MASTER

The development of technological and export capabilities of a country explained along trajectories

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The development of technological and export capabilities of a country explained along trajectories

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Preface

Defining an exact starting point for the motivation of doing this Master of Science thesis is hard. In my undergraduate program I performed my first investigation into the importance of engineering activities into the development of the capabilities of a firm. That was in Brazil, and what struck me is that these Brazilian engineers are so constrained in their activities as most technology, methods and machinery was being developed and delivered by foreign companies. Their employers did barely have the need, or even the wish, to see those engineers developing new technology. On the other hand senior engineers from Embraer argued that engineering courses were not adequate to graduate engineers to actually participate in the development process of a complex product. This was my first impression into the importance of capability building in the development of a country, and how wrong things were apparently being done in Brazil.

Choosing a Master of Science program was therefore not hard. Technology and Policy with specialization in Technology and Development Studies at the Technological University of Eindhoven was, in my words and imagination, the course that taught how to deploy technology for the economic development of a country; how to redeploy these Brazilian engineers in doing what they were trained for and thereby helping to develop the overall economy. Several courses of the graduate program led me through the theory of technological change and economic growth, with a teaching staff that made some economists green of envy. Eventually I landed at the Economic Commission for Latin America and the Caribbean (ECLAC), the headquarters of the United Nations in Latin America. Once more classes from good teaching staff, and once more the argument that engineers in the Latin American countries could not really deploy their activities in the overall benefit of technological and economical growth of their countries. This apparently large problem stimulated me to research the background of this situation. The original and intrinsic objective was a micro-analysis towards the processes of capability building in developing countries, but it eventually turned out as a rather macro-analysis towards the processes of structural change and catch up in a large set of countries. Shifting between the original objective and the eventual output was a tough and long lasting process, but concluded today!

I would like to thank the staff from ECLAC for their support in arranging me the internship and a project proposal, and complementing I would like to thank Alessandro Nuvolari (in his person of graduation coordinator) to take me out of there before I embarked in the further development of that overly complex proposal. Deploying a small part of it was already enough to fill this thesis! I would like to thank Fernanda Puppato for her support and nice words throughout this project: I hope to someday have as much energy as she has! Also the course colleagues are due special thanks for the discussion of all the rest; a pity that the contents of master thesis are so specific that profound discussion and feedback of each other's work was hardly possible. For that matter I had much support of my thesis coordinators: their specific questioning of the thesis was sufficient to stimulate further advancements in the work. Finally, my very special thanks to Anna, who supported me throughout the whole undertaking, assuring me she would still love me even if I ended up depressed and in the social security system!

Summary

In economical literature there is long and ongoing interest in the economic development of nations. The study of the influence of technology in this economical development is a relatively new undertaking of economists, taken-up us as broad research field after 1950. Nowadays literature point to a positive relation between technological change and economic growth: technological upgrading leads to a subsequent export upgrade and higher economic growth. Further, upgrading in technologically advanced and expanding sectors has an even higher impact on economic growth. According to the evolutionary school of economic thought, the technological changes do however have a dynamic of their own, barely being influenced by economic rationality. The community of technology practitioners is guided by their previous experience and sets of heuristics that determine how to do things and how *not* to do things. These professionals have limited knowledge and access to alternative technologies. Furthermore, their activities are conditioned by the broader environment in which they operate, such as regulations, stimulating or restricting policies of a country. As a consequence technological change is expected to be mostly of a cumulative nature; the growth and reallocation of technological capabilities requires long-term policies and interventions to be accomplished.

On the basis of the above theoretical background we analyze the dynamics of the development of the technological and commercial capabilities of 33 countries. We employ the patenting activities at the United States Patents and Trade Office as indicator for the technological capabilities and the export activities as indicator for the commercial capabilities. This data is clustered intro 25 broad sectors. In the empirical part we analyze the amount of reallocation of the export and technological capabilities of countries. As expected, most countries underwent only small changes in their capabilities, evidenced by the low values for the reallocation of shares between the 25 sectors. A small group of countries, however, underwent rather large changes. A posterior analysis demonstrated that these changes were both towards expanding sectors and shrinking sectors. The reallocation towards the shrinking sectors is irrational from an economic point of view, as previous literature demonstrate that expanding sectors offer higher possibilities for economic growth. A posterior analysis demonstrated that the specialization pattern at the start of the period had a strong influence on specialization pattern at the end of the period, for most countries. This analysis is of an intrasectoral nature, that is, it employed the specialization strength of a sector in the first period to explain the specialization strength of that sector in the last period. As such it showed that the cumulative characteristic of the technological change applied to most countries. This analysis was less successful in explaining the development of countries with a large reallocation of capabilities. We argue that, according to the evolutionary school of economic thought, the new acquired capabilities of these countries should be similar to the prior capabilities in the country. To determine similarity of sectors we employed the cumulative number of citations between the patents assigned to these sectors. The citations made by a patent to prior patents reveals relevant knowledge, interpreted here as a demonstration of technological relationship. Processing of these data employing Multi Dimensional Scaling resulted in the ‘technological space’, a visual demonstration of the similarity of sectors. Employing the relation between sectors we demonstrate that the expansion of sectors is positively influenced by the similarity of the expanding sector to sectors with existing strong capabilities. Therefore we explain the expansion of capabilities as being influenced by close prior capabilities.

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1 Introduction and research question

Economic growth is an important item on the agenda of people. At the personal level several persons want a higher salary, at firm level one aims for higher profits, at governmental level for higher overall incomes for the society. Investigation towards the determinants of economic growth has occupied researchers for centuries. One of the most employed measures to compare the economic growth of countries is (the development of) the Gross Domestic product of the country: the sum of all economic activities of a country. A part of this Gross Domestic Product is formed by the exports accomplished by the country: selling to other countries provide money inflow to the country. The ability of a country to produce and export a certain product reflects an increased performance of that country over other countries. In other words, if a country exports a product this can be interpreted as the acquisition, by this country, of an advantage over other countries. Therefore other countries are willing to import that product instead of producing it themselves (Hausmann et al. 2007). The better positioning of the country in producing this certain good may come from a series of factors. Some of those factors are the availability of natural resources as inputs for the exported product, the availability of labor force, capital and of technological capabilities to produce that product.

Studying the influence of 'technology' in the development of commercial/export capabilities and economic growth is a quite recent venture in economic literature. Although earlier work in development economics suggested that industrialization creates spillovers and subsequent growth, mainstream economics was not able to incorporate the technological change in formal models (Hidalgo et al. 2007). In the neo-classical school of economics one introduced the 'factor endowments' theory to explain the activities undertaken by a country's. In this theory it is assumed that technology is equally available for all countries, and therefore does not play an active role in the determination of trade flows (Laursen 1999). Trade flows would rather be guided by factor prices and the economical capabilities of a country: poor countries are assumed to lack capital to invest in technology (machinery, production lines, etc) and a large amount of cheap and unskilled labor while developed countries have capital to invest and develop technology but sparse and high educated labor force. In order to avoid misallocation of funds a poor country should therefore concentrate on 'poor country goods' (and poor country processes) that consist mostly of non processed goods with little technology employed in the production, while a rich country should concentrate on rich countries good that consist mostly of industrialized goods, with high technological content. As a consequence we get a technological dependence of the poor countries on the rich countries, in that the developing countries import innovations from the developed countries and use them passively (Lall 2000).

According to Verspagen (2001) it is only recently that the neo-classical school of factor endowments started to study the characteristics of technological change as explanation of economic growth. As a consequence, studies of technological influence in commercial capabilities have led a marginal life in economic research for a long time. It was only after 1950 that researchers started to pay close attention to the relation of technological efforts buy a country and its economic growth (Soete 2008). One of the earliest attempts of determining the influence of technology was made by Solow. This American researcher determined that the production of the country (gross domestic product) could be explained by inputs of labor, capital, and a residual. This residual was the results of technological effort of the country: production that could not be explained by the inputs of labor and capital should then be explained by another value adding component, which Solow assumed to be technology. But as an unexplained residual it could also be anything else influencing production of the country. Therefore Abramowitz entitled this residual as 'a measure of our ignorance'. It was a first attempt in showing that there was something else besides capital and labor that explained production (Thirlwall 2006). In 1982 Dosi writes that there is clear evidence of a relation between technical progress and economic growth which supports the view that structural change is a possibility to accomplish growth by a country. In the same publication the author comments that there is no evidence of the direction of the causal relation between technical progress and economic growth. On one hand an increased economic capacity by an actor will lead to resource accumulation that can be invested in the exploration of novel innovative opportunities, while on the other hand the exploration of the innovative opportunities gives raise to increased productivity figures and consequently economic growth. This causality question was further investigated and more recent views on the relationship will be given later in this work. Soete (1983, 1987) analyzed the influence of technological efforts in economic growth, and pioneered the analysis employing a country's patents and Research and Development (R&D) spending as indicators of technological output and input, respectively.

Montobbio and Rampa (2005) studied the worldwide growth of technological capabilities and export by sectors for the period 1985 to 1998. They find that in this time period there is a worldwide dramatic increase of trade and innovative activities in sectors related to electronics, physics and pharmaceuticals. Those sectors present above average growth in both the technological content as well as exports. That is, there is an apparent relation between the growth of technological efforts in a sector and the growth of exports of that sector. They also find that some countries experience a strong shift in the technological as well as export outputs, steering their structure towards the fast growing sectors. The shift in the composition of the exports as well as the technological capacities of the country is entitled 'structural change'. The authors affirm that the structural change in technology and exports experienced by those countries explains the posterior economic growth. That is, countries that increase their technological efforts will experience an increase in the export figures, and consequently their economic performance. Fagerberg (2000) writes that there are several models that suggest that countries specializing in technologically progressive activities will enjoy higher rates of productivity growth than other countries, while countries specializing in low technology sectors are expected do have relatively slow productivity growth. In a free market situation the increases of productivity would reflect into lower prices, but Montobbio and Rampa (2005) found that price elasticities of high technology products are higher than for low technology products. They do this by analyzing the export elasticities to the income of the trade partner. They find that the faster growing economies among the developing countries have high-income elasticities for their exports and lower import elasticities for their imports. This corroborates the idea that exports specialization as well as trade play a role in the economic growth rates of these economies.

The findings from Montobbio and Rampa (2005) and Fagerberg (2000) suggest that a country seeking the achievement of economic growth should shift to the fastest growing sectors. This would lead to an increase of the export figures, and consequently the economic growth. According to economic rationality this could be a path to follow by underdeveloped countries in achieving the expected and desired economic growth as well that is should steer developed countries in reallocation of their capabilities towards the sectors with potential higher growth. Although those shifts could be expected, prior empirical studies show that there is limited structural change among most countries worldwide. In 1990 Dosi et al. describe that in the past decennia the technological efforts are dominated by a small sample of countries and only Japan was able to enter the group in the post-war period. In the last thirty years only a limited number of countries achieved an extensive growth and reallocation of their technological and export capabilities (Montobbio and Rampa, 2005; Uchida and Cook 2005a & b; Laursen, 2000; Amendola et al. 1998). These authors find that technological and trade patterns of countries follow a persistent pattern. Their research concentrated mostly on the influence of past specialization patterns on newer specialization patterns, using the similarities between both specialization patterns as an explanation for this persistent characteristic of the technological endowments. The apparent persistence of a country's technological capabilities as well as export figures does, however, not agree with the economic rationality of increasing economic gains. The explanation of these authors for the 'economically irrational' choice by the countries is based on the intrinsic characteristics of technological development (nature of technological dynamics) as explained by the evolutionary school of economics. According to this school of economic thought the technological development of a country is rather influenced by its existing capacities than by the opportunities offered by worldwide upcoming new sectors (such as the Information and Communication Technologies in the past decennia's). This assertion is based on the observation that technological development is basically achieved by a gradual process of incremental improvements of the technology. These processes are based on technological inputs – entitled technological paradigms – whose repetition process leads to gradual technological progress, called the technological trajectory. In short, the authors of this economic school defend the idea that technological dynamics are influenced by the general characteristics related to technological processes, and not by the characteristics of economic rationality. This technological process incur the accumulation of knowledge over large time spans in certain field, therefore it is hard for an actor to move into another technological field as this one will also be based on earlier activities. This characteristic of technological changes was also observed by Lall (2000), who writes that the technological upgrading of developing countries has resulted from long and cumulative processes of learning and the agglomeration of knowledge.

Earlier research has employed a limited set of countries in their analysis. Studying the results and conclusions of the different analysis we find that most developed countries presented a persistent pattern. Developing countries, on the other hand, showed a rather diverse pattern, with some highly dynamic ones and some stagnant ones. The earlier analyses (whose conclusions are used to build up the above taxonomy) were performed for either developed countries or developing countries, where each work employed different indicators, what makes the comparison of the statistical outputs of each work harder. Therefore we decided to redo part of the earlier analysis for the largest possible and feasible set of countries, including a variety of countries 'tags': developed, developing, etc. Possibly due to the predominance of the persistent patterns, earlier authors concentrated on their explanation using the concepts of technological paradigms and trajectories. The (scarcer) dynamic patterns were not explained yet by these concepts at the macro-level. Montobbio and Rampa (2005) are some of the authors that spent more attention to the structural change processes in developing countries. They observe that the countries that achieved an overall growth of technological capabilities developed part of this growth in the less dynamic sectors. They call this a perverse pattern, as one would expect the countries to grow toward the sectors that experienced higher dynamics: higher growth of technology, but mostly, of exports, which would eventually lead to economic growth. The authors do not explain why countries developed this pattern. In this work we will perform an analysis in which we demonstrate that structural change is influenced by the concepts of technological paradigms and trajectories. We will do this by demonstrating that countries followed some patterns in redeploying their specialization pattern. We argue that the changes of countries capabilities will happen through the growth of sectors that are close/similar to sectors that already have high capabilities, so that the technological capabilities in the already developed sector influence the development of the close/similar sector in spite of the distant/dissimilar sector. That is, we will explain the development of technological patterns observed among countries by employing the characteristics of technological relationship between different technologies.

The main research question of this research is therefore:

> Do technological paradigms and technological trajectories influence the development of the technological structure of countries in the period 1976 until 1999?

We aim to explain the development of the countries specialization pattern in the given period based on the assumptions of technological change as described by scholars of the evolutionary school of economicss. Some initial details have been given above, further details will be exposed in chapter 2: Theory and background.

The main research question is divided into sub-questions:

> How are major world economies characterized according to their technological structure? Do they demonstrate technological patterns that resemble persistence/cumulativeness and/or structural change?
>
> Can the cases of persistence/cumulativeness be explained by the theory on technological paradigms and trajectories?
>
> Can the cases of structural change be explained by the theory on technological paradigms and trajectories?

Each sub-question is the basis for one of the chapters of this work. Together they should answer the main research question in the overall conclusion of this work. The indicators that will be employed to answer the sub questions are:

1 – The specialization pattern of the country: the identification of the technological capabilities of the country. This is the pattern that will influence the posterior specialization pattern of the country, either if the country shows persistency pattern or if it moves actively into structural change. We will employ two indicators for this analysis which complement each other. The first indicator is based on the technological capabilities as indicated by the patenting activities of the country. The second indicator is based on the export capabilities of the country. Both indicators and their characteristics are discussed in the further chapters of this work.

2 – An indicator for the relationship between technological classes. Cimoli and Dosi (1995) relate the concepts of technological paradigms and trajectories to the properties of learning, an activity that is both local and cumulative. The local aspect is related to the idea that new products or new ideas are developed/sought after in the neighborhood of existing capabilities. Therefore we need to define a measure of relatedness between technological sectors, to be able to assess if newly developed sectors are indeed close to sectors in which the country was already present.

Before entering the exploration of the characteristics of technological capabilities development we will succinctly present the characteristics of the employed theories and results of related prior research in the second chapter. This chapter deals with the theory on technical development as presented by the evolutionary school of economics. These theories were originally used to explain microeconomic processes, but throughout the literature they have also been applied to explain macroeconomic processes such as the persistence of technological and export patterns of countries. We will argue that these theories can also be used to explain structural change found in a country, by assigning a similarity measure to the technological sectors and studying the development of technologies based on these similarities. Besides employing a technological variable (patents) we also introduce the exports of a country as a variable to explain structural change. Exports will be used as an indirect indicator for the technological capabilities of the country. In the third chapter we present the employed data as well as an introduction to their analysis and the employed methodologies. As this work builds on earlier findings described in the introduction and the first chapter, we will reproduce the exercises done by those authors employing a database with more countries as well as different processing of the data. The main objective is to confirm that the specific data prepared for this work also reveals the same characteristics, corroborating the findings by those authors and reinforcing the validity of the data for the final analysis that is new and expected to complement the findings of the early research. The analysis towards the development of trade and technological capabilities of the countries and the sectors developed in the last decennia's is done by applying three methodological tools to the data. The first analysis, described in chapter four, is related to the first sub-question and determines the characteristics of the technological development of the countries in the sample. The second analysis, presented in chapter five, is related to the second sub-question, where we study the persistence of specialization patterns. We will also study the co-influence of trade and exports, arguing that advantages in exports may lead to technological advantage, or vice versa. In the third analysis, presented in chapter six, we will explain the development of new capabilities for the sectors of a country (structural change) by looking at the other capabilities that the country had. Finally we gather all evidence in the overall conclusion.

2 Theory and background

In the introduction chapter we have referred to earlier work about the extensive differences in the growth rates of technological capabilities and trade numbers for different countries. Montobbio and Rampa (2005) have shown that the largest worldwide growth rates for trade and technology were experienced by sectors related to pharmaceutics, electronics and physics. The same literature also shows the differences between the performance of different (groups of) countries. This chapter is dedicated to study some of the existing theories that explain technological change and related to that the accomplishment of structural change. It will focus on the possibilities and limitations imposed to the technological change of a country. Structural change is therefore defined as the analysis of the changes in technological as well as export capabilities (capacities) for countries. Further, we will study how the changes of technological and export capabilities are related. Therefore the further paragraphs of this chapter focus on some of the studies and theories about the changes of technological as well as trade capabilities, and the relation between technology and trade.

2.1 The fundamental properties of technological change at the micro level

In the discussion of the changing technical capacities Cimoli and Dosi (1995), Dosi (1988) and Dosi (1982) defined some fundamental properties of technology, assigned to the evolutionary theory. These properties expose the features of the procedures and direction of technical change. The development of the structural change within countries as observed in the further chapters of this paper will be explained by the description of the here described features of technical change. The names given to those features are not consistent in the literature. The aforementioned authors use the terms technological paradigms and technological trajectories, therefore they will be used in this text as well.

Technological paradigms are based on three fundamental ideas that form "a pattern of solution of selected technological problems, based on selected principles derived from natural sciences and on selected materials technology" (Dosi 1982). The selected technological problems concern a satisfactory description of technology and how it changes: it should contain a representation of specificities of the knowledge incorporated in that technology. The technology and its changes cannot be reduced to the standard view of blueprints (for example manuals containing the description and functioning of a machine). Technology and its changes do rather concern the problem-solving activities to varying degrees, including the tacit forms of knowledge embodied in individuals and organizational procedures. Tacit knowledge refers to the knowledge that is not – or cannot be – written in product manuals as it concerns aspects of particular expertise, experience of past attempts and earlier technological solutions that are now inferior or obsolete. Obsolete or inferior technological solutions are not contained in products/machines or described in manuals, so a passive agent (i.e. user) will not have access to what aspects of technological content have been improved upon. As a consequence of the importance of the tacit effects one cannot rely on passive forms of technology acquisition, for example by importing and operating a machine, as mean to catch up technologically. The explanation is simple: there is more knowledge in the production of that machine than the machine itself. Here one can apply the difference, introduced by Bell and Pavitt (1993) between "production capacity" that concerns the stock of resources, the nature of technologies, labor skills, products, etc and the "technological capabilities" that is related to the knowledge and resources needed for the creation and coordination of technical change. Importing of the machines infers in acquiring production capacity (even though for correct operation of the machine some tacit knowledge may be needed through the installation and/or operation by a foreign technician), but the country will not have the 'technological capabilities' to understand the working of the machine: why did the developers of the machine use technique A to accomplish function X as technique B could be used as well? Knowing and understanding those choices is part of the technological capability building, and also the second aspect of the concept of technological paradigms.

Making choices about employed techniques is therefore (part of) the second characteristic of a paradigm. It entails the heuristics and shared visions on how one should to things and how to improve on things, based on the selected principles from natural sciences. The heuristics are classified in "positive heuristics" and "negative heuristics". The first entails the shared visions by the community of practitioners concerned with that particular activity, for example engineers, firms or technical societies on how to do things. The "negative heuristics" indicates the same community on how *not* to do things. Examples concern basic concepts of an airplane that consists basically of a circular body (for better aerodynamics) with wings attached to both sides whose function is to create upward force to sustain the airplane in the air (make it airborne).

The third aspect of technological paradigms is that there are basic models of artifacts and systems which are progressively modified and improved over time. They are mostly described as the technological and economical characteristics of the product. Returning to the example of the airplane those attributes refer to economic characteristics as the needed input and the production costs, but also technical characteristics as the maximum take-off weight, cruise speed, etc. This attributes complement the general characteristics of the product as described in the second aspect: an airplane used to spread pesticides and an airplane for intercontinental flights will have the same general characteristics regarding principles to make it airborne, but both will have differing technological attributes to make them apt for the required function, eventually implying in different body size, choice of engines, etc.

Based on the three mentioned characteristics of technology and its changes Dosi (1982) write that technology entails the perception of a limited set of technological alternatives and of future developments. The few alternatives and the notion of how the future will 'look like' imply that an actor should know what has been done in the past, to possibly make the right choices, the "positive heuristics" and avoiding the choice for techniques that were previously made superfluous, obsolete or uninteresting, the "negative heuristics".

