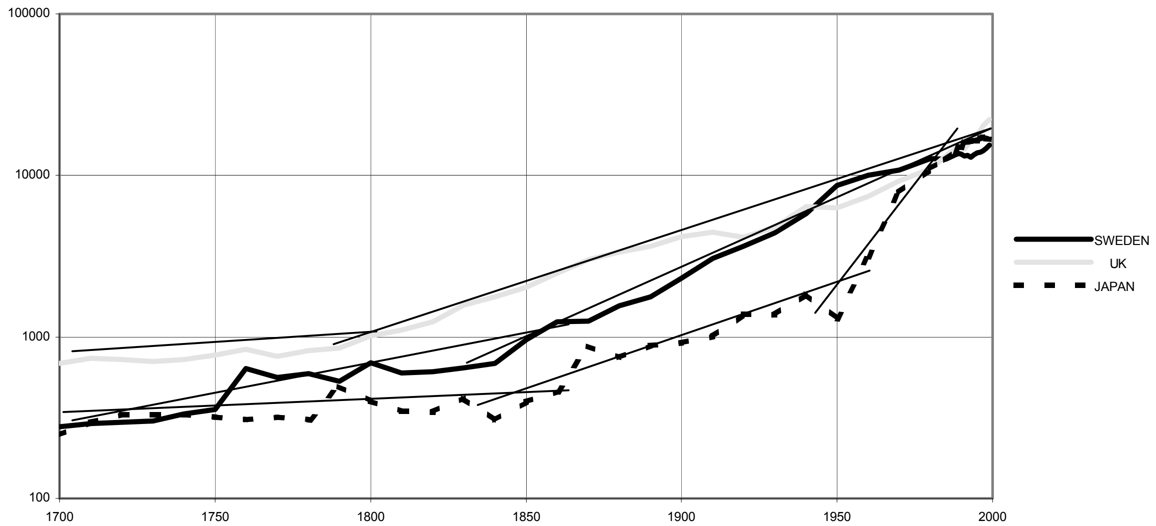
Note: For items 1, 2 and 5 and 6 column 1 in the worst growth case has been indexed 100 for reference. Exit and entry are expressed in terms of number of firms. The absolute numbers do not relate to similar registered numbers for the Swedish economy because the total number of firms in the MOSES firm population is much lower than the real population of firms.

Figure 1A. Manufacturing production and productivity in Sweden 1549-2000



Source: Eliasson (1988, p. 158) and updatings.

Figure 1B. GNP per capita in Sweden, England and Japan 1700-2000



Source: Eliasson (1986, p. 49) and updatings.

Figure 2A. Best sustainable growth case – high exit, fast C&C diffusion, fast entry

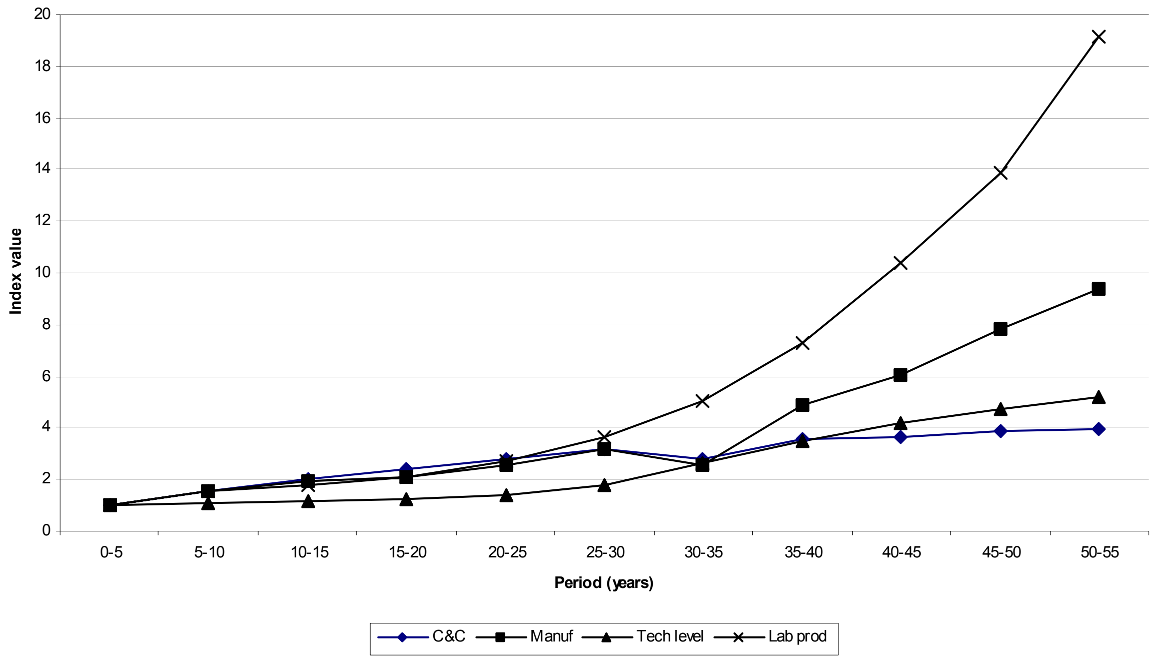


Figure 2B. Manufacturing output level in high exit, fast C&C diffusion, fast entry experiments – five Monte Carlo variations

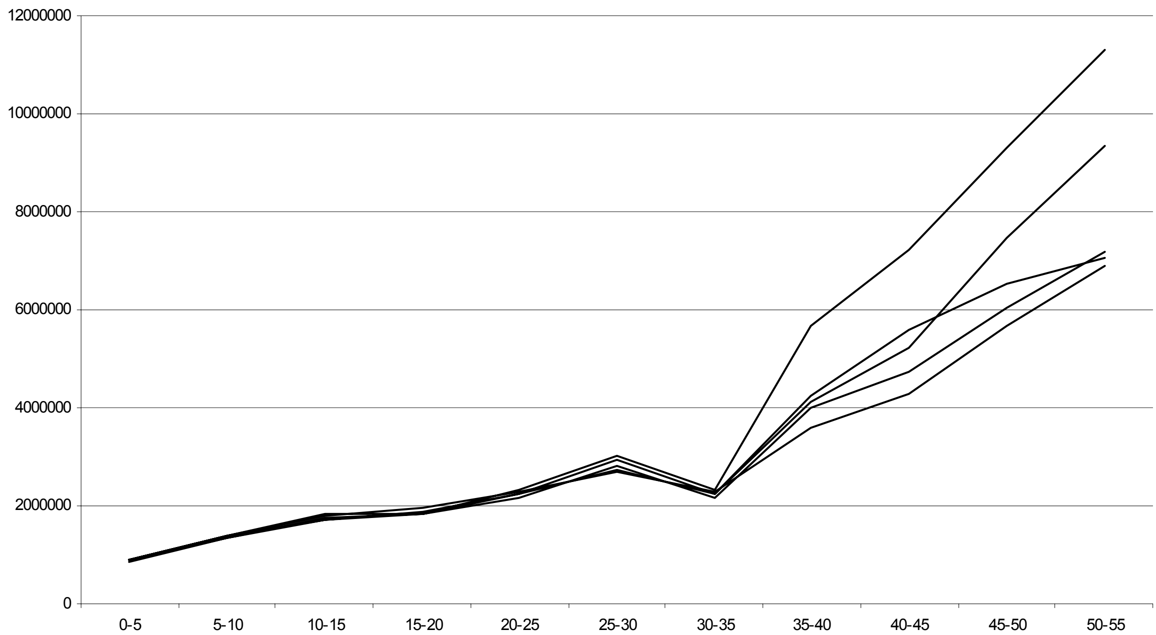


Figure 3A. Worst growth case, high exit, slow C&C diffusion, no entry

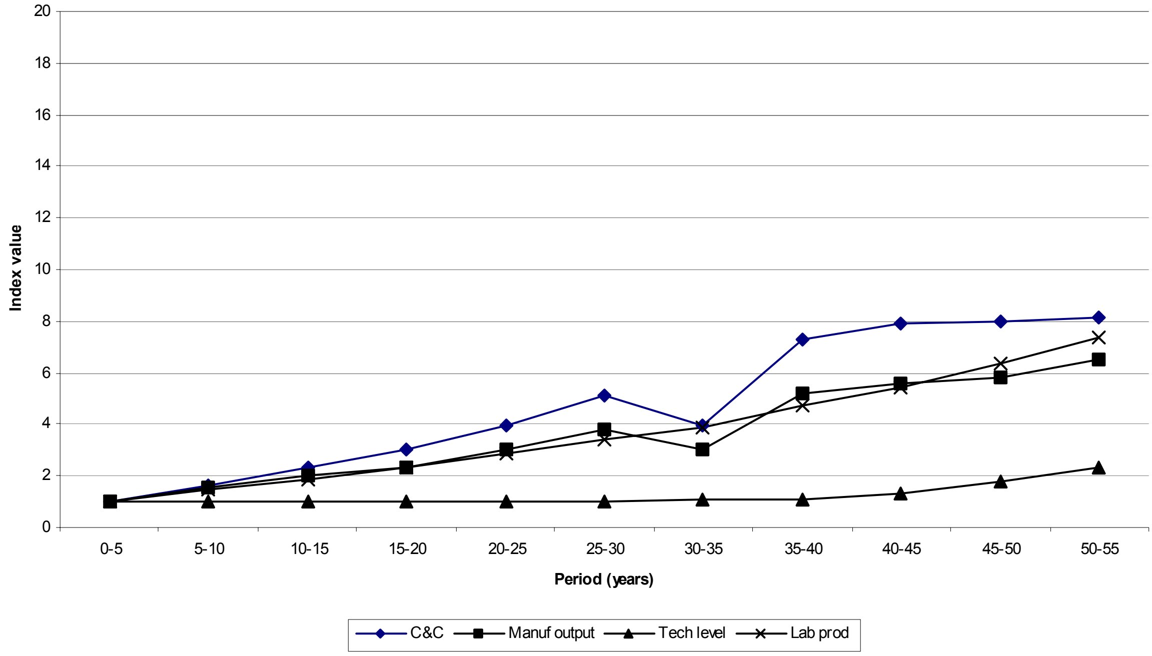


Figure 3B. Manufacturing output level, high exit, slow