The concept of technological trajectory is associated with the progressive and gradual realization of the innovative opportunities associated to the technological paradigms, that is, the deployed activities based upon: i) the set of selected technological problems, ii) the selected principles derived from natural sciences and iii) on selected materials technology (Dosi 1982). Therefore a technological trajectory is seen as an activity deployed in a constrained environment in which engineers and organizations are focused on rather precise directions while they ignore alternatives that fall outside their 'selected' environment: a strong exclusion effect caused by the technological paradigm in which the agents are active. On the other hand the technological paradigms offer the opportunity for progress based upon technological needs and/or recombination. The paradigms therefore shape and constrain the rates and direction of technological change irrespective of market inducements (Cimoli and Dosi 1995).

A second aspect of the technological trajectory, related to the one mentioned above, is that one will be able to observe regularities and invariance in the patterns of change that still hold under different market conditions, disruptions will be caused by radical changes in knowledge-basis that are constrained to the technological paradigms (the selected technologies, materials and techniques).

The third aspect is that changes are driven by repeated attempts to adjust to the technological imbalances created by the advancement itself: the production of a new material that allows higher temperatures and therefore faster rotation of an engine will require further improvements on the balancing of the engine's shaft.

Cimoli and Dosi (1995) relate the concepts of technological paradigms and technological trajectories to a general property of the innovation literature, in that learning is local and cumulative. The development of technological paradigm was observed to be dependent on selected technological problems, selected principles and selected materials technologies. Within this context engineers work in a rather blind fashion, disregarding most technological alternatives, but they also achieve progress through learning. The theory from innovation literature says that this learning will be of local character, in that the engineers in achieving the progress will rather take techniques that are close (in the neighborhood) of techniques that they are already using (techniques they already selected). In the earlier paragraphs it was also mentioned that heuristics can be both positive and negative, the first being the view on how to do things while the second is the view on how *not* to do things. The cumulative aspect of learning matches with this heuristics, in that engineers make choices among new/alternative techniques based upon past experiences.

2.2 Technological paradigms and trajectories at the macro-environment

The discussion on technological paradigms and technological trajectories as presented above was originally performed for the micro-technological level, more specifically on the research by Dosi (1982) on the development of the ICT sector in the post war period. Therefore it was used to explain the dynamics and development within a single sector. Still the work has also been adapted to macro-economic environments, such as firms and sectors within countries. Cimoli and Dosi (1995) argue that a paradigm-based theory of innovation and production is highly consistent with the evidence shown by the paradigms and trajectories on the micro level. They note that the paradigms are embodied in the larger technological systems and even in larger economic-wide systems of production and innovation. Therefore they conclude that for their purposes (the analysis of learning patterns for development) the micro- and meso-economic theoretical building blocks (technological paradigms and trajectories) are consistent with broader institutionalist analyses of National Systems of Production, Innovation and the governance of socio-economic relations. They explain that the evolutionary microtheories are apt to explain the processes of technological gaps and diversities between national institutions over long spans of time. It may also explain, based on learning capabilities, how countries catch up.

Dosi et al. (1990) refer to the technological paradigms and trajectories as explanation of the relationship between economic forces and the seemingly autonomous development of technology within firms and sectors. In this processes the dynamics of a firm (within a country), their improvement and diversification of technological capabilities is based on search processes in zones where they can build upon their existing technological capabilities. It is a process of microeconomics of innovations, where firms are repositories of technological knowledge. The authors attribute the eventual success of the firm in achieving these microeconomical improvements to the imperfect or asymmetric information, the knowledge and competences that pre-exist in the environment, that is, each firm will have a (country) bounded environment in which it can evolve. The prior information available in each country differs, and that will influence the posterior development of the firms within that country. Besides the micro-economical environment related to prior available knowledge, the development of a firm is also influenced by the zones in which the firm operates: it is strictly delimited by the characteristics of the country, and include incentives and opportunities generated by positive feedback, institutional context and economic signals they face.

> […]These characteristics of technology produce irreversible technological paths and lock-in effects with respect to technologies that may be inferior (based on welfare measures) to other technological paths, but still be dominant due to historic influence. (Cimoli and Dosi, 1995: p.255)

Due to the influence of the environment on the development of firms within countries they cannot freely tap into a general pool of technological knowledge. In the empirical part of this work we will return to this issue, and present both a measure for the prior information available to the country as well as a measure for the global pool of technology. This global pool is interpreted as an indicator of the similarity between technologies, but a country's technological development is eventually assessed on their own prior technological capabilities.

The theory employed for this analysis build upon the learning characteristics, which are expected to be of local character and between close sectors. While the earlier research explained the persistence of technological and trade patterns using the cumulative characteristics of knowledge acquisition, this analysis will try to relate the changes of structural change to the similarities between technologies, that is, the changes that countries underwent go along with the existing patterns of relationship between technological sectors. This is based on the idea that technological trajectories are dependent on the development of new technologies based upon existing strong existing capabilities: the sectors that show growth are closely related to sectors in which the country had prior technological capability. Using data on exports, Hidalgo et al. (2007) found that in the process of structural change a country has a higher tendency to move to closely located/similar products.

2.3 The relation between technology and trade: the technology gap model

After introducing the fundamental characteristics of the patterns of technological advancements as used in this work, we will proceed to some of the work done for the relation between technology and exports of a country. We do this as it is shown that persistency and change through close sectors is not only limited to technological patterns or the export patterns. Also the co-influence of technology and exports is believed to be persistent or move through close sectors. In 1982 Dosi writes about the clear evidence of the relation between technical progress and economic growth. Therefore increasing one's capabilities may bring growth to a country. The author, however, comments that there is no evidence for the direction of the causal relation between technical progress and economic growth. On the one hand an increased economic capacity in a country will lead to resource accumulation that can be invested in the exploration of novel innovative opportunities, while on the other hand the exploration of the innovative opportunities gives raise to increased productivity figures and consequently economic growth. To study these patterns we employ the technology-gap model. The technology gap model assumes that technological capabilities precede the trade capabilities of a country. This has been empirically tested and found to be true for several countries. However, technology gap (and the related empirical studies) does study the relation between specific sectors; in other words, advancement in technological capabilities around electronics will result in posterior expansion of electronics exports. On the other hand, a trade advantage in a certain sector may lead to technology and capital accumulation which can be used to foster the development of specific technological capabilities in other sectors. In their description of the taxonomy of the development of a national production capacity Cimoli and Dosi (1995) write that almost every country starts with manufacturing of clothing and textile (possibly also natural resources processing) and from there some countries move on to more complex and knowledge intensive sectors. The earnings and generic capabilities such as production lines obtained in a certain activity may be employed to foster a posterior activity.

The formal model to be employed in the search to the relation between technology and trade will be the 'technology gap' model. This model was first introduced in the 1960 and emphasizes the distribution of endowments across technological sectors within a country (Montobbio and Rampa 2005). It is related to the dynamics of technological change described earlier as the model depends on the specific and cumulative trajectories specific to the country. The development of the trajectories may then lead to productivity advantages in some sectors of that specific country. In the technology gap model it is less important to study the relative adjustments between sectors within countries based on relative factor prices and quantities, but rather concentrate on the technological factors. The process of accumulation implies the existence of trajectories and irreversibility (Cimoli and Dosi 1995). Lall (1992, 2001) observes that technology plays a role in shaping the trade patterns of both advanced as well as developing countries, as the specific characteristics of knowledge creation and technological accumulation may lead to specific capabilities development. The development of the specific capabilities makes the export structures difficult to change. Jaffe (1986) wrote that the technological position of countries (firms) are, in the long run, chosen by the country (firm) and that it more profitable technological opportunities might stimulate countries to move. He expects, however, that changes in the technological endowments van only be accomplished in a rather slow way due to constraints in acquiring expertise, goodwill and reputation in the new markets.

The main hypothesis of the technology gap model are summarized by Fagerberg (1987) as follows:

> […] 1. There is a close relation between a country's economic and technological level of development;
>
> 2. The rate of economic growth of a country is positively influenced by the rate of growth in the technological level of the country.
>
> 3. It is possible for a country facing a technological gap, i.e. a country on a lower technological level than the countries on "the world innovation frontier", to increase its rate of economic growth through imitation ("catching up").
>
> 4. The rate at which a country exploits the possibilities offered by the technological gap depends on its ability to mobilize resources for transforming social, institutional and economic structures. (Fagerberg, 1987: p. 88)

Amendola et al. (1998) find evidence that supports the technology gap theory by referring to empirical evidence that points to the relation between a country's technological capacities (measured by patents at the USPTO) and the ability to penetrate foreign markets (measured by revealed comparative advantage of exports). Montobbio and Rampa (2005) also take the technology-gap hypothesis in account in their analysis of developing countries. One objective of their work is the evaluation of the relationship between technology and trade. They affirm that the technological processes within countries have as most important outcome a change within each sector of the countries shares of world exports (named "Sectoral world market share dynamics"). Therefore one should focus on the analysis of the relation between technological efforts and the outcomes in terms of competitiveness (which is assumed to be obtained when the country exports the product), expressed in terms of changes of the world market shares for the same industry. In this analysis particular attention is paid to the study of the impact of reallocation of capabilities, that is, structural change. This reallocation is expected to be driven by technological advancements and to impact the distribution of the export activities and market shares. Therefore the authors assume that technological advancements (measured by the patents issued for the country at the USPTO) will precede the export activities. Soete (1987) studied the relation between technological and trade specialization by applying rank correlation (Spearman correlation coefficient) to the structure of technological advantage and trade advantage, confirming the expectation that there is a positive relation between both specializations, although only significant for smaller countries (which have higher specialization rates). Uchida and Cook (2005a,b) refer to a vast number of researchers that also found the same. This literature relates to the two first hypotheses, which state that trade and technology are related and, most important, that trade growth is positively influenced by technology growth. It is assumed that countries will experience technological advantage before trade advantage, as they will start by developing a product or process and due to the increased technological input reduce the costs and therefore attain trade advantages in that specific sector.

Amendola et al. (1998) performed an assessment for the technology-gap theory on a set of developed countries and found the relation between technology and trade to be existing and significant. Besides they found that the technological and export specialization patterns are very strong between close periods. Only over longer time spans they get weaker, due to a reallocation of capabilities to other sectors (Laursen 2000). Uchida and Cook (2005a) found the same sticky pattern for a set of underdeveloped countries, but they also found rather high dynamics for another set of (former) non-developed countries. These results are also observed in the work by Huang and Miozzo (2004) who looked at both technology intensity of exports through an assessment of trade balances and a measurement of technological specialization through the patents registered at the USPTO database. Beelen and Verspagen (1994) and Laursen (2000) observe that most turbulence in specialization patterns is observed among (former) 'developing countries', even if they belong to the OECD (as Portugal, Greece, Spain, etc). In the past twenty years the Latin American countries have not been able to change their technological capabilities considerably, while Singapore and China fared much better (Montobbio and Rampa 2005). In the search for the dynamics of turbulence, Uchida and Cook (2005a) do an extensive analysis for technological and trade specialization for East Asia countries: Hong Kong, South Korea, Singapore, Indonesia, Malaysia, Philippines and Thailand, showing high dynamics in some of this countries as well (mostly in South Korea). With a somewhat different focus Uchida and Cook (2005b) analyze a set of additional countries, obtaining results that corroborate the view that developed countries do not significantly change trade and technological specialization.

2.4 Imitation as a strategy to catch up

Of the four hypothesis of the technology-gap model one can apply the third hypothesis to the study of the developing countries, which on the worldwide plan did rather imitate than innovate, by either learning by doing or by the adaptation of foreign technologies (Cimoli and Dosi, 1995). A quite extensive body of research has been produced based on the analysis of catching up of developing countries that tries to give answers as to the performance of the mechanisms to achieve structural change. Archibugi and Pietrobelli (2003) studied the influence of new technological opportunities on the development of developing countries, dividing them according to the strategies employed to achieve economic growth. They applied a taxonomy to developing countries, classifying them into either receivers of FDI or self-exploiters. Sanjaya Lall (2003, 2000) studied the interaction of policies, capacity and capability building, Montobbio and Rampa (2005) studied the influence of FDI, school enrollment, R&D figures, etc. Eventually (Montobbio and Rampa 2005) used patents filed at the USPTO as measurement of structural change.

That is not to say that the first two hypothesis of the technology gap are not valid, also for developing countries it can be claimed that the assumption of technology preceding trade is intrinsically correct as the country will need to have an industrial infrastructure to allow the production of goods to be exported. The way this structure is built up is described according to a taxonomy by Cimoli and Dosi (1995).

> […] At a general level, learning patterns can be taxonomized according to the relative importance of the corporate activities involved, namely a) the acquisition of an existing technology associated with the paradigm prevailing in the developed world, b) its adaptation and modification in the local environment and c) the creation of new innovation capabilities with respect to products and processes. The importance of the three often follows a temporal sequence. Already the modification of the adopted technology implies learning of new production skills which grows through the adaptation of this capabilities to local specificities. Note, however, that there is no inevitability in the learning-by-doing process which, on the contrary, requires adequate organization conditions, both within each firm and each environment. (Cimoli and Dosi, 1995: p. 259)

The taxonomy by Cimoli and Dosi (1995) as well as the third hypothesis of the 'technology gap' indicates that imitation can be a tool used by underdeveloped countries to build up their technological capabilities in catching-up with developed countries. Other authors also found evidence for the influence of commercial activities on posterior innovation. Salomon and Shaver (2005) find that through the exporting activities there are diverse knowledge inputs which are not normally available in the market whose knowledge can flow to the local firms, possibly increasing innovation. Consequently, exports are associated with posterior innovation, that is, there is evidence for learning by exporting. Vaidya et al. (2007) find that the Chinese industry is becoming more competitive in their exporting activities due to capability development based on international technology transfer and learning processes.

Most literature on the relation between technology and trade is concentrated on developed countries and uses figures on R&D as well as patents as indicators of respectively technology inputs and technology outputs. These measures are, however, problematic as they reveal only a part of the technological efforts, even for developed countries. For developing countries the figures on R&D are inaccurate. For example most imitating companies do not have a dedicated R&D department, and if they do it will probably not account for the innovation that comes from the process learning on the working floor where one aims, for example, at increasing the efficiency of production. In the imitation stage done by developing countries efforts are spent on the adaptation of technologies, which may also not be recorded in official R&D figures.

One should observe that technological advantage by the use of USPTO patents is only revealed at the stage that the country is innovating at a worldwide scale, the local innovation (the first two steps in the taxonomy presented above) are not described properly by these statistics. The acquisition as well as the adaptation and modification for the local environment are expected not to generate patents at the USPTO patent database, used in most research for developed countries is not a good indicator. Vespagen (2001) comments that patents must be considered as indicators of the development of new knowledge. This implies that the industrial infrastructure build up by those countries will not necessarily (probably not) be reflected at the USPTO patent database, as it is most certainly imported technology that will be used in the initial stages of production, while the patents issued at the USPTO reflect state of art technology.

Developing countries may, therefore, show differing patterns for the technology gap in that trade advantage precedes technological advantage as the imported (or copied) technology is not the state of art, but aimed at mass production for the export market. With this possibility in mind, Uchida and Cook (2005a) argue that the relation between technology and trade is more complex. They defend the idea that there is no specific direction of the causal relation, and that there is therefore also the possibility to have a reverse relation between technology and trade, that is, advantages in trade will lead to technological advantages in the future. They demonstrate that the fastest growing countries, in both exports and patents, actually showed a pattern of structural change where trade advantage preceded technological advantage. This showed the existence of the reverse relation for a small amount of the fastest growing countries in Asia.

In sum, if the technological efforts of developing countries cannot be captured by the USPTO data it does not mean that there is no technological effort (and structural change) in those countries. When using exports and USPTO issued patents as indicators of countries sectoral composition it can well be expected that the efforts of developing countries in using imitation strategies to achieve structural change may well reflect in an advantage in exports before a technological advantage measured in USPTO patents. Still this will not position countries at the technological frontier: when countries reach and explore the third step from Cimoli and Dosi's (2005) taxonomy they will have to develop new innovation capabilities, possibly at a worldwide level. Lall (2003) writes that countries that seek to internationally exploit their technological capabilities take patents at the USPTO. Therefore the use of patents from the USPTO base is valid if one wants to account the true worldwide innovators, separating them from the imitators.

2.5 The fourth hypothesis of the technology gap model

The fourth hypothesis from the "technology gap" model refers to the relation between countries endowments and accomplishing structural change. This theme is explored in the literature, for example by the earlier mentioned works of Lall as well as some references made by Montobbio and Rampa (2005). This work points towards the importance of targeted policies by the government to overcome the historical disadvantages of underdeveloped countries. With successive correct policies a country can accomplish the capability creation needed to perform the successive stages of industrialization underwent in the structural change process. The strategies employed by Asian countries to accomplish structural change have been based on either the activities of multinational corporations and/or progressive government policies aimed at improving competitiveness (Lall 2000). Archibugi and Pietrobelli (2003) divided the Asian countries on either of the groups. There are several authors that cite that learning by doing and the local policies were most influential in Asia: the results of which will firstly be demonstrated by exports growth (trade advantage) and thereafter possibly by technological advantage (through patents). Lall (2000) argues that Latin America's poor performance in low-technology exports suggests that its weaker domestic low-technology manufacturers are unable to build regional supply chains and marketing connections with buyers in rich countries, which has allowed Asian exporters to flourish by exploiting lower wages. Montobbio and Rampa (2005) point to the importance of a wide and diversified education system, targeting of policies on a large scale, the weak linkages between schools, universities and the productive system, failing National Systems of Innovation. From these different sources it becomes clear that structural change is not an automatic process, but in reality one that requires continuous and correct interventions. Having acknowledged this, we emphasize that the literature briefly mentioned above will not become part of the research as we will not study the relation between specific policy aspects of the country and their structural change.

2.6 The relation between technological specialization and economic performance

In the process of structural change countries allocate their capabilities to other sectors, changing their shares in technological sectors. It can be expected, however, that a country will not move randomly among technologies, but try to search for the technologies that deliver higher opportunities for economic growth, for example. A legitimate question is what guides a country in moving to other sectors: is there a measure of attractiveness that can be related to a sector? Earlier research on structural change use varieties and quality ladders models to distinguish between levels of technological advance (Hidalgo et al. 2007). Montobbio and Rampa (2005) used two mechanisms to study the more interesting sectors. The first are the dynamics of the sector. They find differences in the growth of sectors, and confirm the earlier findings by Laursen (2000) that the fastest growing sectors offer a larger chance for entrance of newcomers (or conversely, that newcomers have a relatively high participation in the expanding sectors). Secondly they looked at an OECD classification that assigns technology intensity levels to each of the technological classes used, based upon the ratio of R&D expenditures and production. The sectors with highest technology intensity are, however, not the most powerful in value adding: in the OECD classification the most technology intensive sectors are related to electronics and ICT (Montobbio and Rampa 2005), whereas research from Fagerberg (2000) shows that the electronics/ICT sectors are among the ones where manufacturers have lowest power, that is, prices are adjusted according to supply to the market[1].

Another attempt to determine which products offer higher opportunities for economic growth has been proposed by Hausmann et al. (2007) and Hausmann and Klinger (2006). They present a method that relates the GDP/capita of a country to the products exported by this country, generating a scale ranging from ‘poor country’s’ products to ‘rich country’s products’. A poor country’s product is a product that is mostly being exported by poor countries, and the most commons examples concern an extensive set of primary products. Rich country’s products are exported by rich countries, and consist mostly of industrialized products. These findings are consistent with the neo-classical school concerning factor endowments. In this school it is assumed that this division stays constant over time, but the authors find that poor countries that start producing and exporting ‘rich country’s products’ will eventually reach the income levels of this ‘rich countries’. Therefore they defend that poor countries should exit the ‘equilibrium position’ proposed by factor endowments theory in order to develop their economic performance.

The exercise from Hausmann et al. (2007) is based on the availability of information for all countries, as even the poorest countries do export. Besides, the distribution of exports is better spread over the countries. Patenting at the USPTO, which is our measure for technological innovation is, however, not done by all countries. Dosi et al. (1990) reveal that more than 90% of the patent activities at the USPTO are undertaken by no more than 10 developed and rich countries. Applying a similar exercise as from Hausmann et al. (2007) to the patent data

[1] It has to be noted that the concordances employed by both aforementioned authors differ.

would therefore probably render useless results, as almost all patenting activities are done by developed countries which all have high income levels.

Archibugi and Pianta (1998) performed a study that is also interesting to be mentioned. Based on the patent portfolios of countries they do a study for the technological similarity of countries. They find that among 13 developed countries large countries have a broad technological base, while smaller countries have narrower technological bases. Those narrow technological bases differ across countries. Although they did not relate the patterns of technological specialization to income levels, one observes that eventually these 13 developed countries achieved similar income levels. Lastly we refer again to the observations by Cimoli and Dosi (1995) that within the paradigm-based story a significant change in relative prices will not have an impact on the innovative search of the countries. This innovative search would remain constrained by the narrow paths determined by the technological characteristics (paradigms) that guide the technological trajectory. Based upon the above argumentation we decided that we will not assign an attraction indicator to the technological sectors.

2.7 General conclusions and application for the further analysis

In this chapter we have introduced the theory and background for the further analysis in this work. We started with a review of the basic characteristics related to the technological change and its development along trajectories and paradigms at the micro level. Afterwards we presented the transition from these originally micro-dynamic concepts to the macro environment. In this step we explain how these concepts are interpreted and applied for the analysis towards the development of the technological and export activities undertaken by countries. We further introduce the technology-gap model that explains the relation between the technological and export pattern of a country. This model demonstrates the relation between improved technological capabilities and economic activities. At last we argued for the use of export characteristics of developing countries as means to access their posterior technological specialization pattern.

3 Description of the data

This chapter will expose the data employed in this research. The research concerns the participation of countries in the worldwide arena of trade and technology. As proxy for trade we use export data from Feenstra et al. (2005) for the period 1976 to 2000, while for technology we make use of patents issued by the United States Patent and Trade Office (USPTO) in the period 1976 until 1999.

3.1 Patents, patent statistics and their use in innovation studies

Before diving into the use of patents in this work we will briefly introduce some basic notions of patents and their use in innovation studies. A patent is a public document issued by an agency authorized by the government that grants the right to the assignee to exclude others from using the knowledge described in the patent. A patent can be granted to a new device, apparatus or process, given that it is novel, non-trivial and has a commercial value. The protection offered by the patent expires after a certain period of time. In exchange for the acquired exclusivity, the assignee is required to give full disclosure of his product or process, aiming at an overall increase of the worldwide stock of knowledge. The process of patent application and maintenance is a rather costly, from which one may assume that the (company of the) assignee expects a financial return. The patent also represents an invention, an improvement on past knowledge that passed the analysis as to novelty, non-triviality and commercial applicability by the patent office. Therefore patents are assumed to represent characteristics that are of interest for both commercial as well as technological changes and developments. The patent is requested by the inventor(s), whose name is/are registered at the patent and the rights may then be assigned to someone else: employer, a corporation or be licensed to another party. This right can only be enforced by a potential threat or legal suits in court, based on possible damages suffered by the person who had his rights infringed (Pilkington et al. 2002). In the United States of America the patent system started in the late 18th century, while the nowadays employed numbering and reporting system started to be used in 1870, resulting in more than 6 million patents consistently reported over a period larger than 100 years (Hall et al. 2001), what makes for a non-negligible amount of data available for research. An interesting feature of patents is the addition to each of patent of citations to prior patents and sometimes to scientific articles. This is a legal requirement that should indicate the relevant state of art prior to the patent and specifically how the content of the patent improves on them. Lastly, each patent is assigned to a technological class and subclass. When the content of the patent is broader than technological class the patent will also be assigned to additional technological classes, so that all its features are covered. This allows one to analyze patenting activities for certain technological classes.

3.2 The USPTO database and its earlier use in economic research

After having presented the basic characteristics of a patent and its working, we present the database of patents used in this analysis, namely the patents issued by the United States Patents and Trade Office (USPTO). The USPTO database as used for this paper contains about 3 million patents issued to country (year of assignment and technological class) for the period 1963 – 2003 as well as the citations between patents, starting in 1976. For this analysis we use the patents granted and their citations for the period 1976 until 1999. In this time period the USPTO issued 2.061.404 patents that made a total of 11.803.154 citations. This number refers to the citations made by the patents issued in the period 1976 to 1999, therefore the citations do also include the references made to patents issued before 1976. For the analysis the patent data spans a period of 24 years, which were divided in four time cohorts of 5 years plus the last time cohort of 4 years. The fact that the last time cohort is one year shorter will not affect the results, as the applied methodologies are based upon shares of patents, and not on absolute amounts. The original patent data consists of ~411 USPTO classes, which are further divided into thousands of subclasses. For this analysis the USPTO classes were aggregated to 25 technological classes, following a classification system provided by the USPTO and further expanded by Montobbio and Rampa (2005) who added the trade sectors to form a concordance table between technology and trade. As developing countries – which are of interest for this analysis – have a relative low number of issued patents per year (Montobbio and Rampa 2005), the data was added for periods of five years. This results in five time cohorts: 1976-1980 (1), 1981-1985 (2), 1986-1990 (3), 1991 to 1995 (4) and 1996 to 1999 (5). Therefore 1976-1980 is not an indication of changes that happened between 1976 and 1980, but rather an accumulation of the patents issued in this period. In the posterior analysis we will use the corresponding numbers (1 to 5, given between brackets) to facilitate interpretation, for example period 1 – 2 represents the changes in the shares from the values obtained for the sum of patents between 1976-1980 (period 1) to the sum of patents between 1981-1985 (period 2).

The aggregation of patents in higher order classes is suggested for a clearer demonstration of the network characteristics (Benner and Waldfogel 2008), but is not without precautions. An example given by Laursen (1999) reveals that companies active in the car manufacturing industry have their patents spread over several technological sectors, including electronics, production techniques, and chemicals. His conclusion is that a concordance can therefore be better made at a relatively high aggregation level, that is, a limited number of technological classes. The same argument is presented by Montobbio and Rampa (2005).

Earlier research on patenting activities, reviewed by Basberg (1987) and Grilliches (1990), concentrate mostly on econometrical exercises based on patent counting and not so much on the citations. The creation of, among others, the NBER database containing the USPTO patents and the citations (Hall et al. 2001) combined with the improvements in computing power seems to have given an additional impulse to patent based research, including more complex exercises using the citations between patents. These citations have been extensively used in the assessment of linkages between inventions (Mina et al. 2007), inventors, scientists, firms (Maurseth and Verspagen 2002) locations (Jaffe et al. 1993) and technological fields/sectors (Strandburg et al. 2006). The linkages have been used to assess the flows of technology and spillovers, the creation of indicators for the importance (valuation) of individual patents and for the relation between technological classes. Marco (2007) describes three applications of patent citations that dominate the innovation literature in economics nowadays: the measurement of patent "quality"; the measurement of knowledge flows and spillovers, and the investigation of strategic behavior by firms. These different strands of research do attribute some real economic value to the patent citations by telling something about its quality as well as the knowledge transferred to another party. This research will concentrate on yet another aspect of the use of patents and their citations, namely the technological relationship between technological classes based upon the sum of interclass citations as proposed by Strandburg et al (2006).

The main advantages for the use of patents in the assessment of technological capabilities are the inherent need for novelty, the long times series available with millions of patents and citations, and in the case of using the patents granted by one agency that all patents are subject to a common measure of novelty (Laursen 2000). There are also drawbacks in the use of patents, presented in the next paragraphs. Even though the drawbacks are quite extended we have no other data available for this analysis. We have already seen in the chapter on the theory that an alternative to patent data is the use of data on research and development numbers, but that this data is also rather scattered and incomplete for developing countries. Where possible we will circumvent the problems of the patent data by the employed methodology. When this is not possible we will make special references to the limitations and when possible take this in account when describing the conclusions on the obtained results.

A classic drawback of patents as indicators of technological capabilities is that not all inventions are patentable and not all patentable inventions are actually patented: firms may choose for other protection strategies, such as secrecy or advantage of first mover (Basberg 1987). From the patented knowledge/technology the quality (technological as well as commercial value) of the patented inventions differ greatly (Griliches 1990), not the less because patents represent inventions, while commercial success (and financial returns) are consequence of successful innovations (Wartburg et al. 2005). Several authors worked on methodologies to value patents based upon citation characteristics (Giuri et al. 2007; Hummon and Doreian, 1989; Verspagen, 2005, Mina et al 2007). Assumptions in those analyses are, for example, that a citation indicates the directions and geographical extent of a knowledge flow from the cited to the citing patent. A second assumption is that the amount of received citations by a patent is related to its importance (value). Those measures apply relatively well for the analysis of one determined technology, as they are quite parsimonious (Mina et al, 2007). As this analysis will focus extensively on the use of the citations between patents it is important to expose some additional characteristics of the citation processes and how they have been used throughout literature.

The study of knowledge flows through the citations between patents has been studied for both the USPTO and the European Patent Office (EPO) database. The patenting procedure in both databases is different (Criscuolo 2006) and one of the differences may severely undermine the knowledge flows in the EPO database. In the EPO system inventors are not obliged to cite patents: it is the examiner who adds them. Therefore only 7% of the cited patents come from the inventor, and the citations added by the examiner do not implicitly reveal a knowledge flow, as the inventor may not even have been aware of the former patents. Therefore Wartburg et al. (2005) argue that European patent citations should not be used for knowledge flows analysis. In the USPTO system, inventors are obliged to cite older patents, risking penalties if they omit to do so. Pilkington et al. (2002) write that the validity of a patent granted by the USPTO is often challenged on the basis of an incomplete disclosure of the prior art. Therefore they cite several prior patents, with a bias towards one owns prior patents. Michel and Bettels (2001) comment that this practice eventually resulted in prior art descriptions that have more of a documentary search characteristic than a patentability analysis. Still, several citations are added by examiners (Alcacer and Gittelman 2004). On the other hand Criscuolo (2006) conclude that inventors may indeed have a tendency to omit relevant citations that may endanger their patent claims. In view of the disagreement about the existence of knowledge flows between patents, Strandburg et al. (2006) interpret the citations as a 'technological relationship' instead of knowledge flows. The definition of 'technological relationship' does suit better to the purpose of this research, as in the study we take the relationship between technological classes as determinant for the "easiness" of reallocation of national endowments. In this analysis will not consider individual patents and their individual citations made or received, but rather their aggregation in technological sectors. Therefore we will not value patents and neither concentrate on further characteristics of the valuation process as we employ the citations as indicators of technological relationship.

A seconds criticism against the use of USPTO database as indicator of technological innovation is that there is a varying propensity to patent in each technological class (Griliches 1990). This research concentrates on the interclass citations of technological sectors. From existing literature (Atallah and Rodriguez, 2005; Levin et al. (1987) one knows that the propensity to cite does vary between classes. As most literature up to date concentrate on the development of a single class the varying propensity does not influence the results, but in an analysis where different classes are combined influence of the differences in propensity to cite may be expected. Imbalances in patent activities between sectors could distort the results of the research, as some sectors may appear more prominently. An example of this diversity in citation propensity is that some technological classes may appear to be growing faster, which can be interpreted as an increase of their importance. In other words, those growing classes seem to be overtaking other technological classes. To study this effect we will also look at the absolute amount of patents and at the dynamics of the exports in the respective sectors. With this analysis we can observe if sectors that experienced a decrease in technological output also decreased their participation in exports.

A third criticism refers to the additional uses of patent. In the legal sense patents do not strictly allow one to develop the idea into a product, it rather prevents that other people use the idea. Therefore taking a patent on a product or idea is not synonymous for exploring it commercially. Atallah and Rodriguez (2005) describe evidence that the motives for patenting vary across technological categories. Giuri et al. (2007) describe six typical uses for patents: I) internal use: the patent is used for commercial or industrial purposes by either incorporating it into a product or a process; II) licensing: the patent is licensed to another party, happens mostly in the computer and telecommunication industry (Cohen et al. 2000); III) Cross-licensing: a (set of) patent(s) is licensed to another firm in exchange for another (set of) patent(s), is also frequent in the computer and telecommunication industry (Ibid.) ; IV) licensing and use: a combination of the above, in that the patent is used by the own firm as well as licensed to another firm; V) blocking patent: the patent is not used by the assignee, neither licensed. It's only function is to block (technological and commercial) advancements of the competitors. This strategy is often observed in the chemical industry (Ibid.) and finally VI) sleeping patent: the patent is not employed for any of the purposes above, but it has a value as a protection mean for a different technical approach which is not explored further by the assignee. Such a patent will not block competitors.

As some of these strategies are specific to some technological sectors it may well be that some of the patenting in these sectors is not directly related to the advancements of technology, but solely for the protection of a competitive position in the market. This may lead to an increase of patenting in some sectors, but we cannot point to an explicit relation to the unequal patenting as observed in the paragraph above. Still we can observe, through the analysis of the absolute amount of patents as well as the exports of the sectors, how the dynamics of patenting activities compares to the dynamics of export performance.

A fourth criticism refers to the allocation of patents to a single class in the USPTO based databases. In the database the only reference for the patent is to the first class of assignment, while the patent may be assigned to more classes as well. Assignment to multiple classes only occur if aspects of the patents cannot be assigned to any other subclass of the first technological class, therefore mentioning the first patent class only may not represent the full technological breadth of the patent. In addition, patent class as Nanotechnology is cross-references only: a patent belonging to nanotechnology must be assigned to another Original classification: nanotechnology will never appear as the first patent class on a patent. (Benner and Waldfogel, 2007). Debackere et al (2002) mention that in the international patent classification patents are divided both according to function, as to process. So there is a class for turbojets, and another for propulsion techniques. A turbojet engine can, and will, therefore be classified in both, but its first classification code (given in the employed USPTO database) will be as a product (function), not as a process. Unfortunately this problem cannot be solved in our analysis, as the database employed only includes the first technological class.

A fifth criticism is the inconsistency between R&D figures and patenting figures. The pioneering work of Soete (1983, 1987) and Pavitt (1983) in examining the relationship between investment in research and development (R&D) and the number of patents at the national level demonstrated that there is a significant relationship between them. That is, the patent applications by foreign countries in the US (revealed by the USPTO database) are a good proxy for the technological output of those countries. This work has been criticized on the basis of its static nature; it is inaccurate in that it neglects the complex and evolving relation between innovation, enterprise, competition and the development and growth of a country (Gay 2007). Watanable et al (2001) criticizes this work based on the inconsistency between patent statistics and R&D investment, as their patent statistics include applications by foreign firms while R&D investment does not include investment by foreign firms. The same is found by Sood and DuBois (1995) that show that patents granted to US subsidiaries of foreign corporations are counted as patent grants of US corporations, as the addresses of these partially and wholly-owned subsidiaries are located in the United States. Those findings imply that patent statistics are not an accurate reflection of national scientific effort in those industries that include significant foreign direct investment in the United States. These results may also indicate why Huang et al (2003) found that the USA occupied a very central position in the research towards nanotechnology, as much research in this field may be done by foreign companies with R&D divisions located in the USA. Even though the figures on research and development expenditures are therefore apparently better for the assessment of the innovation efforts of a country, they are not readily available per sector besides being fraught with other problems as discussed in chapter 2(page 7). The use of patents may then be less ideal, but it is, again, the only available data.

A sixth criticism/remark concerns the citations between patents as indicators of technological relationship. Pilkington et al. (2002) comment that due to legal construction the citing patents at the USPTO exhibit a bias toward citing patents by the same applicant. Castaldi and Los (2008) write that although about 40% of the patents registered at the USPTO are owned by foreign companies more than 90% of the citations point to American patents: that is, American patents represent 60% of the USPTO database, but receive more than 90% of the citations, while 40% of the patents in the database compete for less than 10% of the citations to be received. Criscuolo (2006) writes that patents do mostly cite national prior art, not worldwide prior art which is in agreement with the observation of Pilkington et al. (2002) that firms tend to cite their own patents, which aggregated to the national level indicates that countries cite their own patents. She concludes that there is evidence for 'home advantage', as USA companies will patent more in USPTO, EU companies will patent more in EPO, etc.

The implication of this citation propensity biased towards the US patents will probably influence an analysis towards the development of technological trajectories as performed by Mina et al. (2007) on basis of the USPTO database. In this analysis one employs the amount of citations between patents as indicator of their individual importance: as the US patents have higher propensity to receive citations it is probable that they will get more important than non US-based patents. The end result may thus reflect a technological trajectory which is based solely on US-owned patents. Although the higher propensity of citing US based patents is arguably not correct, it will not affect the methodology employed in this work. We will employ the citations between patents as indicators of the relationship between the technological sectors to which the patents belong. In this analysis the nationality of the patent will not be accessed (a patent's nationality will only be employed when analyzing a country's technological specialization pattern). What remains is the fact that citations are biased: both the country bias (Criscuolo 2006) and firm bias (Pilkington et al. 2002) indicate that these citations do cite specific other patents instead of the 'global' related technologies.

A seventh criticism/remark about patents refers to the ownership of the patent: The patents assigned to a country can be divided into patents owned by the firms or persons from the country and patents owned by foreigners. According to Quach et al. (2006) this distinction is important in order to assess the potential of countries to capitalize on their patents. The authors analyzed the patenting activities of developing countries in the biotechnology field and found that patent ownership ranged from just over 40% in China to almost 100% in Cuba. Cuba is therefore expected to have a larger possibility to capitalize on their patents, whereas royalties obtained upon the 60% of Chinese patents owned by foreigners could eventually flow out of the country. Montobbio and Rampa (2005) states that most research in developing countries is done for national interests, also observed by Quach et al. (2006). This is not to say that patents owned by foreigners are not important for the technological capacities of the developing country. Such patents could be a consequence of FDI, which has been shown to be positively correlated with export growth of developing countries (Montobbio and Rampa, 2005).

An eight remark consists of the truncation problem as described by Hall et al. (2001). The propensity to receive citations is directly related to the age of the patents as older patents have a higher time span in which they can be cited than newer patents. In the analysis towards the quality of patents based on the number of received citations the truncation problem is evident, as older patents have higher propensity to be considered 'important'. The problem is related to the fact that a patent makes all citations at once (when it is issued), but it can receive citations for indefinite time, even after expiring. Truncation is therefore a problem that occurs when one's interest is the number and distribution of citations received by a patent. In this work we circumvent this problem as we do not employ individual patents and their received citations, but rather the number of the citations made by the patents aggregated into technological sectors and time-cohorts.

Even considering the above limitations, some of which do impact our research and some which do not, we still will employ the patents issued by the USPTO as indicator for the technological capabilities of countries. This is done due to the earlier mentioned advantages and due to the non-existence of another source of data at such a detailed level.

3.3 The data for exports: the NBER database

In the introduction and theory chapter we have presented an extensive description of the relation between technology and economic growth. Further we described the characteristics of technological development as explained by the evolutionarists and the technology gap model that relates technological progress to the economic activities of a country. A frequently employed indicator for the economic activities of a country consists of the assessment of the exports. Montobbio and Rampa (2005), Uchida and Cook (2005a,b), Laursen (2000, 1999), Amendola et al (1998) , Soete (1987) and Soete and Wyatt (1983) have performed analysis in which patent data was combined with economic data in the form of exports to study the co-influence of technology and trade.

The data used is taken from Feenstra et al. (2005). The authors processed the original data collected by the United Nations Comtrade database. The database is classified according to the Standard international trade classification (SITC) 2nd revision, further on denominated as SITCrev2. This data is processed for the a time span of 25 years (1976 until 2000), therefore obtaining a total of five cohorts for this research: 1976-1980 (1), 1981-1985 (2), 1986-1990 (3), 1991 to 1995 (4) and 1996 to 2000 (5). Therefore 1976-1980 is not an indication of changes that happened between 1976 and 1980, but rather an accumulation of the exports in this period. In the posterior analysis we will use the corresponding numbers (1 to 5, given between brackets) to facilitate interpretation, for example period 1 – 2 represents the changes in the shares from the values obtained for the sum of exports between 1976-1980 (period 1) to the sum of exports between 1981-1985 (period 2)[2].

The values of the exports are given in current dollars, and therefore not adjusted for the inflation. This is not expected to be a problem for this analysis, as all further analysis are based on the shares of the exports by the respective sector in the respective time cohort.

3.4 Combining the indicators USPTO patents and exports

Besides studying the above indicators individually, we are also interested in their co-influence. After presenting the characteristics of the technological indicator as well as of the export indicator, we need to combine both to study their co-influence. In an extensive literature review of the performed work relating technology and trade Grilliches (1990) describes two major problems in using patents for economic analysis. The first problem is related to the classification, while the second is related to the intrinsic variability of patents (the difference in value). The variability of the (economic) value of a patent was presented before. The problem of classification is related to researcher's wishes to combine the technological efforts in a product with the economical characteristics achieved by that product. With this information one can access if the technological efforts of a sector are related to the economical results for that sector. The problem relies on the difficulty in combining the technological characteristics of a patent to the economic characteristics of a product. Basically the problem is related to the fact that patent data refers to technological and functional principles, while trade refers to products. It is instinctive to assume that a certain technology may be applied to several product categories, and conversely, that a product category may consist of patents assigned to different technologies. From the research performed by the authors mentioned earlier there is no unambiguous answer to the question of how to best match the trade and patent data. Still several attempts have been made in creating concordances between technological sectors in pa-

[2] The time cohorts of patents and exports match each other, save for the last time cohort, which covers four years for the patenting activities (1996 to 1999) and five years for the export activities (1996 to 2000). This is not expected to become a problem for the further deployed analysis as they are all based on shares.

tenting, industries and exports. For this research we used and aggregation level for the patents also employed by Montobbio and Rampa (2005) based upon 25 technological classes. The authors assigned almost all of the trade classes (with the exception of classes entitled ‘all others’) of the SITCrev2 to one of the 25 technological classes, that is, it also includes primary products which may barely have any patented technology. Other concordances only match manufacturing sectors from the trade database to the technological classes, possibly leaving out sectors as agriculture which has actually build up quite a large technological base to attain nowadays production levels. A table with the 25 technological sectors and their corresponding SITC rev2 and USPTO patent classes can be found in the Appendix, page 89.

3.5 Description of the characteristics of the employed data

Having presented the characteristics of the indicators in the above paragraphs, we do now show some of the characteristics of the data aggregated to the 25 technological sectors. We start with the distribution of the patents assigned to each sector in each time cohort, afterwards we present the exports accomplished by each sector in each time cohort and finally we do a small assessment of the dynamics of development of patents and exports growth. These data is al based on the characteristics of the technological sectors. Here we will not present the patents issued and the exports accomplished by countries in each time cohort, this data can be found in the Appendix, page 88. We return to the characteristics of countries when analyzing their dynamics, from chapter 4 onwards.