diffusion, no entry – five Monte Carlo variations

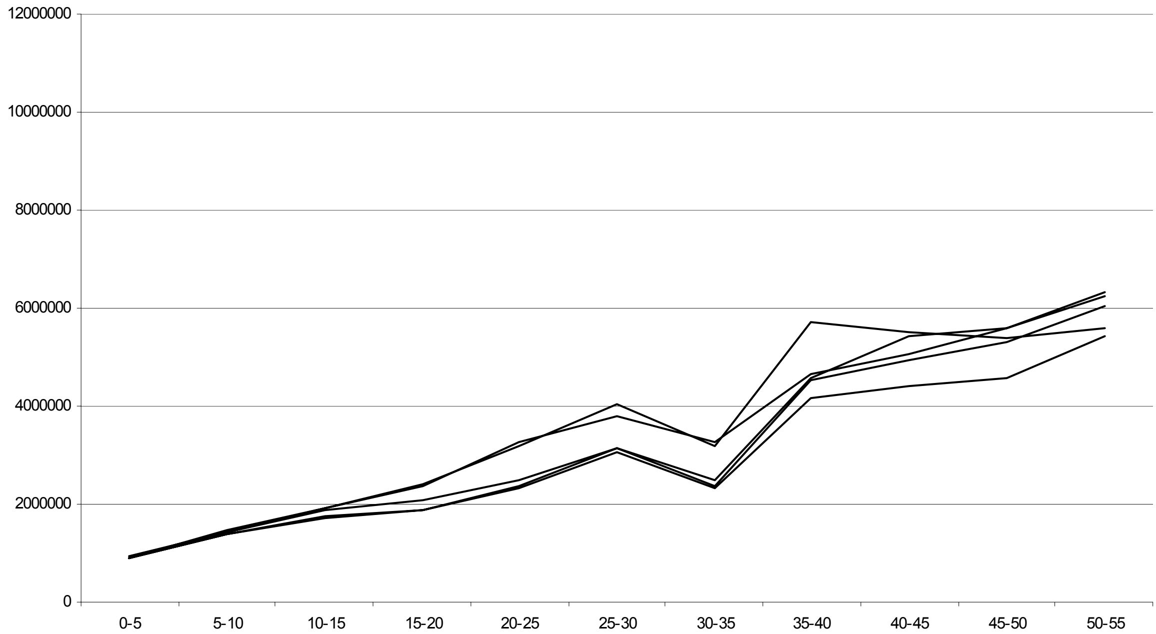


Figure 4. Relative performance of high exit/fast C&C diffusion/fast entry vs. high exit/slow C&C diffusion/no entry experiment