3.5.1 The technological output indicator: patents issued by the USPTO

Table 1 shows the total number of patents issued by the USPTO in each time cohort as used in this paper. The values between brackets refer to the share of the patents of the respective sector in the respective cohort (given in %). The technological sectors are grouped according to the broader technological sector to which they belong. The codes (first column in the table) starting with digit 1 indicate the sectors related to mechanical engineering, the codes starting with digit 2 refer to general engineering, the codes starting with digit 3 refer to the chemical engineering and the codes starting with digit 4 refer to the electronical engineering sectors.

Comparing the first and the last time cohort for each sector reveals that there are only 2 sectors (22: earthworking and civil engineering and 33: organic chemistry) that have a lower number of patents in the last time cohort. One should note that the last time cohort is one year shorter and therefore it has less chance to pick patents. Taking the first and penultimate time cohort (as both cover a five year period) one observes that all sectors experienced an increase in the amount of issued patents. This is interpreted as a demonstration of the ongoing importance of all technologies. In the theory chapter we referred to the difficulty of attaining a value to a patent class as there are apparently not more or less interesting classes. The statistics of the issued patents seem to corroborate this view in that they show that there are no sectors that are losing in number of issued patents, which could be interpreted as a decrease of their importance. Even if sectors did not lose patents as absolute amount, one observes that some sectors in the chemical (31 and 34) and electronical (41, 43, 44, 45) experienced an above average growth of the amount of issued patents, what is revealed by the increase of the shares owned by these technological classes as indicated by the values between brackets (in %).

Code	Description of the technological class	Patents issued by the USPTO in each time cohort (values between brackets represent the share in the respective cohort, in %)				
		1976 to 1980 (1)	1981 to 1985 (2)	1986 to 1990 (3)	1991 to 1995 (4)	1996 to 1999 (5)
11	Tools–hardware–pipes–joints	12054	11141	13964	13502	12372
		(3,86)	(3,49)	(3,35)	(2,73)	(2,38)
12	Receptacles–containers–supports–partitions–furniture	10268	9694	15612	17036	16060
		(3,29)	(3,04)	(3,74)	(3,45)	(3,1)
13	Motors–engines–pumps	10803	12047	12998	13716	11414
		(3,46)	(3,77)	(3,12)	(2,78)	(2,2)
14	Manufacturing–assembling–metal working	12351	11267	15717	16728	14035
		(3,96)	(3,53)	(3,77)	(3,39)	(2,7)
15	Rotary machines and mechanical power	7729	7620	10723	10261	9418
		(2,48)	(2,39)	(2,57)	(2,08)	(1,82)
16	Machining and cutting	9778	9314	11479	12669	11075
		(3,13)	(2,92)	(2,75)	(2,56)	(2,13)
21	Material or article handling	9884	9128	10873	12373	10233
		(3,17)	(2,86)	(2,61)	(2,5)	(1,97)
22	Earthworking and civil engineering	5950	6074	6889	6847	5364
		(1,91)	(1,9)	(1,65)	(1,39)	(1,03)
23	Heating–cooling–buildings–fluid/gas handling	19173	20902	23047	22730	21413
		(6,14)	(6,55)	(5,53)	(4,6)	(4,13)
24	Vehicles and transportation	9813	9213	12818	13836	12306
		(3,14)	(2,89)	(3,07)	(2,8)	(2,37)
25	Office devices–paper handling–coatings	4110	4204	5346	6490	6123
		(1,32)	(1,32)	(1,28)	(1,31)	(1,18)
26	Textiles and apparel	8187	8090	9161	9020	8925
		(2,62)	(2,53)	(2,2)	(1,83)	(1,72)
31	Biochemistry	11810	13088	19240	26888	40885
		(3,78)	(4,1)	(4,61)	(5,44)	(7,88)
32	Chemical engineering	19678	20940	22479	26647	23673
		(6,3)	(6,56)	(5,39)	(5,39)	(4,56)
33	Organic chemistry	32951	27508	27820	35250	28628
		(10,56)	(8,62)	(6,67)	(7,13)	(5,52)
34	Surgery–body care–cosmetics	7112	9108	15858	23093	26154
		(2,28)	(2,85)	(3,8)	(4,67)	(5,04)
35	Materials–compositions–explosives	21397	22320	26563	30208	27245
		(6,85)	(6,99)	(6,37)	(6,11)	(5,25)
36	Agriculture and farming	10208	9852	12705	13250	11389
		(3,27)	(3,09)	(3,05)	(2,68)	(2,19)
41	Computing and data processing	8247	11356	20737	31030	50183
		(2,64)	(3,56)	(4,97)	(6,28)	(9,67)
42	Electricity and electric power	21504	24041	30321	31844	34934
		(6,89)	(7,53)	(7,27)	(6,45)	(6,73)
43	Electronics and components classes	8359	8810	15081	23685	28764
		(2,68)	(2,76)	(3,62)	(4,79)	(5,54)
44	Optics–radiant energy–photography	14842	15725	26049	32141	31789
		(4,75)	(4,93)	(6,25)	(6,51)	(6,13)
45	Communications and networking	12912	13806	23098	30028	40961
		(4,14)	(4,33)	(5,54)	(6,08)	(7,89)
46	Other science and engineering, measurement, nuclear	16576	18116	21318	25307	26187
		(5,31)	(5,68)	(5,11)	(5,12)	(5,05)
47	Music–education–games	6466	5833	7190	9497	9353
		(2,07)	(1,83)	(1,72)	(1,92)	(1,8)

Table 1 – Number of patents (and shares) issued by the USPTO (per sector and cohort)

Source: own calculations based on USPTO data

Note: The patents are aggregated into five time cohorts. Each time cohort covers a period of five years, save the last cohort which covers a period of four years. The cohorts are: cohort 1 refers to the period 1976-1980, cohort 2 refers to the period 1981-1985, cohort 3 refers to the period 1986-1990, cohort 4 refers to the period 1991 to 1995 and cohort 5 refers to the period 1996 to 1999.

Table 2 is more comprehensive demonstration for the growth of the sectors. This table demonstrates the changes of the shares between time cohorts.

Code	Description of the technological class	Change of the shares of sectors between time cohorts: cohort 2 to 1 (cohort 2 to 1)	cohort 3 to 1 (cohort 3 to 2)	cohort 4 to 1 (cohort 4 to 3)	cohort 5 to 1 (cohort 5 to 4)
11	Tools–hardware–pipes–joints	-0,37	-0,51	-1,13	-1,48
		(-0,37)	(-0,14)	(-0,62)	(-0,35)
12	Receptacles–containers–supports–partitions–furniture	-0,25	0,45	0,16	-0,19
		(-0,25)	(0,71)	(-0,3)	(-0,35)
13	Motors–engines–pumps	0,31	-0,34	-0,68	-1,26
		(0,31)	(-0,66)	(-0,34)	(-0,58)
14	Manufacturing–assembling–metal working	-0,43	-0,19	-0,57	-1,25
		(-0,43)	(0,24)	(-0,38)	(-0,68)
15	Rotary machines and mechanical power	-0,09	0,09	-0,40	-0,66
		(-0,09)	(0,18)	(-0,49)	(-0,26)
16	Machining and cutting	-0,21	-0,38	-0,57	-1,00
		(-0,21)	(-0,17)	(-0,19)	(-0,43)
21	Material or article handling	-0,31	-0,56	-0,66	-1,19
		(-0,31)	(-0,25)	(-0,1)	(-0,53)
22	Earthworking and civil engineering	0,00	-0,25	-0,52	-0,87
		(0)	(-0,25)	(-0,27)	(-0,35)
23	Heating–cooling–buildings–fluid/gas handling	0,41	-0,62	-1,54	-2,02
		(0,41)	(-1,02)	(-0,93)	(-0,47)
24	Vehicles and transportation	-0,26	-0,07	-0,34	-0,77
		(-0,26)	(0,19)	(-0,27)	(-0,43)
25	Office devices–paper handling–coatings	0,00	-0,03	0,00	-0,14
		(0)	(-0,04)	(0,03)	(-0,13)
26	Textiles and apparel	-0,09	-0,43	-0,80	-0,90
		(-0,09)	(-0,34)	(-0,37)	(-0,11)
31	Biochemistry	0,32	0,83	1,66	4,10
		(0,32)	(0,51)	(0,83)	(2,44)
32	Chemical engineering	0,26	-0,91	-0,91	-1,74
		(0,26)	(-1,17)	(0)	(-0,83)
33	Organic chemistry	-1,94	-3,89	-3,42	-5,04
		(-1,94)	(-1,95)	(0,46)	(-1,62)
34	Surgery–body care–cosmetics	0,58	1,52	2,40	2,76
		(0,58)	(0,95)	(0,87)	(0,37)
35	Materials–compositions–explosives	0,14	-0,49	-0,74	-1,60
		(0,14)	(-0,62)	(-0,25)	(-0,86)
36	Agriculture and farming	-0,18	-0,22	-0,59	-1,08
		(-0,18)	(-0,04)	(-0,36)	(-0,49)
41	Computing and data processing	0,92	2,33	3,64	7,03
		(0,92)	(1,41)	(1,31)	(3,39)
42	Electricity and electric power	0,64	0,38	-0,44	-0,16
		(0,64)	(-0,26)	(-0,82)	(0,29)
43	Electronics and components classes	0,08	0,94	2,12	2,87
		(0,08)	(0,86)	(1,18)	(0,75)
44	Optics–radiant energy–photography	0,17	1,49	1,75	1,37
		(0,17)	(1,32)	(0,26)	(-0,38)
45	Communications and networking	0,19	1,40	1,94	3,76
		(0,19)	(1,21)	(0,54)	(1,82)
46	Other science and engineering, measurement, nuclear	0,37	-0,20	-0,19	-0,26
		(0,37)	(-0,56)	(0,01)	(-0,08)
47	Music–education–games	-0,24	-0,35	-0,15	-0,27
		(-0,24)	(-0,1)	(0,2)	(-0,12)

Table 2 – Change of shares of the respective sector compared to the first period (in %)

Source: own calculations based on USPTO data

Note: The cohort numbers above refer to the five time cohorts as employed in this research. Each cohort is the sum of patents over a period of 5 years (save for the last cohort which covers 4 years). We use the following cohorts: Cohort 1: 1976-1980, cohort 2: 1981-1985, cohort 3: 1986-1990, cohort 4: 1991 to 1995 and cohort 5: 1996 to 1999. Cohort 2 to 1 refers to the changes in shares observed between the sum of patents/exports of the period 1981 to 1985 (cohort 2) and the period 1976 to 1980 (cohort 1).

The first line for each of the sectors demonstrates the cumulative change underwent by the sector, starting with the difference between cohort 2 (1985-1981) and cohort 1 (1976-1980) up to the difference over the whole period: cohort 5 (1996-1996) and cohort 1 (1976-1980). The values between brackets (second line) represent the change in share between two subsequent cohorts. As the comparison is based on shares there is no expected problem in the last period consisting of only 4 years, instead of the 5 years of earlier periods.

We start the analysis of the results of Table 2 by observing the cumulative change in shares of the sectors over the whole period (last upper-cell for each sector). This value demonstrates how much share a sector gained/lost throughout the whole period under study. We observe that in the mechanical engineering and engineering (general) group all sectors lost shares. Also in the chemical engineering sectors four of the six sectors lose shares over time, while two others increase their shares. These findings agree with the earlier findings by Huang and Miozzo (2004) that write that large corporations are losing interest in the general chemical engineering sectors. On the other hand Biochemistry increased its shares, what may be explained by the upcome of biotechnology which is expected to become the next technological paradigm (Quach et al. 2006). The other sectors whose share increased are all situated in the electronical engineering. This growth is most probably related to the upcome of the ICT paradigm. Besides an expected real increase in technological output, one should also note that both sectors have an overall higher propensity to cite. That is not only reflecting technological advantage, but also related to strategies as forcing competitors in patent exchange for electronics as well as barring competitors from entering into markets for the chemical sector (Giuri et al. 2007). The changes in share are, however, relatively small: only seven out of the 25 technological sectors demonstrate changes higher than +/-2% (the highlighted cells). This observation demonstrates the persistent character off technological endowments. There are six sectors that gained shares: adding the values of these shares gives an insight in the total reallocation in the period, which is 21,89%. This is the total shares that the shrinking sectors lost in spite of the expanding sectors. The persistent pattern of technological change is also demonstrated when one observes the patenting behavior throughout the sectors over the whole time period. One does observe that the changes in shares of the sectors either increase or decrease, following a relatively structural pattern. That is, for most sectors the differences in shares become larger if the periods are more apart. The interpretation for this observation is that changes (either increase or decrease) do not happen abruptly, but are slowly developed over time.

3.5.2 The commercial output indicator: exports

To assess the commercial specialization of countries use was made of exports. Table 3 gives the value of the exports of each sector in current US$ (x 1.000.000). The values between brackets represent the share of the sector in the respective time cohort. From Table 3 we observe that there is a constant growth of the exports throughout the period, which is observed for all sectors. The conclusion of this observation is that there are apparently no sectors that lost importance in this period. Besides an expected expansion of world trade due to overall economic growth of countries and globalization, some of the ‘growth’ is also due to fact that the values given are in current dollars, and therefore not corrected for inflation. To compare the value of US$5.773 million of the first period with the US$ 26.584 million of the last period the value of the first period should be corrected for 20 years of inflation: assuming 4% inflation per year results in a cumulative inflation of 219%[3] and a corrected value of exports US$ 12.642 million.

3. Cumulative inflation is calculated with the equation: (1+inflation rate) ^ (number of years)

Code	Description of the technological class	Exports of the sector in each time cohort, in current US$ (values between brackets represent the share of the sector in the cohort)				
		1976 to 1980 (1)	1981 to 1985 (2)	1986 to 1990 (3)	1991 to 1995 (4)	1996 to 2000 (5)
11	Tools–hardware–pipes–joints	172	190	279	444	596
		(2,98)	(2,69)	(2,56)	(2,33)	(2,24)
12	Receptacles–containers–supports–partitions–furniture	62	74	152	295	429
		(1,07)	(1,05)	(1,39)	(1,55)	(1,61)
13	Motors–engines–pumps	152	186	318	599	909
		(2,63)	(2,63)	(2,91)	(3,15)	(3,42)
14	Manufacturing–assembling–metal working	400	383	641	1095	1440
		(6,93)	(5,42)	(5,87)	(5,76)	(5,42)
15	Rotary machines and mechanical power	2	10	31	71	98
		(0,03)	(0,14)	(0,28)	(0,37)	(0,37)
16	Machining and cutting	150	157	301	540	687
		(2,6)	(2,22)	(2,76)	(2,84)	(2,58)
21	Material or article handling	130	127	221	451	617
		(2,25)	(1,8)	(2,03)	(2,37)	(2,32)
22	Earth working and civil engineering	49	55	63	89	115
		(0,85)	(0,78)	(0,58)	(0,47)	(0,43)
23	Heating–cooling–buildings–fluid/gas handling	93	99	149	299	416
		(1,61)	(1,4)	(1,37)	(1,57)	(1,56)
24	Vehicles and transportation	661	774	1360	2449	3335
		(11,45)	(10,96)	(12,46)	(12,88)	(12,55)
25	Office devices–paper handling–coatings	145	169	318	503	622
		(2,51)	(2,39)	(2,91)	(2,64)	(2,34)
26	Textiles and apparel	467	541	1019	1690	2026
		(8,09)	(7,66)	(9,34)	(8,88)	(7,62)
31	Biochemistry	59	72	137	312	521
		(1,02)	(1,02)	(1,26)	(1,64)	(1,96)
32	Chemical engineering	1104	1518	1208	1782	2457
		(19,12)	(21,5)	(11,07)	(9,37)	(9,24)
33	Organic chemistry	396	463	769	1299	1776
		(6,86)	(6,56)	(7,05)	(6,83)	(6,68)
34	Surgery–body care–cosmetics	78	104	197	312	433
		(1,35)	(1,47)	(1,81)	(1,64)	(1,63)
35	Materials–compositions–explosives	125	136	222	418	564
		(2,17)	(1,93)	(2,03)	(2,2)	(2,12)
36	Agriculture and farming	826	974	1337	1963	2365
		(14,31)	(13,79)	(12,25)	(10,32)	(8,9)
41	Computing and data processing	85	181	471	929	1630
		(1,47)	(2,56)	(4,32)	(4,88)	(6,13)
42	Electricity and electric power	115	148	297	637	1002
		(1,99)	(2,1)	(2,72)	(3,35)	(3,77)
43	Electronics and components classes	117	172	364	877	1639
		(2,03)	(2,44)	(3,34)	(4,61)	(6,17)
44	Optics–radiant energy–photography	84	95	150	252	312
		(1,46)	(1,35)	(1,37)	(1,32)	(1,17)
45	Communications and networking	133	195	383	706	1145
		(2,3)	(2,76)	(3,51)	(3,71)	(4,31)
46	Other science and engineering, measurement, nuclear	58	76	140	266	419
		(1)	(1,08)	(1,28)	(1,4)	(1,58)
47	Music–education–games	110	162	386	743	1031
		(1,91)	(2,29)	(3,54)	(3,91)	(3,88)
	Total of exports, current dollars (x 1.000.000)	5773	7061	10913	19021	26584

Table 3 – Exports by sectors. In current US$ (x 1.000.000)

Source: own calculations based on NBER data from Feenstra et al. (2005)

Note: The exports of each sector are aggregated into five time cohorts. Each time cohort covers a period of five years. The cohorts are: cohort 1 refers to the period 1976-1980, cohort 2 refers to the period 1981-1985, cohort 3 refers to the period 1986-1990, cohort 4 refers to the period 1991 to 1995 and cohort 5 refers to the period 1996 to 2000.

Table 4 shows the dynamics of the exports in the period studied in this work.

Code	Description of the technological class	period 2 to 1 (period 2 to 1)	period 3 to 1 (period 3 to 2)	period 4 to 1 (period 4 to 3)	period 5 to 1 (period 5 to 4)
11	Tools–hardware–pipes–joints	-0,29	-0,42	-0,65	-0,74
		(-0,29)	(-0,13)	(-0,22)	(-0,09)
12	Receptacles–containers–supports–partitions–furniture	-0,03	0,32	0,48	0,54
		(-0,03)	(0,34)	(0,16)	(0,06)
13	Motors–engines–pumps	0	0,28	0,52	0,79
		(0)	(0,28)	(0,24)	(0,27)
14	Manufacturing–assembling–metal working	-1,5	-1,06	-1,17	-1,51
		(-1,5)	(0,45)	(-0,12)	(-0,34)
15	Rotary machines and mechanical power	0,11	0,25	0,34	0,33
		(0,11)	(0,14)	(0,09)	(0)
16	Machining and cutting	-0,37	0,16	0,24	-0,01
		(-0,37)	(0,53)	(0,08)	(-0,25)
21	Material or article handling	-0,45	-0,23	0,12	0,07
		(-0,45)	(0,23)	(0,35)	(-0,05)
22	Earthworking and civil engineering	-0,07	-0,27	-0,38	-0,42
		(-0,07)	(-0,2)	(-0,11)	(-0,04)
23	Heating–cooling–buildings–fluid/gas handling	-0,21	-0,25	-0,04	-0,05
		(-0,21)	(-0,04)	(0,21)	(-0,01)
24	Vehicles and transportation	-0,49	1,01	1,43	1,10
		(-0,49)	(1,5)	(0,41)	(-0,33)
25	Office devices–paper handling–coatings	-0,12	0,40	0,13	-0,17
		(-0,12)	(0,52)	(-0,27)	(-0,3)
26	Textiles and apparel	-0,43	1,25	0,80	-0,47
		(-0,43)	(1,68)	(-0,45)	(-1,26)
31	Biochemistry	0	0,23	0,62	0,94
		(0)	(0,24)	(0,38)	(0,32)
32	Chemical engineering	2,37	-8,05	-9,75	-9,88
		(2,37)	(-10,43)	(-1,7)	(-0,13)
33	Organic chemistry	-0,3	0,19	-0,03	-0,18
		(-0,3)	(0,49)	(-0,22)	(-0,15)
34	Surgery–body care–cosmetics	0,12	0,45	0,29	0,28
		(0,12)	(0,33)	(-0,16)	(-0,01)
35	Materials–compositions–explosives	-0,24	-0,13	0,03	-0,04
		(-0,24)	(0,11)	(0,16)	(-0,08)
36	Agriculture and farming	-0,51	-2,06	-3,99	-5,41
		(-0,51)	(-1,54)	(-1,93)	(-1,42)
41	Computing and data processing	1,09	2,84	3,41	4,66
		(1,09)	(1,75)	(0,57)	(1,25)
42	Electricity and electric power	0,1	0,73	1,36	1,78
		(0,1)	(0,63)	(0,63)	(0,42)
43	Electronics and components classes	0,41	1,31	2,58	4,14
		(0,41)	(0,9)	(1,28)	(1,55)
44	Optics–radiant energy–photography	-0,11	-0,08	-0,13	-0,28
		(-0,11)	(0,03)	(-0,05)	(-0,15)
45	Communications and networking	0,46	1,21	1,41	2,00
		(0,46)	(0,75)	(0,2)	(0,6)
46	Other science and engineering, measurement, nuclear	0,07	0,28	0,39	0,57
		(0,07)	(0,21)	(0,12)	(0,18)
47	Music–education–games	0,39	1,63	2,00	1,97
		(0,39)	(1,24)	(0,37)	(-0,03)

Table 4 – Change of shares of the respective sector compared to the first period (in %)

Source: own calculations based on USPTO data

Note: The cohort numbers above refer to the five time cohorts as employed in this research. Each cohort is the sum of exports over a period of 5 years. We use the following cohorts: Cohort 1: 1976-1980, cohort 2: 1981-1985, cohort 3: 1986-1990, cohort 4: 1991 to 1995 and cohort 5: 1996 to 2000. Cohort 2 to 1 refers to the changes in shares observed between the sum of patents/exports of the period 1981 to 1985 (cohort 2) and the period 1976 to 1980 (cohort 1).