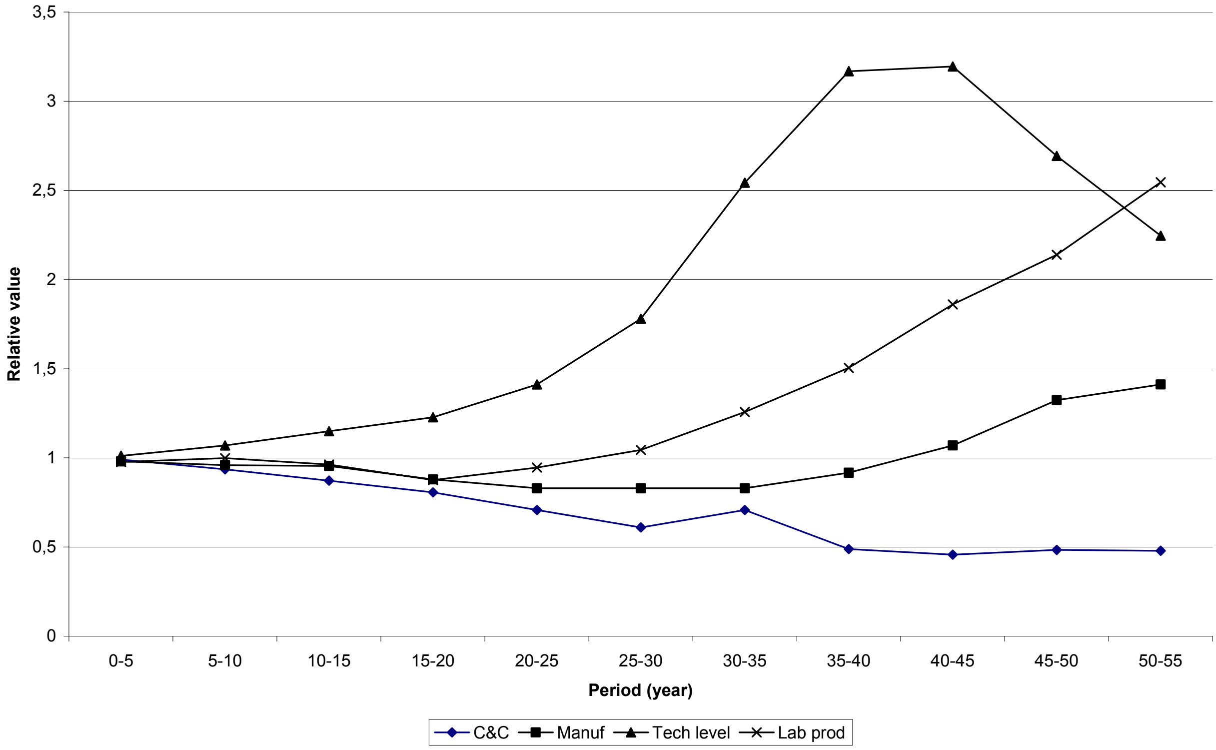


Figure 5. Best 60 Year Growth case – low exit, fast C&C diffusion, some entry

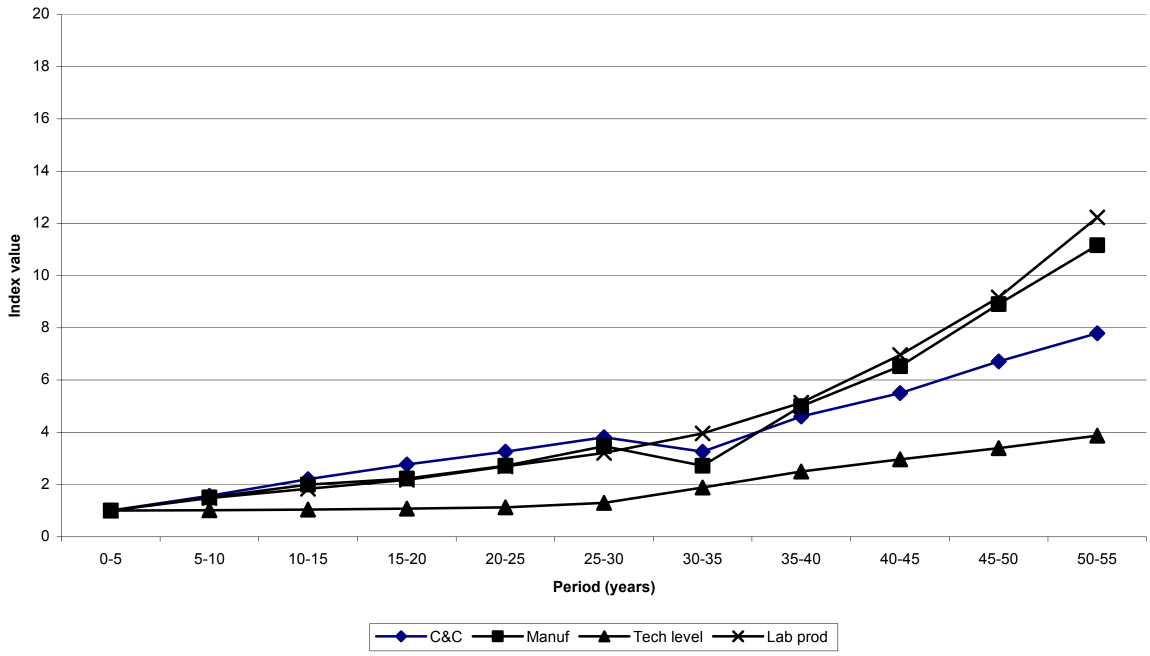


Table 2 gives key "end of 60 years" data for three of the 16 quarterly simulation runs. For each of the 16 simulation experiments five Monte Carlo variations[10] have been run to test for robustness (Figures 2B and 3B). Table 2 and Figures 2A, 3A give average outcomes. The Worst Growth case experiment features (a) no entry, slow diffusion of C&C technology and a high exit rate. The Best Sustainable Growth case experiment (b) features significant entry, fast diffusion of C&C technology and fast exit of low performing firms. If we vary the parameters of the entry function in the model we find that the maximum growth scenario (the best sustainable growth case) is obtained when rates of entry and exit are balanced (Eliasson et al., Taymaz, 2001).

With sustainability we mean that the circumstances are such that fast growth most probably will continue beyond the simulated long run horizon (see below). Figures 2A and 3A show the evolution over time of C&C industry output, total manufacturing output, the level of technology and labor productivity in the best sustainable and the worst growth scenarios respectively. The B figures show Monte Carlo variations in manufacturing output for the same scenarios. The technology level is an index of the productivity levels achieved in the most successful new technology introductions from which all other firms can now learn.

The worst growth case experiment has been designed to show the absence of a successful new economy introduction. The negative institutional circumstances that prevent the introduction of a New Economy are very crudely represented by the absence of new entry (vs fast and very fast entry) and the slow diffusion of C&C technology. But this is sufficient to generate a remarkable difference in long term industrial development, best shown in the B figures. The Best Growth case shows (Figure 2B) a rapid phase shift onto a faster growth

[10] by varying the seed number of four pseudo-random number generators in the model that affect (a) the sequencing of firms sending hiring signals in the labor market, (b) the timing of entry, conditional on objective

pattern after some 30 “ productivity paradox” years. The Monte Carlo experiments show a significant spread of the new economy introductions, but the whole “fan” points strongly upward. Nothing of the kind can be registered in the 3B figure. The economy “misses the fan”, or the New Economy entirely. The A figures and Figure 4 tell why. Figure 4 compares the four indexes in the two runs using the Worst Case as a benchmark (i.e. as index 1).

The technology level index surges ahead dramatically in the Best Sustainable Growth scenario. There are plenty of successful new technology introductions of firms across industry to learn from. Labor productivity in all manufacturing firms also begins to catch up, but only after some 25 years of “productivity paradox” have passed. With a delay of several years manufacturing output surges ahead.

We should also observe (Eliasson et al., 2001) that the Best Growth Successful New Economy introduction scenario features a balanced entry and exit process (Table 1). None of the other experiments did that.

The only peculiar circumstance to observe is that C&C industry output in the best Best Successful New Economy introduction case grows much more slowly than in the worst growth case. The reason appears to be the productivity of C&C equipment. The larger the share of C&C equipment in total investment the higher the probability of radical innovation and successful imitation raising productivity levels in the investing firms. Since C&C equipment is very productive, demand for C&C equipment expressed in volume terms decreases.

Finally we have (Figure 5) the Best 60 year growth case. It differs from the Best Sustainable growth case only in one way. Exits have been slowed down. Fast exits mean that rational firms shut down after some years of below market average rates of return, and release their resources (physical capital and labor) in the market. Slow exit means that firms do not

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incentives, (c) the degree of success of R&D outcomes and (d) new firm characteristics as a random drawing exit until their net worth is turning negative ("bankruptcy"). This means that badly performing firms on the average stay on longer in production in the low exit than in the fast exit simulations, locking in resources and raising factor prices for the fast growing successful firms, thus, lowering growth. Such was the common sense hypothesis based on earlier model experience (Carlsson 1983, Eliasson and Taymaz, 2000). But here the model comes up with a surprise.[11] Capacity utilization and employment are completely endogenous in the model and the new economy experiments all turned out to be significantly less than full employment scenarios.[12] We have encountered something of a "Keynesian situation". Keeping the low performing firms alive longer meant significantly reduced labor productivity across manufacturing (cf. Figure 2A with Figure 5) but much less unemployment (Table 2). Apparently, the lowered supply of factors was not sufficient to raise factor prices significantly and the "Keynesian" effect dominates over the factor reallocation effect. Manufacturing output becomes higher than in the best sustainable growth scenario.[13] On the macro surface we can observe the emergence of a strong upward shift in growth. Also the C&C industry grows rapidly. But new technology introductions are negatively affected (the technology index) and there will not be much in the form of successful new technology introductions to learn from. Compared to the fast entry, fast C&C diffusion and fast exit case (Figure 2A) this faster growth case is not positioned for sustained faster growth beyond the 60-year simulation horizon. Could the sudden unexpected emergence of fast growth after many "productivity

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from an empirical distribution (Eliasson and Taymaz, 2000).