We start the analysis of the results of Table 4 observing the cumulative change in shares of the sectors over the whole period (last upper-cell for each sector). This value demonstrates how much share a sector gained/lost throughout the whole period under analysis. We observe that, contrary to the dynamics of the patenting activities, some of the mechanical as well as some of the engineering (general) group increased their shares in the exports. The results for the chemical engineering sectors match those of the patent analysis: four sectors lose shares while two sectors increase their shares. In the sectors related to electronical engineering only one of the seven sectors lost export shares in the period. As was already noted by the analysis of the patenting activities, one does also observe that the changes in share are, however, relatively small: only five out of the 25 technological sectors demonstrate changes higher than +/- 2% (the highlighted cells). The total reallocation between sectors is 19,17%: this is the amount of shares that were replaced from the shrinking sectors to the expanding sectors. This observation demonstrates the persistent character of the export endowments. There are changes in the export structure, but their impact is far from causing a dramatic change in the overall export structure of countries. It is worthwhile to note that for the exports we observe an expansion of some of the sectors related to the mechanical and general engineering group. This shows the importance of these sectors, even though the patenting activities grew slower than the sectors related to electronical and chemical engineering.

3.6 A preliminary analysis for the relation of patents and exports dynamics

The above analysis studied the dynamics of the sectors according to the patents issued by the USPTO as well as the dynamics of the exports of the sectors. In the reviewed theory we found references to the relation between the dynamics of technological output and exports for sectors. With the dynamics of the sectors calculated above, more specifically, the changes in the shares of the exports and the technological output of sectors, it is possible to statistically assess this suggested relation. The analysis consists of a bivariate two-tailed Pearson correlation between the changes in the shares observed for the technological output (obtained from Table 2, page 26) and the changes of shares observed for the exports (obtained from Table 4, page 29). The correlations have been assessed for different time intervals as indicated in Table 5. The indication for the changes between periods is done employing the codes determined for the five time cohorts as employed in this research[4].

	Changes between the periods							
	2 to 1	3 to 2	4 to 3	5 to 4	2 to 1	3 to 1	4 to 1	5 to 1
Correlation	0,4**	0,35*	0,27	0,58***	0,4**	0,33	0,37*	0,5**

Table 5 – Correlation between the technological and exports dynamics of sectors

Source: own calculations based on USPTO and NBER data (from Feenstra et al. 2005)

Note 1: The cohort numbers above refer to the five time cohorts as employed in this research. Each cohort is the sum of patents/exports over a period of 5 years. We use the following cohorts: Cohort 1: 1976-1980, cohort 2: 1981-1985, cohort 3: 1986-1990, cohort 4: 1991 to 1995 and cohort 5: 1996 to 1999. Cohort 2 to 1 refers to the changes in shares observed between the sum of patents/exports of the period 1981 to 1985 (cohort 2) and the period 1976 to 1980 (cohort 1).

Note 2: Significance values as follows: *** significant at the 0,01 level (two-tailed), ** significant at the 0,05 level (two-tailed), * significant at the 0,1 level (two-tailed)

[4] There are five time cohorts employed in this research: 1976-1980 (1), 1981-1985 (2), 1986-1990 (3), 1991 to 1995 (4) and 1996 to 1999 (5). Therefore 1976-1980 is not an indication of changes that happened between 1976 and 1980, but rather an accumulation/sum of the patents/exports in this period. In this and posterior analysis we will use the corresponding numbers (1 to 5, given between brackets) to produce less text and facilitate interpretation. In the above table the period 2 to 1 represents the changes in the shares from the values obtained for all patents/exports for the period 1981-1985 (period 2) to the values obtained for all patents/exports for the period 1976-1980 (period 1), etc.

Table 5 shows that the correlation values between the dynamics of exports and the dynamics of technological output have the expected (positive) sign for all of the time intervals analyzed. Moreover, for most time intervals the correlation factor is statistically significant. This finding corroborates the earlier suggested relation between technological output and trade: that the increase of either is related to the increase of the other. It is important to note that this analysis does not indicate the direction of causality: it does not tell if it is an increased technological output that has impact on future exports (the technology-gap model) or if the relation is the other way around. These aspects will return later in the text.

3.7 An introduction to the analysis and the employed methodologies

Past literature is rather scattered as to the research towards structural change: some researchers studied developed countries, while others concentrated at developing countries. Some work on the exports, others on patent data. Therefore this work is unique in performing the analysis for a large set of countries analyzing for both structural change in technology according to the patents and for the exports. The assessed list of countries with their related patents and exports is given in Appendix (page 88). The main criteria to select which countries would be analyzed relied on the amount of patents issued to the country, as one need a meaningful number of patents to conduct the methodologies described in the next chapters. The list contains 33 countries, including developed, fast-developing and stagnant developing countries from all continents (excluding Africa). Thailand has got the least number of patents, 91 in the whole period, followed by Chile, with 117 patents. In this analysis China, Taiwan and Hong Kong are analyzed separately. Hong Kong is officially part of China since 1997, but for most legal, technological, and commercial purposes it is separated, having an own legislation. The status from Taiwan towards China is controversial, still for this research it is analyzed separately from China. The data introduced above will be used in the analysis and characteristics of the structural change underwent by countries. We use three methodologies and their respective interpretation; the three analyses are performed in a chronological order. The most important objective of the first analysis (chapter 4) is to identify the dynamics of the countries throughout the period 1976 and 1999. The analysis determines, besides the overall dynamics of the country, also if the country changed its technological pattern towards expanding or shrinking sectors. It does, however, lack explanation power as to the developments of the specialization patterns of countries in this period. Therefore we perform a second and third analysis, both aimed at explaining the patterns observed employing the theories on technological paradigms and technological trajectories. In the second analysis (chapter 5) we study the specialization patterns of countries: an indicator for the strong and weak sectors of a country. These specialization patterns are compared between different time periods, indicating if a country's pattern has changed or remained constant. The results of this comparison will, however, only be statistically significant if the patterns did not change drastically as the analysis test for persistence. So the more the patterns of two time periods are similar, the higher the explanation factor of this methodology. Therefore it is suited well for the identification of intrasectoral cumulativeness/persistence and it leads to the conclusion that technological and export patterns of most countries are quite stable, confirming the theory of technological cumulativeness. We therefore conclude that structural change has therefore been a rare phenomenon in the past 30 years. From the first analysis we have, however, observed that some countries present a considerable structural change. Due to its inherent search for similarities of patterns, the second analysis failed to explain this structural change. Therefore we perform a third analysis (chapter 6), in which we do explain the expansion of some sectors based on prior capabilities the country had in similar sectors.

4 The dynamics of technology and exports for countries

The first empirical chapter consists of the analysis of the dynamics in technological and export capabilities underwent by countries and sectors in the time interval of this study. This analysis attempts to answer the first sub-question of this research, which is reproduced below:

> How are major world economies characterized according to their technological structure? Do they demonstrate technological patterns that resemble persistence/cumulativeness or structural change?

4.1 Assessment of structural change of countries

In the theoretical discussion we referred to past literature that demonstrates that countries experience mostly a persistent pattern of the export and technological capabilities. This persistence is explained by the characteristics of technological change. Still a minor set of countries achieved a reallocation of their endowments towards higher dynamic sectors and we argue that these reallocations should also be influenced by the characteristics of technological change. Prior to this discussion we show some of the characteristics of the dynamics of countries. We start by defining the meaning of the technological pattern or export pattern of a country as an indicator of the endowments of a country; it reveals what the technological and economical activities of the country look like. In this chapter we will employ shares to determine the technological pattern of the country: dividing the activities of each of the 25 sectors through the sum of the activities of the country indicate how much of the technological and export capabilities of the country are allocated to each sector. Having defined the characteristics and determinants of the pattern of a country, we can now define the empirical assessment of persistence and structural change. Persistence (or cumulativeness) is characterized by a pattern that does not change over time: a country spread their exports and patents over the 25 sectors and the shares of each sector remain constant over time. Structural change is characterized by a pattern that does change over time: at the start of the period the country has their exports and patents randomly divided over the 25 sectors and after some time one will find that the shares of sectors changed: some sectors expanded in spite of other sectors. The extremes of this scale Persistency – Structural change would be indicated by exact patterns over time and inversed patterns, respectively.

4.2 Reallocation and growth of technological and export capabilities

After this short recapitulation of the theory and concepts of persistence and structural change it is time to show some empirical evidence of what countries actually experienced in the time span covered by this study. Therefore we start this chapter demonstrating the dynamics of the individual countries. The dynamics of the sectors of a country are determined by the reallocation of endowments between the 25 sectors, which together form the technological and the export output of the country. We also employ the growth of the total activities of the countries over the period as a determinant for the catch-up accomplished by the country. Catch-up is here defined as the excessive growth: most countries grew throughout the period, but we will see that some countries grew more than others. The countries that achieved excessive growth were (and some still are) developing countries with small economies and a low participation in patent and export activities at the start of the period. They have however diminished their backwardness towards the developed countries by growing faster than those countries. The components used in this analysis are:

s = subscript that refers to sector
c = subscript that refers to country
$t-1, t$ = superscript for first cohort (1976-1980) and last cohort (1996-1999/2000), respectively
$NPAT_{sc}$ = number of patents granted to country 'c' in sector 's'
EXP_{sc} = exports of country 'c' in sector 's'
$npat_{sc} = NPAT_{sc} / \sum_c NPAT_{sc}$ = share of patents for country 'c' in sector 's'
$exp_{sc} = EXP_{sc} / \sum_c EXP_{sc}$ = share of patents for country 'c' in sector 's'
$real\ npat_c$ = total reallocation of patent shares in country 'c'
$real\ exp_c$ = total reallocation of export shares in country 'c'
$growthpat_c$ = the growth of the technological output of the country
$growthexp_c$ = the growth of the export output of the country

The equations to define the change in share underwent by each sector for patents [1] and exports [2] are given below. The total reallocation between the sectors is given by equations [3] and [4]. These equations indicate the amount of shares that were reallocated from the shrinking sectors to the expanding sectors.

$$\Delta\ npat_{sc} = \left(\frac{NPAT_{sc}}{\sum_c NPAT_{sc}}\right)^{\mathrm{t}} - \left(\frac{NPAT_{sc}}{\sum_c NPAT_{sc}}\right)^{\mathrm{t-1}} \quad (1)$$

$$\Delta\ exp_{sc} = \left(\frac{EXP_{sc}}{\sum_c EXP_{sc}}\right)^{\mathrm{t}} - \left(\frac{EXP_{sc}}{\sum_c EXP_{sc}}\right)^{\mathrm{t-1}} \quad (2)$$

$$real\ npat_c = (\textstyle\sum_c |\Delta \mathrm{npat_{sc}}|)/2 \quad (3)$$

$$real\ exp_c = (\textstyle\sum_c |\Delta \mathrm{exp_{sc}}|)/2 \quad (4)$$

$$growht\ npat_c = \ln(\textstyle\sum_c \mathrm{NPAT_{sc}^{t}} / \sum_c \mathrm{NPAT_{sc}^{t-1}}) \quad (5)$$

$$growht\ exp_c = \ln(\textstyle\sum_c \mathrm{EXP_{sc}^{t}} / \sum_c \mathrm{EXP_{sc}^{t-1}}) \quad (6)$$

Equations [3] and [44] are applied to the exports and to the patents granted to each country in our sample. The results are plotted in figure 1 .

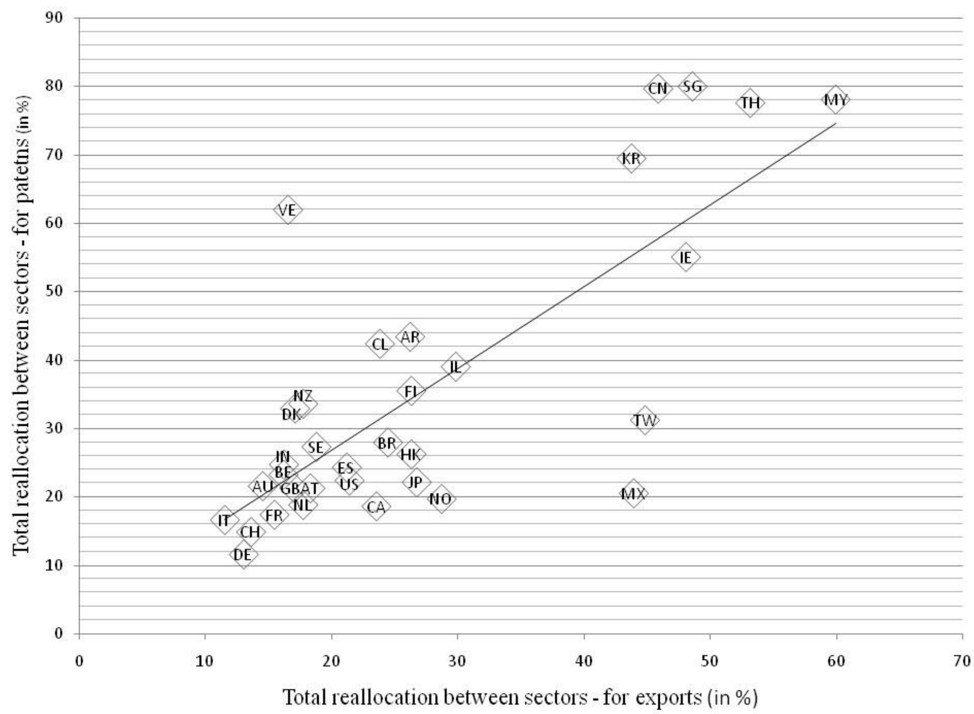

Figure 1 – Reallocation of patents and export shares between sectors for 33 countries
Source: own calculations based on USPTO and export data from Feenstra et al (2005)
Abbreviations and respective countries: AR - Argentina; AT - Austria; AU - Australia; BE - Belgium; BR - Brazil; CA - Canada; CH - Switzerland; CL - Chile; CN - China; DE - Germany; DK - Denmark; ES - Spain; FI - Finland; FR - France; GB - Great Britain; HK - Hong Kong; IE - Ireland; IL - Israel; IN - India; IT - Italy; JP - Japan; KR - Korea Rep.; MX - Mexico; MY - Malaysia; NL - Netherlands; NO - Norway; NZ - New Zealand; SE - Sweden; SG - Singapore; TH - Thailand; TW - Taiwan; US - USA; VE - Venezuela

The values for the reallocation of exports are given in the horizontal axis, while the values for the reallocation of shares of patents are given in the vertical axis. The line indicates the fitted linear regression (coefficient = 1,19, significant at the 0,01 level, R^2 adjusted = 0,57), whose slope is positive (1,19), indicating that the reallocations are positively related. Still one is not able to demonstrate causality: is it the reallocation in exports that lead to reallocation in patents, or the other way around? The chart reveals two large groups of countries: in the upper right corner, which indicates the highest rates of reallocation (thus structural change) we find Korea, Ireland, China, Singapore, Thailand and Malaysia. With the exception of Ireland these are all Asian countries. In the lower left of the graph we find the countries that experienced the least changes in their endowments, such as Italy, Germany and Switzerland. This group can still be split into two subgroups: in the extreme left we have the countries that are considered to be 'developed' for a long time, including the G7 countries and several smaller European countries (Sweden, Denmark, Netherlands, Belgium). Also Australia and New Zealand are in this group. The upper right corner of the group is constituted of some South American countries: Chile, Argentina and Brazil as well as some 'developed countries': Japan, Hong Kong, Finland, Israel and Norway. The first three countries are developing countries which achieved some reallocation of capabilities, but still not as far reaching than the developing countries in the upper right group. The developed countries in this group have different pasts: the chart is demonstrating what may be the last step in Japans catch up with the developed countries. Finland is known for their recent successes in the ICT sector, Israel is a fairly young country with massive investments in R&D, which may explain why it changed relatively much. These are countries that are relatively persistent over the time span covered by this study.

In the equation obtained for the trendline the coefficient is higher than 1, where export is being used as predictor of the patents. Although no causality can be inferred from this relation, one does observe that a value higher than 1 indicates that for a certain value of reallocation in exports the reallocation in patents is expected to be higher: it would therefore be easier for countries to change their technological structure than their export structure. Besides one observes that the group of countries with most reallocation between the two cohorts is located above the trendline, indicating that in these cases the change in patents in relation to exports are even more extreme: China reallocated almost 80% of their patents between the two cohorts, while the change in the export performance did not even reach 50%. There are also some outliers on this graphic: Taiwan and Mexico which did actually experience a higher reallocation rate for exports than for patents and on the other hand Venezuela, which barely changed the exports pattern, but conversely achieved almost 60% reallocation in the technological profile.

Figure 2 and figure 3 demonstrate the relation between reallocation of respectively patents and exports (equations [3] and [4]) and the overall growth of the country's patents and export capabilities (equations [5] and [6]) throughout the period. The vertical axis in these figures represents the differences in the growth of the countries: developed countries are located in the bottom of the graph, while catching-up countries are located in the top of the graph. The horizontal axis demonstrates the measured reallocation of the country.

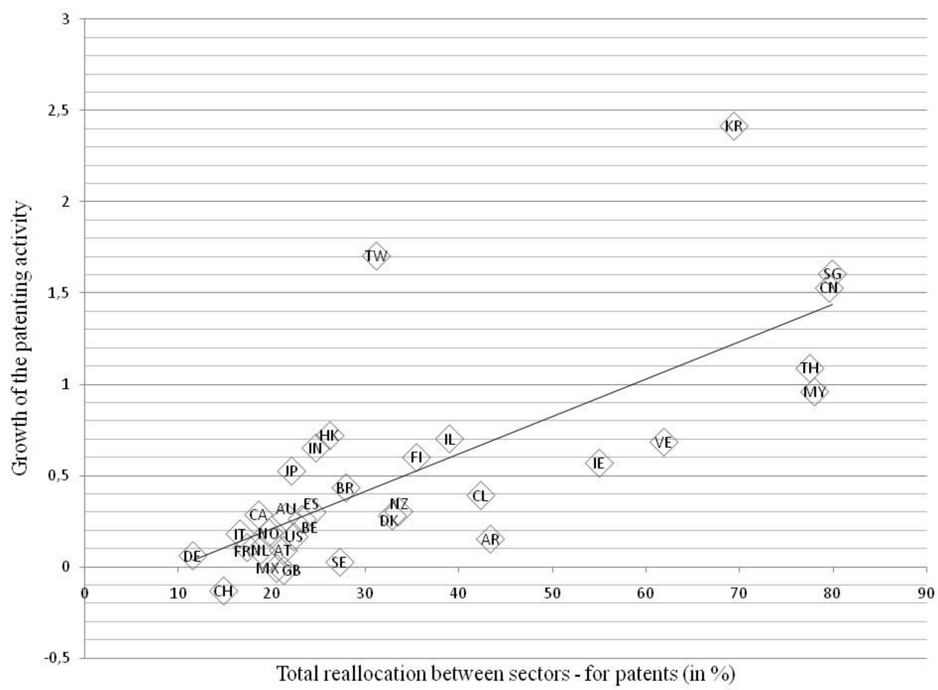

Figure 2 – Relation between the reallocation of shares and the growth of patenting
Source: own calculation based on USPTO database
Abbreviations and respective countries: AR - Argentina; AT - Austria; AU - Australia; BE - Belgium; BR - Brazil; CA - Canada; CH - Switzerland; CL - Chile; CN - China; DE - Germany; DK - Denmark; ES - Spain; FI - Finland; FR - France; GB - Great Britain; HK - Hong Kong; IE - Ireland; IL - Israel; IN - India; IT - Italy; JP - Japan; KR - Korea Rep.; MX - Mexico; MY - Malaysia; NL - Netherlands; NO - Norway; NZ - New Zealand; SE - Sweden; SG - Singapore; TH - Thailand; TW - Taiwan; US - USA; VE - Venezuela

The relation between the reallocation of shares and the growth of the patenting activities experienced by the countries of our sample shows a positive and highly correlated figure (0,74). That is, the accomplishment of catch-up in patenting activities is related to the capacity of the country of reallocating endowments. Figure 3 demonstrates the similar exercise, applied to the data for the exports of countries. Here again the relation is positive and highly correlated (0,84): accomplishing catch-up in exports requires the country to change their patterns of exported products.