[11] Which it frequently does because of its extreme complexity.

[12] Because the new database and the calibration took much longer than expected we have not had the time needed to design an entirely new set of experiments where a higher level of capacity utilization is maintained.

[13] One should of course not overdo the interpretation of the simulation details, but it is tempting to make one comment here. During the real industrial revolution in Sweden during the 19th century expansion began first in output and growth in productivity took more than a quarter of a century to catch up (Figure 1A). The difference might have a Keynesian explanation in the sense that strong export demand supported output growth, but output growth still was not sufficient to keep labor fully employed. Measured productivity caught up with output when a surge in emigration to the U.S. began. This interpretation is perfectly testable on the MOSES model but was not anticipated when the experiments were designed and would be a new project to reenact through simulations.

paradox years" in the U.S. economy and then the sudden collapse of parts of the C&C industry have anything to do with this "sustainability" issue. More slack in the economy (cf. Figure 2A) caused by a faster exit process would have paved the way for a better very long term sustainable future than the slow exit case (cf. Figure 5).

6. Conclusions

Three propositions of the New Economy have been tested through experiments on the Swedish Micro-to-Macro model MOSES.

1. The gestation period of the radically new organization of an economy needed to realize the potential productivity gains proposed for the new economy is very long. Hence the "productivity paradox".
2. When the productivity gain is finally being realized at the macro level the background relationships are far to long winding and complex to be explained in the near term. The macroeconomic growth surge appears "unexpectedly" out of the blue.
3. If the circumstances defining the receiver competence of new technology at all levels are not right, the economy will miss the train to the New Economy and continue along the previous growth trend, so well illustrated historically in Figure 1A.

We conclude that the theory of the Experimentally Organized Economy and of competence blocs as represented crudely by the current version of the Swedish M-M model, including also learning and competent technology selection based on genetic algorithms (Ballot and Taymaz, 1998) has been capable of capturing all three paradoxes within the same theoretical and quantitative modeling framework.

***Supplement*:**

The New MOSES 1997 Database – including the C&C industry

Creating an initial database for the Swedish micro-to-macro model MOSES (Eliasson, 1977, 1978, 1985, 1991a) is a major research undertaking. Not only has data for a consistent micro firm to macro GNP (National Accounts) level database to be collected (Albrecht et al., 1992) and adjusted for complete consistency. The model also has to be dynamically calibrated/estimated (Taymaz, 1991b). For practical reasons the same initial databases, therefore, have to be used for years. The previous fully consistency adjusted initial databases were compiled for the years 1968, 1974, 1976 and 1982. They increasingly meant the creation of a complete and consistent micro-to-macro national accounts system (Albrecht et al., 1992). 1976 was the first year planning survey data on firms and divisions of firms specifically designed for the MOSES model were used (Albrecht, 1992). A "synthetic" (deidentified) database for outside use was put together for 1990. Only for 1976 was it possible to obtain the complete input output table for the OECD end use industrial classification that we use (Ahlström, 1978).

From 1997 a new micro firm based industry, the C&C industry has been introduced. This required the creation of a completely new database for 1997. The initial database has, therefore, been shifted from 1982 to 1997 and the model has been completely recalibrated.

This supplement briefly explains the nature of the micro-to-macro database and the new C&C industry. For more detail the reader is referred to Albrecht et al. (1992). To begin with, value added and employment shares are presented for the industries with micro data used in the 1997 version of the model. This had to been done to make future comparisons possible. Value added and employment shares for the 1982 database have been included for comparisons.

To our knowledge, official value added data on the C&C industry has only been published by Statistics Sweden for the year 1998. We have, therefore, used the official data for 1998 to approximate value added for the C&C industry in 1997. Assuming the same relations in 1997 and 1998, the shares of employees in the different industries have been used to approximate the 1997 shares of value added with value added data for 1998.

We also include Salter curves on the rates of return and on labor productivities of the real firms included in the model. These firm data are based on firm surveys.

There is also a brief comparison of the Swedish C&C industry share with similar data for the U.S. economy published by Jorgenson (2001), even though Jorgenson uses a different method for calculating value added by industry. Since most writing on the New Economy originates in the U.S. this comparison of the size of the C&C industries in the two economies is of interest to understand the magnitudes involved.