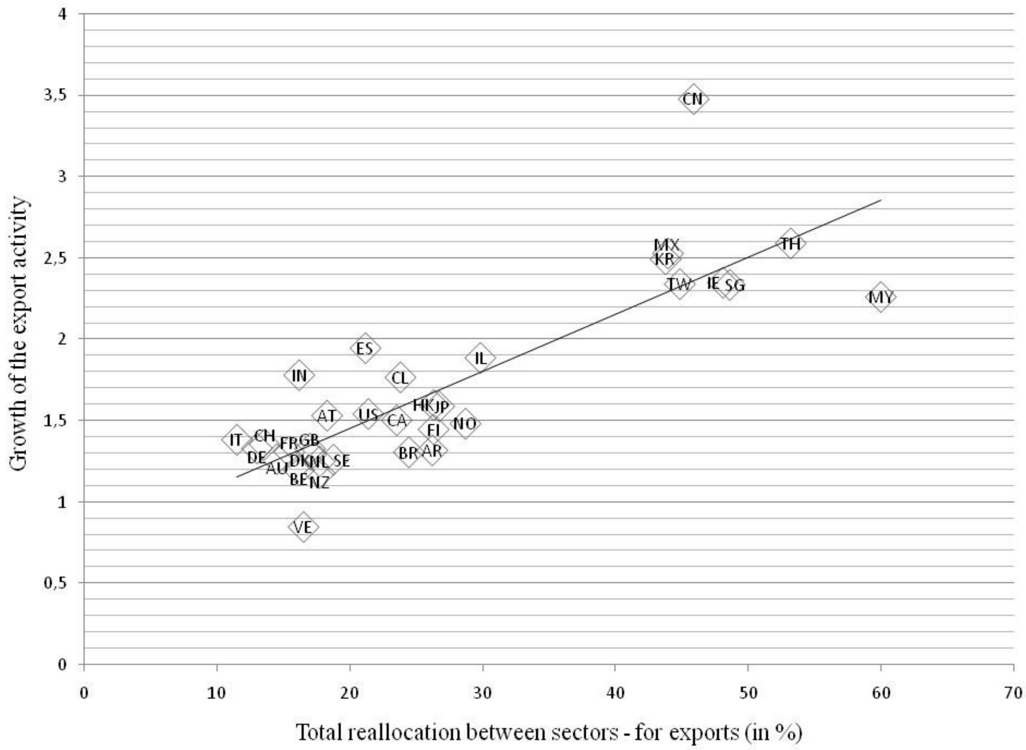

Figure 3 – Relation between the reallocation of shares and the growth of exports
Source: own calculation based on NBER, Feenstra et al (2005)
Abbreviations and respective countries: AR - Argentina; AT - Austria; AU - Australia; BE - Belgium; BR - Brazil; CA - Canada; CH - Switzerland; CL - Chile; CN - China; DE - Germany; DK - Denmark; ES - Spain; FI - Finland; FR - France; GB - Great Britain; HK - Hong Kong; IE - Ireland; IL - Israel; IN - India; IT - Italy; JP - Japan; KR - Korea Rep.; MX - Mexico; MY - Malaysia; NL - Netherlands; NO - Norway; NZ - New Zealand; SE - Sweden; SG - Singapore; TH - Thailand; TW - Taiwan; US - USA; VE - Venezuela

In the next chapter of this work we will further assess the characteristics of the specialization pattern of the countries here described. Prior to this assessment we will perform a further analysis of the development of the capabilities in patents and exports by these countries.

4.3 Decomposition of the technological and export activities

In the previous paragraph we performed an exercise that indicated the varying degrees of reallocation of technological and export activities achieved by the countries. This was an exercise performed on the individual countries, demonstrating for each country how much reallocation and growth it experienced. In the next paragraphs we will expand on this assessment, by analyzing: i) the growth of a country's share in worldwide patents or exports; ii) the reallocation between sectors of a country's endowments and iii) the dynamics of the reallocations by comparing the country's reallocation to the world reallocation. To perform this analysis we apply a methodology that splits the total change in trade and technology of a country into subcomponents (described below). The results describe the different components of improvements or declines experienced by a country. The main purpose of this exercise is to demonstrate the varying growth of the technological capabilities by the countries measured by the amount of patents granted to the country by the USPTO as well as by the worldwide exports of the country.

The decomposition of growth is a common tool for the analysis of international trade, which Fagerberg and Sollie (1987) developed into a new model that is the model applied in this analysis. The tool was originally developed for trade data, but was also applied to patent analysis by Laursen (1999).

The analysis is based on the changes of shares throughout the period. We perform the analysis over the longest available time interval: the changes of shares between the first time cohort (1976-1980) and the last time cohort (1996-1999/2000). The components uses are described as follows.

s = subscript that refers to sector
c = subscript that refers to country
$t-1, t$ = superscript for first cohort (1976-1980) and last cohort (1996-1999/2000), respectively
N_{sc} = number of patents granted to country 'c' in sector 's'
$n_{sc} = N_{sc} / \sum_c N_{sc} =$ share of patents for country 'c' in sector 's'
$n_c = \sum_s N_{sc} / \sum_s \sum_c N_{sc}$ = country 'c' aggregated share of patents
$o_s = \sum_c N_{sc} / \sum_s \sum_c N_{sc}$ = sectors 's' aggregated share of patents

The change of the aggregate share of world patents of a country 'c' is written as equation [7]

$$\Delta n_c = n_c^t - n_c^{t-1} = SH_c + ST_c + AD_c \qquad (7)$$

Where:

$$SH_c = \sum_s (\Delta n_{sc}\, o_s^{t-1}) \qquad (8)$$

is called the technology share effect and measures the gain or loss of the world shares of patents belonging to country 'c', assuming that the world sectoral distribution of patenting is fixed over time. It indicates the country's innovative performance without considering structural change. It is based upon the change in the share of patents in each sector, but it disconsiders the relative change of sectors worldwide.

$$ST_c = \sum_s (n_{sc}^{t-1}\, \Delta o_s) \qquad (9)$$

is called the structural technology effect that indicates what the change in country 'c's share of world patent would be, if its shares on individual sectors remained constant. The output shows whether a country increases or decreases its share as a consequence of a right or wrong initial technological specialization. The changes are guided by Δo_s which indicates the growth in terms of technological opportunities of sector 's' at world level, that is, the changes in value for ST_c are guided by a mostly exogenous factor, the changes of shares worldwide. The term 'right' or 'wrong' initial technological specialization is based solely on the dynamics of the sectors, right referring to a country having its initial pattern of technological specialization in line with the worldwide dynamics, and a wrong pattern otherwise.

$AD_c = \sum_s (\Delta n_{sc} \, \Delta o_s)$ (10)

measures the capacity of the country 'c' in transforming the structural composition of its technological activities to the structural changes in world patterns of technological opportunities, that is, if it is able to direct their technological endowments measured by Δn_{sc} according to the world dynamics measured by Δo_s. If a country is able to move along the worldwide dynamics the output will be positive, which can be accomplished in two ways: with either a positive or negative value for both factors. The first case represents the entering of new markets by both the country and the world; the second case is the exit by the country of technological sectors that are decreasing worldwide. (Laursen 1999) decomposed the component AD_c into two sub-components: technology growth adaptation effect GR_c that indicates a country's capacity in the entering expanding technological sectors and technology stagnation adaptation effect SG_c that indicates (when positive) the country's capacity in exiting shrinking sectors. The equations to calculate both are:

$$GR_c = \sum_s \{\Delta n_{sc} (\Delta o_s + |\Delta o_s|)/2\} \quad (11)$$

$$SG_c = \sum_s \{\Delta n_{sc} (\Delta o_s - |\Delta o_s|)/2\} \quad (12)$$

A drawback using the SD methodology on patents is that it is well known that the propensity to patent differ across sectors. As the methodology applies first differences, large sectors will tend to grow faster than small sectors. However, this problem is common to all studies looking at aggregate patenting (Laursen 1999)

4.3.1 Structural decomposition of the technological indicator

Table 6 shows the results for the application of the methodology above to the patent portfolios of countries at two points in time: the cumulative value for 1976-1980 and 1996-1999. The second column shows the share of the country in the first cohort, while the third column shows the share in the second cohort. The total rate of change (increase/decrease of share) is given in the fourth column. The last four columns represent the components of the decomposition as explained above. The values between brackets show the proportion of the total rate of change explained by the respective component. The sum of the components equals the total rate of change, while the sum of percentages equals 100%. All values are given in %.

Due to the large amount of countries present in this analysis Table 6 is divided into five clusters of countries, according to their overall economical (and geographical) characteristics. These five clusters will be kept throughout the period, as the countries in them reveal common characteristics for several of the analyzed dynamics. The sum of shares equal 100% in both periods, while the total rate of change equals 0%. Here we can make an analogy to a 'pizza', which is divided over the 33 countries in cohort 1. Over time some countries took little pieces of the pizza of other countries, leading to the expansion of the participation of some countries, in spite of the participation of other countries. Prior to the analysis of the different cohorts one can already observe that for most countries the technology share effect was the most important factor in either growth or shrinking of the country's overall share. This effect is based on the acquisition/lost of world shares by a country in a sector, weighted by the share of the sector at the start of the period. Therefore it is an indicator of the innovative performance of the country, explaining the proportion of the worldwide patents that were acquired or lost by that country.

	Share in cohort 1 (1976-1980)	Share in cohort 5 (1996-2000)	Total rate of change	Technology share effect		Structural technology effect		Technology growth adaptation effect		Technology stagnation adaptation effect	
USA	62,2	54,8	-7,48	-7,84	(105)	0,25	(-3)	-1,44	(19)	1,56	(-21)
Germany	8,9	6,2	-2,76	-1,44	(52)	-0,67	(24)	-0,76	(28)	0,12	(-4)
France	3,3	2,5	-0,77	-0,66	(86)	0,13	(-16)	-0,31	(41)	0,08	(-11)
UK	4,0	2,3	-1,73	-1,67	(97)	-0,01	(1)	-0,38	(22)	0,34	(-20)
Italy	1,1	1,0	-0,10	0,073	(-72)	-0,05	(46)	-0,08	(82)	-0,05	(44)
Switzerland	2,0	0,9	-1,15	-0,96	(83)	-0,18	(16)	-0,22	(19)	0,22	(-19)
Sweden	1,3	0,8	-0,47	-0,46	(96)	-0,09	(20)	-0,03	(7)	0,11	(-23)
Netherlands	1,0	0,7	-0,27	-0,25	(98)	0,12	(-45)	-0,16	(59)	0,03	(-13)
Austria	0,4	0,3	-0,11	-0,01	(37)	-0,05	(45)	-0,02	(20)	0,00	(-2)
Norway	0,15	0,13	-0,011	0,012	(-107)	-0,02	(172)	0,00	(-24)	-0,01	(59)
Canada	1,7	2,0	0,29	0,491	(172)	-0,13	(-47)	0,07	(23)	-0,14	(-48)
Australia	0,4	0,46	0,053	0,109	(204)	-0,03	(-53)	0,01	(21)	-0,04	(-72)
Belgium	0,4	0,4	0,04	0,095	(237)	-0,03	(-80)	0,01	(17)	-0,03	(-74)
Spain	0,13	0,15	0,026	0,047	(185)	-0,02	(-60)	0,01	(21)	-0,01	(-46)
New Zealand	0,06	0,07	0,012	0,019	(156)	-0,01	(-55)	0,00	(29)	-0,00	(-30)
Denmark	0,24	0,28	0,036	0,040	(112)	-0,01	(-28)	0,02	(54)	-0,01	(-38)
Finland	0,17	0,41	0,24	0,262	(109)	-0,03	(-13)	0,07	(27)	-0,06	(-24)
Israel	0,16	0,48	0,32	0,242	(75)	0,00	(-1)	0,12	(36)	-0,03	(-11)
Ireland	0,03	0,06	0,033	0,030	(89)	0,00	(-6)	0,01	(35)	-0,01	(-18)
Korea Rep.	0,01	1,96	1,949	1,610	(83)	0,00	(0)	0,59	(30)	-0,25	(-13)
Singapore	0,004	0,09	0,082	0,065	(79)	0,00	(0)	0,03	(32)	-0,01	(-11)
Japan	10,2	20,7	10,45	8,849	(85)	1,00	(10)	2,18	(21)	-1,57	(-15)
Taiwan	0,07	2,07	2,000	1,987	(99)	0,00	(0)	0,41	(20)	-0,39	(-19)
Hong Kong	0,03	0,09	0,064	0,071	(112)	0,00	(2)	0,01	(10)	-0,01	(-23)
India	0,02	0,05	0,034	0,044	(131)	0,00	(1)	0,01	(15)	-0,02	(-47)
China	0,003	0,05	0,049	0,052	(106)	0,00	(0)	0,01	(20)	-0,01	(-25)
Malaysia	0,003	0,02	0,013	0,015	(118)	0,00	(-7)	0,00	(17)	-0,00	(-28)
Thailand	0,001	0,01	0,008	0,009	(106)	0,00	(2)	0,00	(15)	-0,00	(-22)
Brazil	0,034	0,06	0,022	0,033	(153)	0,00	(-17)	0,00	(10)	-0,01	(-46)
Venezuela	0,008	0,02	0,015	0,022	(150)	0,00	(-2)	0,00	(2)	-0,01	(-50)
Chile	0,005	0,007	0,002	0,004	(163)	0,00	(-5)	0,00	(-8)	-0,00	(-51)
Mexico	0,07	0,04	-0,029	-0,01	(65)	0,00	(12)	-0,01	(31)	0,00	(-8)
Argentina	0,034	0,03	-0,005	-0,00	(138)	0,00	(-24)	0,00	(30)	0,00	(-44)

Table 6 – Decomposition of technological changes experienced by countries

Source: own calculations based on USPTO data

Note: columns two and three refer to the shares of patents issued to the country in respectively the first time cohort (1976 to 1980) and the last time cohort (1996-1999)

The first sub table refers to developed countries: it contains 5 of the G7 countries and several smaller countries which have a relatively long and stable story of technological endowments. Still all these countries lost shares in the period. In agreement with the previous general observation, we observe that most of the share loss is explained by the technology share effect, but some countries (Germany, Austria) have it spread over the different components. Only the USA, the Netherlands and France have a positive value for the structural technology effect. A positive value for this variable indicates that the county had an initial specialization pattern that agreed with the sectors that presented the highest growth rates. Therefore positive values for the country are only possible if it had considerable shares in the sectors that expanded throughout the period (two chemical sectors and four electronics sectors, Table 2, page 26). The USA does have a broad technological base, while France is strong in chemical sectors. The Netherlands is strong in both electronics and chemicals which explains the positive value. Negative values are obtained for countries that have a strong presence in (some of) the other 19 technological sectors, including general engineering and mechanical engineering.

The last two columns refer to the dynamic characteristics of the structural change of countries by calculating if a country expanded throughout the period in sectors that also expanded (penultimate column) and/or if the country expanded through exiting the shrinking sectors (last column). The results in the penultimate column are only generated by the 6 sectors that experienced an expansion in the period, the further 19 sectors do not contribute to the values here generated. A negative sign for a country indicates that this country shrank their participation in these sectors, while a positive value indicates that the country expanded their activities in these sectors. Therefore it is called 'adaptation effect': it indicates the success of a country to adapt its structure to the opportunities offered by worldwide expansion of sectors.

The story for the last column is the inverse as the results are only influenced by the 19 shrinking sectors. These two columns do show an interesting dichotomy between developed countries (the first group) and the three groups subsequent groups presented in the table. These three groups have not been presented and discussed yet, but their basic characteristic is that they expanded their participation in the worldwide technological market in this time period, snapping off shares of patents that belonged to the developed countries at the start of the period. The developed countries present negative values in the penultimate column and positive values in the last column, while the two other groups present the inverse pattern. The negative values for the developed countries indicate that they have not increased their participation in the expanding sectors: in fact their shares in these sectors did slightly decrease. For example the Netherlands had an initial technological pattern that matched the expanding sectors but throughout the period it actually left this pattern by diminishing their shares in the expanding sectors. That is in agreement with the general findings of this exercise as revealed in the column 'total rate of change': the positive sign related to the expansion of the sectors worldwide multiplied by the negative sign of the shrinking sectors in the country produce a net negative sign. In the last column we do, however, see positive values, indicating the success of the country in exiting 'shrinking' sectors. One has to be cautious not to interpret this success as a reallocation from a country's endowments from the shrinking to the expanding sectors. In our situation the positive values for the developed countries comes from their shrinking (negative sign) participation in these 19 sectors multiplied by the overall shrinking of the 19 sectors (also a negative sign). Therefore the end-results are positive: the apparent 'success' is thus actually explained by the overall diminished participation of these countries in worldwide patenting (which is not a success), as shown by the sign of the total rate of change. A true reallocation from the endowments from the shrinking to the expanding sectors is given by the sum of the change in both columns (as was used in the original decomposition model): adding the two columns we observe that only Sweden achieves a positive value, that is, only Sweden presented a net positive result for the reallocation of its technological endowments towards the expanding sectors.

Conversely to the pattern of the stagnating developed countries, the three following groups of countries present the inverse pattern: positive values for the adaptation effect and negative values for the stagnation effect. The explanation for the signs of these values is similar than the explanation given for the developed countries: whereas the developed countries had negative signs for their changes in worldwide shares, this group of countries hat positive signs for their change in shares, which reflect into the inverted signs relative to the first group. This increase multiplied by the positive sign of the expanding sectors lead to the positive results in the penultimate column. Still the countries also increased their worldwide shares in the shrinking sectors: the positive sign of the increase of the shares multiplied by the negative sign of the shrinking sectors result in the negative values for the stagnation effect. The general interpretation is that countries are expanding their participation in different sectors, thus also in the shrinking ones. Further in this text we dive further in this assessment.

This large group of expanding countries is divided into three clusters of countries according to some commonalities they demonstrate. The first group consists of five developed countries whose development pattern is explained by a high contribution of the technology share effect, a relatively high value of the structural technology effect and a negative net value for the sum of the two last columns. The high value for the technology share effect demonstrates that these countries did not change their endowments throughout time: they did mostly keep their shares constant throughout the period (persistency). The relatively high and negative values for the structural technology effect demonstrates that these countries had an initial specialization pattern in sectors that did not expand throughout time, and finally the relatively small net negative results for the sum of the last two columns demonstrate that the small change in worldwide shares was mostly achieved in the stagnating sectors. For the second and third group of expanding countries we observe, again, that most change is explained by the technology share effect. The structural technology effect shows mostly very small values, which is explained by the low shares of patents owned by these countries at the start of the period. This component analysis if the country had an initial pattern of endowments that matches to the expanding sectors throughout the period. If a country did only have a very small share of the worldwide patents at the start of the period (which indicates it barely owned patents then) this components barely 'gathers' input and stays low in value. The differentiation of these two groups of countries is made on the basis of the net results (sum) of the components in the two last columns. The first group of countries presents a net positive result, while the second group of countries presents a negative result. The interpretation for this difference is that the first group acquired a higher share of patents in the expanding sectors, while the second group of countries acquired a higher share of patents in the shrinking sectors. As was commented earlier, the six technological sectors that expanded in this period match with the identified paradigms (ICT) and with a potentially upcoming paradigm (biotechnology). These sectors were also the sectors that experience the highest dynamics in the world exports, and therefore we would actually expect that more countries would move towards these sectors to participate in these higher economical opportunities. We observe that the first group consists of some European developed countries, Japan, Korea, Taiwan, Singapore and Israel. These countries do have a longer tradition of massive investments in technological upgrading and have achieved to patent, probably even by actively participating themselves, in the expansion of the six high-tech expanding sectors. Although the exact backgrounds are not known (and neither it is the objective of this work to study them), we can identify Israel as a quite young country with massive investments in technological advancements. Finland made massive investments into the ICT sector, while Ireland grew mostly in the software sector. The Asian countries invested heavily in the electronics industry. Common to these countries is that they rely quite heavily on their own high investments in the expansion of technological capabilities, and not on foreign direct investment (Archibugi and Pietrobelli 2003). We believe that their success was made possible by this longer tradition of own investments in R&D (even though longer tradition means no more than 25 years for some of these countries). The other five countries: Hong Kong, India, China, Malaysia and Thailand (penultimate group) have a more recent story of investments, mostly coming from FDI. Therefore these countries do not have a basic technological structure to successfully move into the expanding sectors. Still it is possible that, based on the technological structure they have acquired in this period they will be able to move in the expanding sectors in a nearby future.

The last sub table shows the performance of some of the Latin American countries. Brazil, Venezuela and Chile achieved to increase their worldwide shares, but the values are still rather small and irrelevant on the worldwide scale (although higher than the values obtained by Malaysia and Thailand one should observe that these countries are smaller and presented a faster growth, increasing their participation by a factor 10). Most change is explained by the technology share effect. The values for the structural technology effect are low, a consequence of the low initial values for patents by these countries. In the last two columns we observe that most technological activity was undertaken in the shrinking sectors, which confirms the earlier findings by Huang and Miozzo (2004).

The analysis presented above should also be concluded as a whole. We observe some signs of convergence, as the developed countries lose shares for a set of upcoming developing countries. Still this convergence is not valid for all countries, as also some of the presented developing countries present a decrease in their shares. Furthermore it should be noted that most of the developing countries are not even considered in this analysis as their technological contribution worldwide is too small for proper assessment by the here presented methodology. Related to this convergence we Montobbio and Rampa (2005) and Laursen (2000) indicate that the expanding sectors offered higher opportunity for growth by developing countries, which seems to be at least partially confirmed in this assessment. We do however add to this that the countries that achieved the movement into the expanding sectors were identified as the countries that made most efforts in achieving this expansion. Additionally it was also demonstrated that expanding countries do also expand their shares in the shrinking sectors. Even if this is an irrational process from the economic point of view, countries are apparently not able to move straight to the most dynamic sectors with their related higher economical possibilities. A possible explanation is that in their run for technological upgrading the expanding countries are invariably constrained by their existing technological capabilities and therefore they do also expand their shares into these sectors, which are shrinking worldwide. Our interpretation for this pattern is that countries that underwent structural change do this as an active process in which they do not have much liberty in choosing the end results. Scientists, engineers and technicians in these countries build upon past experiences and past knowledge trying to achieve a new product or a new technology. The path walked by them is therefore from existing capabilities to new capabilities. The new capabilities should, however, be ‘close enough’ to the existing capabilities to still be considered, to be understood and to be included into the paradigms. In the next chapters this interpretation will be thoroughly exposed and tested (chapter 6).