Table S.1 gives the size of the Swedish C&C industry as almost 5 per cent of GDP in 1997 (5.3 per cent in 1998; see Table S.3). The corresponding employment share in 1997 (Table S.2) is 3.8 per cent, or significantly smaller, telling that labor productivity is higher in the C&C industry than in the rest of the economy on average. The C&C industry employment share has also increased since 1982 (from 2.9 per cent to 3.8 per cent, an increase of about one third). Reductions in employment shares between 1982 and 1997 have been reported for raw materials and investment goods producing industries, agriculture, mining, construction and electricity. The interesting thing is the reduction in the investment goods producing industry and a corresponding, large increase in the labor share of intermediary products producing industries. Technically this means that the firms that we have classified as intermediate goods producers have grown faster on average than the firms classified as belonging to the investment goods industry.

Table S.1. Value added distribution, per cent of GDP in 1997 and in 1982, with and without the C&C industry

Sector	1997	1997	1982
Raw	3.78	3.78	1.70
Intermediary	6.56	6.56	6.80
Investment	3.65	5.76	9.04
Consumer	4.98	4.98	6.07
C&C	4.92	-	-
Agriculture	2.17	2.17	3.15
Mining	0.30	0.30	0.38
Oil	0.17	0.17	0.20
Construction	3.45	3.45	7.67
Electricity	2.51	2.51	3.59
Other Services	67.52	70.32	61.40
Total	100.00	100.00	100.00

Note: The sectors are defined as in Bergholm (1989). The only difference is that the C&C industry has been "broken out" from other services (telecommunications firms and data consulting and data services firms) and from investment (manufacturing C&C firms) and is presented separately. There are no value-added data available on the C&C industry in 1982.
Source: Statistics Sweden 2001, MOSES database and own calculations.

Table S.2. Labor distribution, per cent of total in 1982 and in 1997, with and without the C&C industry

Sector	1997	1997	1982	1982
Raw	2.88	2.88	4.20	4.19
Intermediary	6.51	6.51	4.75	4.74
Investment	3.69	5.37	6.73	8.31
Consumer	5.68	5.68	5.28	5.27
C&C	3.82	-	2.88	-
Agriculture	0.99	0.99	1.43	1.42
Mining	0.28	0.28	0.37	0.37
Oil	0.05	0.05	0.05	0.05
Construction	4.96	4.96	6.55	6.54
Electricity	0.75	0.75	1.06	1.06
Other Services	70.40	72.55	66.70	68.04
Total	100.00	100.00	100.00	100.00

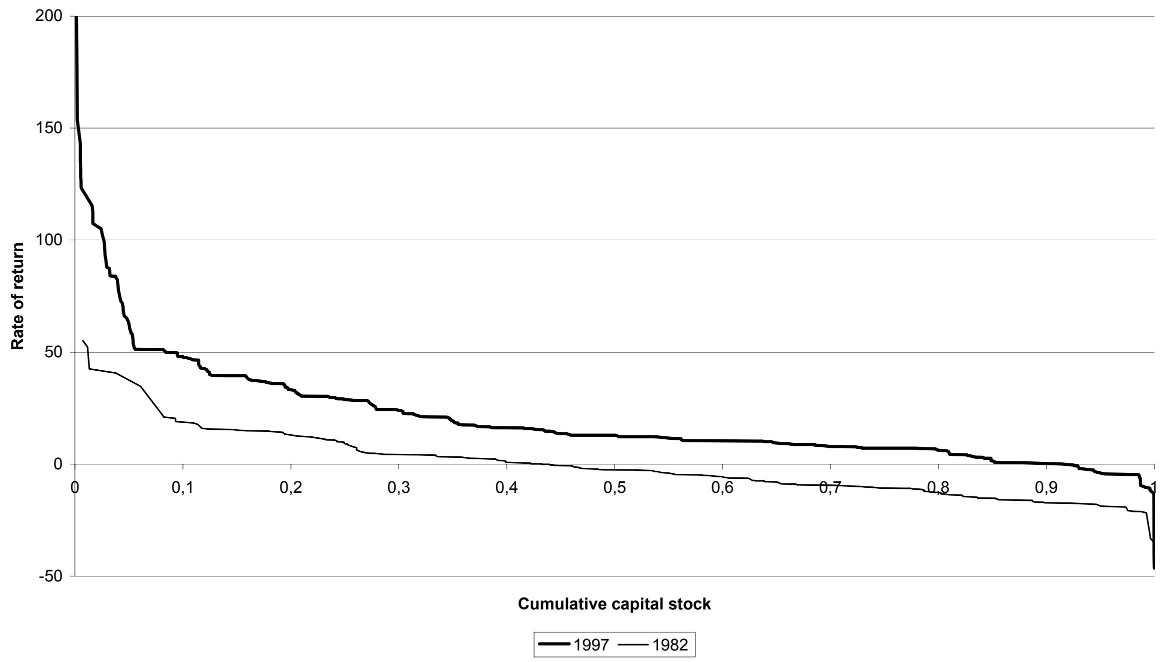
Note: The sectors are defined as in Bergholm (1989). The only difference is that the C&C industry has been "broken out" from other services (telecommunications firms and data consulting and data services firms) and from investment (manufacturing C&C firms) and is presented separately.
Source: Statistics Sweden and own calculations.

Table S.3. C&C industry share of GDP, Sweden and the U.S., 1982

	Sweden	USA
Manufacturing C&C industry (Computer)	2.08	0.93
Telecommunications industry (Communications)	1.48	1.50
Data consulting and data services firms (Software and services)	1.77	3.49
Total	5.33	5.92

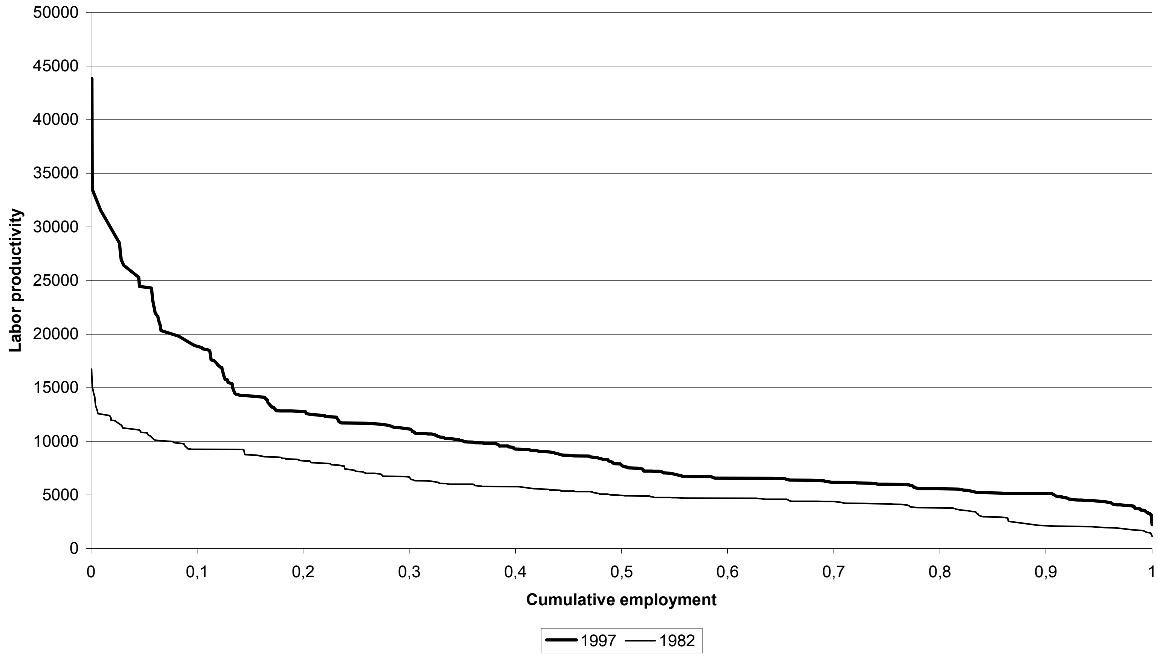
Note: Notations used by Jorgenson (2001) in parentheses. The large share of manufacturing C&C industry in Sweden is partly explained by the fact that Ericsson is classified as manufacturing C&C equipment.
Source: Statistics Sweden (2001), Jorgenson (2001) and own calculations.

Figure S.1. Rates of return (per cent) distributions 1982 and 1997; so called Salter Curves



Note: Swedish manufacturing industry.
Source: MOSES database.

Figure S.2. Labor productivities 1982 and 1997



Note: Swedish manufacturing industry. Labor productivity is calculated as value added (1000 SEK; 1997 prices) per employee.
Source: MOSES database.

The total share of the C&C industry of GDP is about the same in Sweden and the US, the US C&C industry being only slightly larger (Table S3). It is interesting to note that the Swedish share of manufacturing C&C industry is much larger than the same share in the US, while the US software and services industry is much larger than the Swedish counterpart. Telecommunications industry is of about the same size. The C&C services industry is newer and expands much faster than the old manufacturing C&C industry. This indicates a lack of renewal and low industrial transformation of the Swedish industry.

The Salter curves of manufacturing industry (Figures S.1 and S.2) show strong increases for labor productivity and also in rates of return across the entire manufacturing industry. This suggests that the top of the business cycle occurred in 1997, the year of the initial database. This was not the case in 1982, the year of the previous initial database. But Figure S1 also reflects the fact that the same period has seen a return of manufacturing rates of return to more normal levels compared to the depressed level in the 1970s and early 1980s.

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