4.3.2 A new approach: the dynamics of sectors

In the above exercise we analyzed the technological performance of clusters of countries. In the last two columns of that analysis we studied the dynamics of the sectors: what did a country do towards the expanding sectors and what did it do towards the shrinking sectors. The decomposition analysis is, however, incapable of discerning between the specific expanding sector a country entered, and what shrinking sector the country exited. Therefore the analysis is not able to discern the exact sector that contributed to the structural development of a country. To study the contribution of sectors in the development of countries we propose a similar analysis as performed for the countries, but with a twist: instead of decomposing the changes of countries based on the dynamics of the sectors, we will decompose the changes of the sectors based on the dynamics of the countries. The motivation to perform this analysis comes from the suggestion by Montobbio and Rampa (2005) and Laursen (2000) that developing countries could develop their technological capacities by tapping into the expanding/upcoming technological sectors.

This methodology decomposes the changes of the sectors according to the characteristics of the countries that contributed to this change. More specifically: in analyzing the growth of the six sectors that expanded over the period the analysis will decompose this growth according to the dynamics of the countries. An example helps to illustrate the analysis. In the past analysis we measured the influence of the expanding sectors in the expansion of a country's shares (the penultimate column of Table 6, page 39). Inverting (flipping) this analysis, we will now be able to measure the influence of expanding countries into the expansion of the sector. The same holds for the other analysis, further explained in the next paragraphs.

A limitation of this analysis is that one cannot determine the country that contributed to the dynamics of the sectors as the group of countries is distributed in either shrinking or expanding. This will, however, not be a problem for our analysis, as the results from the structural decomposition for the countries (Table 6, page 39) demonstrate that there is a clear dichotomy between upcoming developing countries in Asia which all have positive growths and of the developed countries, of which most had negative growth rates. We will hold to this dichotomy to analyze the results. Returning to the example of the six expanding sectors: if the analysis reveals that (a part of) the growth in some of these sectors is due to the move of these sectors towards expanding countries, we know that these sectors moved to developing countries, or better, to the set of Asian developing countries. The analysis is based on the changes of shares throughout the period. These changes of share were already demonstrated in Table 2 (page 26) and Table 4 (page 29). We perform the analysis over the longest available time interval: the changes of shares between the first time cohort (1976-1980) and the last time cohort (1996-1999/2000).The components used are described as follows.

$s =$ subscript that refers to sector
$c =$ subscript that refers to country
$t-1, t =$ superscipt for the first time cohort (1976-1980) and last cohort (1996-1999)
N_{sc} = number of patents granted to sector 's' in country 'c'
$n_{sc} = N_{sc} / \sum_s N_{sc} =$ share of patents for sector 's' in country 'c'
$n_c = \sum_s N_{sc} / \sum_s \sum_c N_{sc}$ = country 'c' aggregated share of patents
$o_s = \sum_c N_{sc} / \sum_s \sum_c N_{sc}$ = sectors 's' aggregated share of patents

The change of the aggregate share of world patents of a sector 's' is written as

$$\Delta o_s = o_s^t - o_s^{t-1} = SH_s + ST_s + AD_s \qquad (13)$$

Where:

$$SH_s = \sum_c (\Delta n_{sc}\, n_c^{t-1}) \qquad (14)$$

is called the technology share effect and measures the gain or loss of the world shares of patents belonging to sector 's', assuming that the world sectoral distribution of patenting is fixed over time (based on the share of country at the start period). It indicates the sector's innovative performance without considering structural change. It is influenced by the change of the share of patents in each country, but it does not consider the relative change of countries endowments. How much of the growth is gained/lost from the contribution of countries that already had shares in the sector: if countries did not have a share at the start of the period (like most of the upcoming economies in the period of study) they will not contribute.

$$ST_c = \sum_c (n_{sc}^{t-1}\,\Delta \mathrm{n}_c) \quad (15)$$

is called the structural technology effect that indicates what the change in sector 's's share of world patent would be, if the shares on individual countries remained constant. The output shows whether a sector increases or decreases its share as a consequence of a right or wrong initial technological specialization. The changes are guided by $\Delta \mathrm{n}_c$ which indicates the growth in terms of technological opportunities of country 'c' at world level, that is, the changes in value for ST_c are guided by a mostly exogenous factor: the changes of the countries endowments worldwide (the endowmnents of the countries define the development of the sector). If more countries endow in the sector, the higher the output value. The term 'right' or 'wrong' initial technological specialization is based solely on the dynamics of the countries: if the countries with higher initial shares in the sector also grow most, the sector will expand, which is the 'right' pattern…. referring to a sector having its initial pattern of technological specialization in line with the pace of countries, and a wrong pattern otherwise.

$$AD_c = \sum_c (\Delta n_{sc}\,\Delta n_c) \quad (16)$$

measures the capacity of the sector 's' in transforming the structural composition of the country activities according to the structural changes in world patterns of technological opportunities, that is, if it is able to direct the technological endowments of countries, measured by Δn_{sc}, according to the world dynamics measured by Δn_c. If a sector is able to move along the worldwide dynamics the output will be positive, which can be accomplished in two ways: with either a positive or negative value for both factors. The first case represents the entering of new markets by both the sector and the countries with increasing shares of patents; the second case is the exit by the sectors of countries that are decreasing worldwide participation. Laursen (1999) decomposed the component AD_c into two sub-components: technology growth adaptation effect GR_c that indicates a sector's capacity in the entering expanding countries and technology stagnation adaptation effect SG_c that indicates the sector's ability to withdraw shrinking countries. The equations to calculate both are:

$$GR_c = \sum_c \{\Delta n_{sc}(\,\Delta n_c + |\Delta n_c|)/2\} \quad (17)$$
$$SG_c = \sum_c \{\Delta n_{sc}(\,\Delta n_c - |\Delta n_c|)/2\} \quad (18)$$

Table 7 demonstrates the results for the decomposition of the changes of the technological sectors. As was observed before, only six sectors (bold) expanded their shares.

For all shrinking sectors one observes that the technology share effect had most influence on the total rate of change of the sector. This effect measures the gain or loss of the world shares of the referent sector based assuming that the countries maintained the same share of patents over the period. That is, the value indicates the proportion of change in the sector explained by the initial distribution of patents across the countries.

	Share in cohort 1 (1976-1980)	Share in cohort 5 (1996-2000)	Total rate of change	Technology share effect	Structural technology effect	Technology growth adaptation effect	Technology stagnation adaptation effect
Tools–hardware–pipes–joints	3,84	2,39	-1,46	-1,36 (94)	-0,13 (9)	-0,17 (12)	0,21 (-14)
Receptacles–containers…	3,31	3,10	-0,21	-0,03 (13)	0,05 (-23)	-0,22 (104)	-0,01 (5)
Motors–engines–pumps	3,46	2,20	-1,26	-1,28 (101)	0,26 (-21)	-0,39 (31)	0,15 (-12)
Manufacturing–assembling…	3,93	2,71	-1,22	-1,11 (91)	-0,07 (5)	-0,21 (17)	0,16 (-13)
Rotary machines and mech…	2,48	1,82	-0,66	-0,71 (107)	0,11 (-16)	-0,16 (25)	0,11 (-16)
Machining and cutting	3,12	2,13	-0,99	-0,91 (92)	-0,01 (1)	-0,20 (20)	0,13 (-14)
Material or article handling	3,17	1,97	-1,20	-0,99 (83)	-0,19 (16)	-0,15 (13)	0,14 (-11)
Earthworking and civil eng.	1,90	1,03	-0,87	-0,72 (83)	-0,21 (24)	-0,05 (6)	0,12 (-14)
Heating–cooling–buildings	6,16	4,13	-2,03	-1,86 (91)	-0,23 (11)	-0,20 (10)	0,26 (-13)
Vehicles and transportation	3,16	2,37	-0,79	-0,64 (82)	-0,14 (18)	-0,10 (13)	0,10 (-13)
Office devices–paper handl.	1,32	1,18	-0,14	-0,14 (102)	0,09 (-61)	-0,10 (68)	0,01 (-9)
Textiles and apparel	2,63	1,72	-0,91	-0,75 (83)	0,06 (-7)	-0,35 (39)	0,13 (-15)
Biochemistry	**3,79**	**7,86**	**4,07**	**5,07 (124)**	**-0,20 (-5)**	**0,07 (2)**	**-0,86 (-21)**
Chemical engineering	6,28	4,55	-1,73	-1,44 (83)	-0,12 (7)	-0,35 (21)	0,19 (-11)
Organic chemistry	10,56	5,51	-5,05	-4,54 (90)	-0,12 (2)	-1,08 (21)	0,69 (-14)
Surgery–body care–	**2,27**	**5,04**	**2,77**	**3,34 (121)**	**-0,01 (-1)**	**-0,02 (-1)**	**-0,54 (-20)**
Materials–compositions–	6,83	5,25	-1,58	-1,54 (97)	-0,14 (9)	-0,09 (6)	0,19 (-12)
Agriculture and farming	3,28	2,19	-1,08	-0,86 (79)	-0,15 (14)	-0,18 (17)	0,11 (-10)
Computing and data pros	**2,65**	**9,68**	**7,03**	**6,20 (88)**	**0,16 (2)**	**1,44 (21)**	**-0,76 (-11)**
Electricity and electric power	6,84	6,73	-0,11	-0,39 (345)	0,09 (-84)	0,17 (-150)	0,01 (-11)
Electronics and components	**2,69**	**5,55**	**2,86**	**1,70 (59)**	**0,16 (6)**	**1,18 (41)**	**-0,17 (-6)**
Optics–radiant energy–	**4,78**	**6,13**	**1,35**	**0,62 (45)**	**0,39 (28)**	**0,39 (29)**	**-0,04 (-3)**
Communications and netw.	**4,16**	**7,90**	**3,75**	**3,15 (84)**	**0,11 (3)**	**0,93 (25)**	**-0,44 (-12)**
Other science and engineering	5,30	5,05	-0,25	-0,51 (202)	0,12 (-47)	0,04 (-18)	0,09 (-37)
Music–education–games	2,08	1,80	-0,28	-0,28 (101)	0,15 (-54)	-0,18 (65)	0,03 (-12)

Table 7 – Decomposition of the dynamics of the sector, based on patents

Source: own calculations based on USPTO data

Note: columns two and three refer to the shares of patents issued to the sector in respectively the first time cohort (1976 to 1980) and the last time cohort (1996-1999)

We observe that for the shrinking sectors most of the values are close to 100%, which indicates that for these sectors most change is explained by the countries that already owned patents in these sectors. Conversely, we see that for the expanding sectors, mostly the sector ‘electronics and components’ and ‘optics-radiant energy’, the explanation power of the initial pattern of contributing countries is less expressive. In other words, the initial pattern of patents distribution across countries does not explain the change in the sector. From the previous exercise we know that the upcoming Asian countries barely had shares at the start of the period, but acquired them throughput the period: the remaining growth of these sectors is to the entrance of the Asian countries in the worldwide technological arena.

The second variable is the structural technology effect. A positive value for this variable indicates that the sector was strongly represented (at the start of the period) by countries that grew throughout the posterior period. A negative value represents the opposite; the sector was strongly represented by countries that shrank their shares throughout the period. It is interesting to observe that for the expanding sectors the two chemical sectors present negative values, while the four electronics sectors present positive values. This is interpreted as that the chemical sectors are mostly represented by shrinking countries (i.e. developed countries) while the electronic sectors are represented by expanding countries (i.e. the Asian countries, specifically Japan which had a large share of patents at the start of the period).

The two last columns represent the structural change in the period. The technology growth adaptation effect is based on the input provided by the expanding countries (i.e. Asian countries as well as some developed countries) multiplied by the dynamics of the sector. As we know that only expanding countries contribute to this component, all results are consequence of the dynamics of the sectors within these countries. The dynamics of the sector are based on the change of the share of each sector within the expanding countries. It does therefore assess how much of the overall growth of the sectors is due to an increase of the sector in the expanding countries. A negative sign indicates that the sector lost shares in the expanding countries. One observes that Biochemistry and Surgery-body care-cosmetics (which experienced and overall growth in the period) have a small or negative value. This indicates that these sectors did not enter (i.e. did not increase their shares) into the technological pattern of the expanding countries. On the other hand, the expanding electronics sectors do have positive values in this column, indicating that their growth was positively influenced by the entering of the respective sectors in the expanding countries. From the shrinking sectors almost all present a negative sign, indicating that those sectors experienced a shrinking of their shares in the expanding countries. Therefore we conclude that the expanding sectors did experience a dramatic increase of the patent shares in some of the expanding sectors. This does partially corroborate the earlier findings by Montobbio and Rampa (2005) and Laursen (2000) that the expanding sectors offer larger possibility for entrance of newcomers. We do add, however, that not all expanding sectors offer this opportunity, as the chemical sectors did not expand participation in the expanding countries.

The last column (Technology stagnation adaptation effect) is based upon the data obtained from the countries that shrunk their participation in the worldwide shares of patents. These countries are mostly the developed western economies. The changes in the aggregated shares of the country are therefore always negative, that is, the second component from the employed equation is always negative. If the shares of the sectors within these countries decrease we do have a second negative sign, which combined with the first negative sign makes the end result positive. In other words: a positive sign will be observed when the shares of the sector in the shrinking countries decrease. We observe a positive sign for most of the shrinking sectors: this indicates that the developed countries are shrinking their participation in these sectors. A negative sign in this column is an indication that the shrinking countries do observe an increase of their share of patents in the respective sectors. The negative sign is observed for the six expanding sectors: this indicates that the shrinking countries are reallocating their capabilities towards these six sectors.

Concluding, we observe that the upcoming countries did not enter the shrinking sectors, and the developed countries are exiting these sectors. Both upcoming and developed countries are entering the upcoming sectors, still the upcoming countries are concentrating on the sectors related to electronics, while the developed countries concentrate on all expanding sectors.

4.3.3 Structural decomposition for exports

In the previous paragraphs we analyzed the changes in the technological capabilities of countries revealed by patents. The same methodology is applied to the analysis of the export performance of sectors and countries. Instead of employing the patents and their aggregation in either sectors or countries, we use the values for exports, and their aggregation in total exports per sector and total exports per country. As the methodology is identical, the interpretation is also identical as the former analysis based on patents (Table 8).

	Share in cohort 1 (1976-1980)	Share in cohort 5 (1996-2000)	Total rate of change	Technology share effect		Structural technology effect		Technology growth adaptation effect		Technology stagnation adaptation effect	
USA	13,27	13,46	0,18	-1,38	(-749)	2,13	(1153)	-0,89	(-483)	0,33	(180)
Germany	11,64	9,55	-2,09	-2,56	(122)	1,55	(-74)	-1,23	(59)	0,15	(-7)
France	6,69	5,37	-1,32	-1,36	(103)	0,47	(-35)	-0,52	(40)	0,09	(-7)
UK	6,00	4,91	-1,09	-1,31	(121)	0,65	(-60)	-0,45	(41)	0,02	(-2)
Italy	4,92	4,26	-0,66	-0,70	(106)	0,44	(-66)	-0,46	(69)	0,05	(-8)
Switzerland	1,85	1,55	-0,29	-0,39	(132)	0,34	(-115)	-0,25	(84)	0,00	(-2)
Sweden	2,00	1,53	-0,47	-0,59	(126)	0,27	(-58)	-0,17	(36)	0,02	(-3)
Netherlands	4,71	3,56	-1,14	-0,83	(73)	-0,08	(7)	-0,31	(27)	0,07	(-7)
Austria	1,00	1,01	0,00	-0,05	(-1470)	0,12	(3714)	-0,05	(-1581)	-0,02	(-563)
Norway	0,96	0,92	-0,04	0,55	(-1261)	-0,16	(380)	-0,03	(70)	-0,40	(911)
Canada	4,27	4,17	-0,10	0,24	(-227)	-0,25	(236)	0,03	(-29)	-0,12	(119)
Australia	1,59	1,22	-0,37	0,11	(-30)	-0,39	(105)	0,02	(-4)	-0,11	(29)
Belgium	3,73	2,68	-1,05	-0,88	(83)	-0,02	(2)	-0,24	(22)	0,08	(-8)
Spain	1,29	1,96	0,67	0,78	(117)	-0,03	(-4)	0,05	(8)	-0,14	(-20)
New Zealand	0,38	0,27	-0,11	-0,02	(20)	-0,08	(67)	0,00	(3)	-0,01	(9)
Denmark	1,04	0,82	-0,22	-0,13	(61)	-0,04	(18)	-0,05	(21)	0,00	(0)
Finland	0,86	0,79	-0,07	-0,11	(158)	0,01	(-12)	0,04	(-57)	-0,01	(10)
Israel	0,32	0,46	0,14	0,08	(55)	0,00	(-1)	0,06	(41)	0,01	(6)
Ireland	0,49	1,12	0,63	0,43	(68)	0,04	(6)	0,19	(30)	-0,02	(-4)
Korea Rep.	1,01	2,65	1,64	1,22	(74)	0,14	(8)	0,47	(29)	-0,19	(-11)
Singapore	0,78	1,74	0,97	0,48	(49)	0,05	(5)	0,52	(53)	-0,07	(-8)
Japan	8,06	8,56	0,50	-1,27	(-253)	1,89	(376)	-0,20	(-41)	0,09	(18)
Taiwan	1,11	2,50	1,39	0,69	(49)	0,22	(16)	0,53	(38)	-0,05	(-4)
Hong Kong	0,90	0,97	0,06	-0,16	(-244)	0,27	(412)	-0,05	(-74)	0,00	(6)
India	0,58	0,74	0,17	0,25	(150)	-0,06	(-36)	0,02	(11)	-0,04	(-25)
China	0,81	5,73	4,92	4,16	(85)	-0,16	(-3)	1,32	(27)	-0,40	(-8)
Malaysia	0,87	1,80	0,94	0,48	(51)	-0,05	(-6)	0,56	(59)	-0,05	(-5)
Thailand	0,41	1,19	0,78	0,66	(85)	-0,08	(-10)	0,29	(37)	-0,09	(-12)
Brazil	1,26	1,01	-0,25	-0,04	(15)	-0,19	(74)	-0,05	(19)	0,02	(-8)
Venezuela	0,91	0,46	-0,45	-0,05	(11)	-0,44	(99)	0,00	(0)	0,04	(-10)
Chile	0,25	0,32	0,07	0,16	(239)	-0,05	(-68)	0,00	(5)	-0,05	(-76)
Mexico	0,82	2,24	1,42	1,28	(90)	-0,05	(-4)	0,33	(23)	-0,14	(-10)
Argentina	0,60	0,49	-0,11	0,11	(-94)	-0,15	(129)	-0,02	(13)	-0,06	(52)

Table 8 – Decomposition of the changes in export shares experienced by countries
Source: own calculations based on NBER data from Feenstra et al. (2005)
Note: columns two and three refer to the shares of exports by the country in respectively the first time cohort (1976 to 1980) and the last time cohort (1996-2000)

The analysis for the exports by countries was performed for the same set of countries, grouped in the same cohorts as in the assignment based on patents. We observe that in this analysis there is a larger dichotomy between 'developed' and 'developing' countries. While in the previous analysis some European and Anglo Saxon (Australia, New Zealand, Canada) developed countries achieved to improve their technological performance, this analysis demonstrates that they all suffered a decrease in their contribution to worldwide exports. Noteworthy exceptions are Spain and Ireland, European countries that presented a fast growth, what may be explained due to their inclusion in the European community which led to a fast economic development of these countries in the last decennia. Furthermore we observe that the gains are concentrated in the Asian countries[5]. These results indicate that at least a partial convergence effect took place, in that the developing Asian countries have caught-up in worldwide participation of exports in spite of the contribution of developed countries. We refer to partial convergence as we observe that Latin American countries do not catch up (with the exception of Mexico[6]) and we should acknowledge that most smaller developing countries are not accounted for in this analysis, so one can't define if these caught-up.

For the further assessment of the results in this analysis it is important to refer back to Table 4 (page 29) which shows the expansion of sectors over the period 1976-1980 to 1996-2000. Besides the six expanding sectors from the patent analysis, there were another three mechanical, two electrical and two general engineering sectors that expanded over this period. That makes for a total of 12 expanding sectors (of the 25 sectors in total). Due to this more equilibrated division between expanding and shrinking sectors we do now observe that the developed European countries (first group) present positive values for the structural technology effect: Germany is commonly associated with a strong mechanical sector. These sectors lost importance in the patenting activities, but gained importance in exports, explaining the negative signs for Germany in the patents assessment, but positive value in the exports assessment. Similar explanations apply to the other developed countries in the first group.

The first group consists of the developed countries. An interesting case is Austria: this country achieved to maintain its shares (ie a very small increase) constant throughout the period. This was, however, performed by 'drastic' (compared to the total rate of change) changes in the sub-components. Therefore the percentual value of each subcomponent is so large. One observes that most countries from group 1 and 2 experienced a negative rate of change, that is, they lowered their contribution in the world exports. Contrary to the patent analysis, the decomposition shows that the contribution of the 'technology share effect' to the overall change is not as large: the last three columns also have a large impact on the rate of change. The technology share effect describes the performance of the country based on the changes of shares in each of the sectors. The negative values indicate that the countries lost shares respective to their initial position. The structural technology effect reveals mostly positive results: that is an indication that the countries had an initial pattern of exports in the sectors which grew most throughout the period. The technology growth adaptation effect reveals mostly negative values, while the adaptation shows positive results. The explanation for this

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[5] Hong Kong's growth is not very expressive what can be explained by the changes in the processing of the export figures: in the first period Hong Kong re-exported Chinese products, but in the last period those exports were recorded as Chinese (more in Feenstra et al, 2005).

[6] The increase of Mexico's export activities is due to a massive reallocation from the USA manufacturing activities to Mexico, which became an assembling industry for the USA market: the 'maquila' industry. These activities increased the trade (both imports and exports) immensely, but as was seen in the analysis of technological capabilities, Mexico actually lost technological capabilities in this period.

effect is similar as given in the patent analysis: as these countries shrunk their participation in worldwide exports they exited the expanding and shrinking sectors, revealed by respectively the negative sign in the penultimate column and positive sign in the last column. The percentual values for the adaptation and stagnation effect are similar across the countries, with the stagnation effect being much smaller[7]. Therefore the net value (sum of both effects) is negative. A possible explanation for this observation is that between the two periods the developed countries moved a large part of their manufacturing activities – as electronics – to developing countries. Therefore the developed countries will shrink their exports of electronics, which is overtaken by the developing countries.

In the second group of countries we see an interesting and unique pattern for Canada, Australia and New Zealand. The decrease of their worldwide participation is explained mostly by the structural technology effect. The countries had an initial specialization pattern strong in sectors whose total exports decreased over time. As neither country made a significant move to another sector, they lost worldwide shares. These sectors were probably related to agriculture and other primary resources. A last comment for the western countries Israel, Ireland and Spain: their growth is mostly explained by the technology share effect, but also by a movement of the country towards the expanding sectors.

For the Asian countries the growth of exports is positive and relatively high for all countries (with the exception of Hong Kong and India). Japan and Hong Kong demonstrate an interesting and unique case in that they lost shares in the period (technology share effect) but compensated those by having an initial pattern in sectors that expanded throughout the period (structural technology effect). For the other countries the technology share effect explains a large part, but also the last three columns show interesting results which agree with the findings done in the previous exercise based on patents. The structural technology effect is positive for the Asian countries belonging to the first group, while negative for the Asian countries in the fourth group. This may be explained by an industrialization process that is going on for a longer time in the first countries, which were already exporting products in the expanding sectors during the first time period, while the last four countries were still exporting products belonging to the shrinking sectors. In the previous assignment we have seen that the first group did patent more in the expanding sectors, while the last group patented more in the shrinking sectors. The results for patenting and export activities thus match; that is, Taiwan and Korea did both export and patent in the expanding sectors, while India, China, Malaysia and Thailand did export and patent in the shrinking sectors. During the period the fourth group of countries (with the exception of Hong Kong) does, however, catch-up with the Korea and Taiwan, shown by the positive values for the adaptation effect. The last column shows mostly negative values, indicating that throughout the period the Asian countries did also increase their exports in shrinking sectors.

In the last sub-table we are confronted once more with the low participation (low shares) and shrinking of the Latin American countries. This time there is, however, one outlier which is Mexico. As was previously commented, Mexico became the ‘assembling line’ for products and technologies developed and designated for the USA market. Due to this Mexico experienced a large growth and reallocation of the export activities combined with a low growth and reallocation into patenting, as the technological processes are still developed in the USA (Figure 1, page 34).

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[7] the exception is Norway, but this country has a different export structure, heavily relying on the export of oil

One does invariably think of the influence of the expansion of the sectors related to electronics in the overall expansion of the Asian countries, what can be analyzed by the decomposition of the growth of the sector's exports, in a similar fashion as performed for the growth of the sector's patens. Table 9 demonstrates the structural decomposition of the changes in the exports according to the technological sectors. The expanding sectors are indicated in bolf, while the values between brackets indicate the contribution (in %) of the component in the total rate of change.

	Share in cohort 1 (1976-1980)	Share in cohort 5 (1996-2000)	Total rate of change	Technology share effect		Structural technology effect		Technology growth adaptation effect		Technology stagnation adaptation effect	
Tools–hardware–pipes–joints	3,19	2,19	-1,00	-0,89	(89)	0,02	(-2)	-0,19	(19)	0,07	(-7)
Receptacles–containers…	**1,15**	**1,65**	**0,49**	**0,26**	**(53)**	**0,07**	**(15)**	**0,18**	**(36)**	**-0,02**	**(-4)**
Motors–engines–pumps	**2,85**	**3,57**	**0,72**	**0,82**	**(115)**	**-0,25**	**(-35)**	**0,21**	**(29)**	**-0,06**	**(-9)**
Manufacturing–assembling…	7,47	5,34	-2,13	-2,02	(95)	-0,27	(13)	-0,08	(4)	0,24	(-11)
Rotary machines and mech.	**0,04**	**0,38**	**0,34**	**0,38**	**(111)**	**0,00**	**(-1)**	**0,02**	**(5)**	**-0,05**	**(-15)**
Machining and cutting	2,63	2,56	-0,07	-0,02	(32)	0,35	(-500)	-0,34	(497)	-0,05	(71)
Material or article handling	2,44	2,43	-0,01	0,13	(-1011)	-0,24	(1930)	0,11	(-870)	-0,01	(50)
Earthworking and civil eng.	0,91	0,45	-0,46	-0,42	(92)	-0,07	(15)	0,00	(0)	0,04	(-8)
Heating–cooling–buildings	1,73	1,62	-0,12	-0,20	(172)	-0,07	(62)	0,13	(-111)	0,03	(-22)
Vehicles and transportation	**12,37**	**13,14**	**0,77**	**1,37**	**(177)**	**-0,89**	**(-115)**	**0,55**	**(72)**	**-0,26**	**(-34)**
Office devices–paper handl.	2,72	2,39	-0,33	-0,11	(32)	-0,22	(66)	0,01	(-3)	-0,02	(5)
Textiles and apparel	8,61	7,56	-1,04	-2,78	(266)	2,45	(-234)	-0,99	(95)	0,28	(-27)
Biochemistry	**1,10**	**2,07**	**0,97**	**1,21**	**(125)**	**-0,05**	**(-5)**	**0,01**	**(1)**	**-0,21**	**(-21)**
Chemical engineering	13,49	6,67	-6,82	-3,12	(46)	-2,84	(42)	-1,57	(23)	0,71	(-10)
Organic chemistry	7,37	6,79	-0,58	-0,10	(18)	-0,50	(86)	0,17	(-30)	-0,16	(27)
Surgery–body care	**1,46**	**1,67**	**0,22**	**0,27**	**(126)**	**-0,06**	**(-26)**	**0,04**	**(17)**	**-0,04**	**(-18)**
Materials–compositions–	2,33	2,20	-0,13	-0,03	(23)	0,00	(-4)	-0,09	(70)	-0,01	(11)
Agriculture and farming	15,01	9,01	-6,01	-5,59	(93)	2,18	(-36)	-2,94	(49)	0,34	(-6)
Computing and data pros	**1,59**	**6,46**	**4,87**	**3,43**	**(70)**	**-0,05**	**(-1)**	**1,74**	**(36)**	**-0,25**	**(-5)**
Electricity and electric power	**2,16**	**3,92**	**1,76**	**1,30**	**(74)**	**-0,09**	**(-5)**	**0,65**	**(37)**	**-0,09**	**(-5)**
Electronics and components	**2,18**	**6,49**	**4,31**	**3,24**	**(75)**	**0,23**	**(5)**	**0,98**	**(23)**	**-0,14**	**(-3)**
Optics–radiant energy	1,56	1,24	-0,33	-0,41	(125)	-0,01	(2)	0,06	(-17)	0,03	(-10)
Communications and netw.	**2,48**	**4,49**	**2,00**	**1,23**	**(62)**	**0,29**	**(14)**	**0,64**	**(32)**	**-0,15**	**(-8)**
Other science and engi.	**1,08**	**1,66**	**0,59**	**0,60**	**(103)**	**-0,08**	**(-14)**	**0,10**	**(18)**	**-0,04**	**(-7)**
Music–education–games	**2,06**	**4,05**	**1,99**	**1,46**	**(73)**	**0,10**	**(5)**	**0,61**	**(31)**	**-0,18**	**(-9)**

Table 9 – Decomposition of the dynamics of the sector, based on exports

Source: own calculations based on NBER data from Feenstra et al. (2005)

Note 1: columns two and three refer to the shares of exports by the sector in respectively the first time cohort (1976 to 1980) and the last time cohort (1996-2000)

Note 2: names of sectors are abbreviated due to space constraints. The full description of each sector can be found in the appendix.

The patent analysis demonstrated that there were only 6 technological sectors that experienced an increase in their share. According to the trade data the balance is better, in that more sectors (spread over the broad technological bases) have increased their shares in exports. In the mechanical group three sectors increased their shares[8]. The increase in trade

[8] The enormous expansion of 'rotary machines and mechanical power' was checked, but no apparent problems were found in the data processing. Note that it is still a very small sector within the mechanical group, probably split up from another mechanical group during the time interval studied.

without increase in technological capabilities may be explained by the fact that the mechanical industry is important in maintaining the overall industrial productivity. Still it is known to be a 'modest' patenter due to its longer existence and tradition, certainly in comparison with the fast upcoming chemical and electronic sector that are known to patent most due to the novelty of technologies as strategies by companies active in those sectors. Most change in the mechanical sectors was due to the technology share effect, countries that gained or lost shares in the export of mechanical products. One observes that for two sectors the contribution of upcoming countries is quite large, with 16% and 7,4% of the growth being explained by the entering of expanding countries in the sector. Among the general engineering sector not much change can be detected: most sectors lose shares and the mostly negative sign for the structural technology effect demonstrates that this decline comes from the participation of countries whose overall shares decreased in the period, i.e. developed countries. The chemical group demonstrates the same pattern as was seen by the patents. In both trade and technology the biochemistry and surgery-body-care sectors acquired shares, but for trade the values of the penultimate column are slightly positive, indicating that some upcoming country may have entered those sectors, contributing for its growth. Finally we arrive at the electronics sectors, and while in the patent analysis (Table 7, page 45) only four sectors expanded, here we observe that six of the seven sectors expanded. Again, as with the patents, one observes that an important contribution for the growth of these sectors originated from the participation of the expanding economies (expressed by the positive sign for the 'adaptation effect').

4.4 Conclusion

The main objective of this study is to observe the dynamics of the technological and export capabilities of a country, explaining them with the theory on technological change as exposed by the evolutionary school of economics. Therefore we started the empirical part of the analysis with an assessment of the dynamics underwent by the countries in the sample. In the first chapter we performed two broad analyses. Both analyses have a fundamental difference. In the analysis of paragraph 4.2 we consistently employ the term 'reallocation' to express the total change of shares between sectors. Even though we could replace 'reallocation' for structural change, we choose to maintain reallocation, as we use 'structural change' in the decomposition analysis of paragraph 4.3. In these decomposition analyses the term 'structural change' is used to indicate the reallocation of a country's endowments between a cluster of shrinking and a cluster of expanding sectors. It does therefore not observe the reallocation at the 25 technological sectors level, but rather at the dichotomized level of 'shrinking' and 'expanding' sectors, ignoring the reallocation within the cluster of shrinking sectors or the cluster of expanding sectors. Due to this difference the outputs of the analyses are complementary and both reveal interesting insights.

The first broad set of analyses (paragraph 4.2: Figure 1, Figure 2 and Figure 3) were based on the internal dynamics of the countries. These dynamics are based on the reallocation and the growth of the country's export and technological capabilities between the last and the first period. Plotting the performance indicators for all 33 countries on a common graph demonstrates the differences in the individual performance. Most countries demonstrate a low growth and reallocation of capabilities. Conversely, some developing countries demonstrated a radical reallocation of their endowments in the technological and export capabilities and a related large growth of their exports and technological capabilities. This growth was larger than the average growth, implying that these countries achieved to catch-up with the developed countries. Still, the number of countries that achieved catch-up is low. We have not defined a hard threshold of 'catch up', but we observe that only a small set of countries achieved to move out of the 'general cluster of stagnant countries' (the lower left corner in each of the graphs). These results agree with the theory of the evolutionary school of thought, which predicts that technological changes are cumulative, and therefore change is expected to be none or little.

The second broad set of analyses consists of the structural decomposition of the technological and export capabilities of countries. These analyses demonstrated that there are not unique patterns of change. Countries with the same initial 'tags' (developed, developing) underwent different changes: some of the developed as well as some of the developing countries changed their endowments towards expanding sectors, while others grew in the shrinking sectors. Combing the results of both analyses therefore demonstrates that some countries underwent a serious reallocation of their endowments, still they have not explicitly moved towards the expanding sectors. The importance of growing in the expanding sectors is given by previous literature, which relates the expanding sectors to higher possibilities for economical growth (Fagerberg, 2000). So, from an economic point of view countries do not act in a rational way by moving their capabilities towards shrinking sectors. This raises the following question. Why do countries that choose for the hard path of changing their technological and export capabilities not concentrate exclusively on the expanding and economically more interesting sectors? We believe that the answer to this question is given by the evolutionary school of economic thought. Economic rationality does hardly play a role in guiding technological change: it is rather the past characteristics of the actor that will determine its future movements.

This chapter can therefore be briefly concluded as an indicator for the relative scarcity of dynamic countries in our sample (and the world) for the period under study. Also, this small set of dynamics countries develop their structural change in an economically irrational way, by developing part of their activities in technologically and economically shrinking sectors. These findings seem to agree with the definition of technological change by the evolutionary school of economic thought, which defines that the development of a country is explained by its past capabilities. In the next two chapters we do examine if the initial capabilities of a country to indeed explain their posterior performance.

5 The persistence of technology and export patterns

As described in the introduction and theory chapters, earlier research found evidence for the persistency of technological and trade specialization patterns. These findings are however scattered over different authors, data characteristics and concordances. Employing consistent data for a large set of developed and developing countries we found evidence for the persistency of patterns among most of the developed and developing countries in the analysis towards the dynamics of countries described in chapter 4 'The dynamics of technology and exports '. This analysis did however not detail the influence of each individual sector on the further development of the country, and therefore we do now analyze countries characteristics based on individual dynamics of the 25 sectors.

The methodology presented and employed in this chapter is aimed at the identification of the meso characteristics of a country's technological and export patterns, by observing the dynamics of technological capabilities and exports for each sector within the country. The analysis consists basically of two steps. In the first step one assesses the specialization patterns of a country relatively to the world by identifying the intensity of the country's specialization in each sector. The complete methodology is explained under the heading 'revealed comparative advantage'. The second step consists of a comparison of the specialization pattern of the country at two points in time. One observes if the country's specialization pattern at the start of the period under study influenced the country's specialization pattern at the end of the period. The methodology employed for those analysis is described under the heading 'galtonian regression'.

The analysis performed in this chapter shall eventually answer the second sub-question of this research:

> Can the cases of persistence/cumulativeness be explained by the theory on technological paradigms and trajectories?

5.1 Revealed comparative advantage

In the introduction chapter we hold that a common measure for the performance of a country is the assessment of their exports. The motivation to do so is that a country needs to pass some strict market working conditions to be able to export, in other words, its product must be either cheaper, of better quality, i.e., express a value that the importer countries cannot provide themselves. The scale of exporting a product can, however, vary a lot. As an example we present the Netherlands with its large export of mass produced Gouda cheese, compared to a village in France where one produces a very special goat cheese that is exported in small quantities to the most exclusive restaurants in New York and Tokyo. Both products are exported as they reveal a characteristic of the product that cannot be achieved by the importing country. The scale of exports does however differ: the Netherlands has massive exports that contribute significantly to the overall exports of the country, while the French cheese will barely appear in the export statistics of that country. To identify and quantify these differences in export characteristics of a product compared to the overall exports of the country as well as the worldwide trade in the product, Balassa introduced a measurement tool back in the 1960's. This tool compares the contribution of the exports of a certain product in the export package of a country to the overall presence of this product in the export package of all countries used in the analysis. The analysis done in this paper will employ this methodology to identify countries specialization patterns for both trade as technology. The tool was originally employed for the analysis of trade, but recently it was also employed for the analysis of technological specialization.

The calculation of the revealed comparative advantage is performed with equation [19].

s = subscript that refers to sector
c = subscript that refers to country
$t-1, t$ = superscript that refers to first time cohort and last time cohort, respectively
n = exports

$$\mathrm{RCA}_{sc}^{t} = \frac{n_{sc}^{t}/\sum_s n_{sc}^{t}}{\sum_c n_{sc}^{t}/\sum_s \sum_c n_{sc}^{t}} \qquad (19)$$

In equation [19] the numerator represents the share of a given sector in national exports, that is, the exports of each sector divided by the total exports of the country. The denominator represents the share of the exports for the given sector in all worldwide exports, that is, the worldwide sum of the exports of the respective sector divided by the worldwide sum of all exports. The output of RCA will be one if the numerator and denominator have the same value. This will happen when the share of the respective sector in the country's 'c' exports is the same as the share of the sum of all exports of the respective sector of the world's exports: if the share of sector 's' is 1/10 of country 'c' output, and the sum of all sectors 's' worldwide also gives 1/10 of worldwide exports, it can be inferred that the production pattern of the sector 's' of country 'c' is exactly the same as the world pattern, and therefore that sectors has neither an advantage or disadvantage (at ratio 1). Any deviation from this ratio gives either a disadvantage (ratio <1) or advantage (ratio>1): if the exports of sector 's' are 1/5 of total exports of country 'c' and the share of the sum of all respective sectors worldwide is 1/10 of worldwide exports, than that sector has a RCA of 2. This would be a sector with RCA (ratio >1) because that country exports relatively more of that product than the rest of the world, so it has an assumed advantage in producing the respective item. It can be seen that this value can range from zero (no exports for the respective sector by the country) up to infinite, where the middle point lies at one. That makes for an asymmetric output that can produce biased outputs. If, for example, some of the values above one increase over time as well as some values below one increase, the conclusion would be that the level of specialization has increased, while in fact it remained neutral (Laursen 2000). To counteract this problem the author proposes equation [20] that converts the original RCA value to a value that lies between -1 and +1, with the breakpoint at 0 (positive values represent comparative advantage, while negative values represent no advantage).

$$\mathrm{RSCA}_{sc}^{t} = (\mathrm{RCA}_{sc}^{t} - 1)/(\mathrm{RCA}_{sc}^{t} + 1) \qquad (20)$$

The same methodology as presented above can be used to calculate the comparative advantage in patenting activities. In this analysis one employes the patents issued to a specific sector of the country divided by the total of patents issued to the country as numerator and the total number of patents assigned to the sector divided by the total of worldwide patents as denominator. This data is symmetrised. The resulting index is entitled the RSTA for the sector.

The RSCA and RSTA indexes do reveal changes in the composition of the trade and technological capabilities of the countries, and are therefore indicators for the structural change and/or specialization patterns of the country being studied. The indexes do, however, neither reveal the sources of the structural change nor the relation between the sectors. Therefore the indexes reveal the country's development throughout time, but it cannot give insight if this change went along the technological trajectories between technologies.

5.2 Galtonian regressions

To test for the stability of country's specialization as well as to test if the countries tend to become more or less specialized (intra-country) one can employ the method of specialization measurement employed earlier by Uchida and Cook (2005a), Laursen (2000) and Amendola et al. (1998).These are known as 'Galtonian' regression, or regression to the mean. Both stability as well as specialization trends are tested for each country individually by using equation [21] for the specialization pattern revealed by exports and equation [22] for the specialization pattern revealed by patent portfolios.

$$\mathrm{RSCA}_{sc}^{t} = \propto_{s} + \beta_{i}\mathrm{RSCA}_{sc}^{t-1} + \varepsilon_{sc} \quad (21)$$

$$\mathrm{RSTA}_{sc}^{t} = \propto_{s} + \beta_{i}\mathrm{RSTA}_{sc}^{t-1} + \varepsilon_{sc} \quad (22)$$

In the above equations the dependent variable RSCA_{sc}^{t} / RSTA_{sc}^{t} (obtained from the last cohort 't') for sector 's' is tested against the independent variable RSCA_{sc}^{t-1}/ RSTA_{sc}^{t-1} for the respective sector of the first cohort 't-1'. Further, $\propto$ and $\beta$are standard linear regression parameters, and ε_{sc} is a residual. In this regression a $\beta = 1$ corresponds to an unchanged pattern between both time cohorts (the values for the dependent variable are exactly the same as for the independent variable). If β is larger than 1 the country tends to become more specialized due to sectors with earlier specialization increasing further, while areas with earlier despecialization shrink. If β falls between 0 and 1 it is termed $\beta - despecialization$, that is, on average sectors with initial high advantage decrease their value, while sectors without advantage increase their values. In the cases that the coefficient β is smaller than 0 the ranking of sectors has been reversed, that is, sectors with advantage at the start of the period lost it, while sectors without advantage acquired advantage.

Galtonian regression is a technique that reveals statistically significant results for the 'stable' patterns as it is used to test the hypothesis that the pattern of development does not change, that is, $\beta = 1$. This analysis does therefore identify the countries that did not change. The countries that underwent technological change will most probably show non-significant and/or negative coefficients for β.

Besides the application of the regression to the subsequent comparative advantage indexes as proposed above, calculating the Pearson correlation (ρ) between both indexes is an indication for the mobility of the industries. A high correlation (close to 1) value indicates little change of the relative position of the sectors, while a low correlation value indicates a reallocation of the sectors. A high ρ indicates stability (changes of of incremental nature) as it indicates a small change in the rankings of the sectors, whereas a low ρ indicates a change in the ranking of the sectors. The correlation therefore measures the relation between the sectors between two points in time, while the 'regression effect' tests for the direction of evolution: convergence versus divergence versus no changes.

The importance of this measure is explained by Laursen (2000). Even if the value of the regression (β) suggests a fall in the degree of specialization (indicated by a $\beta < 1$), this can be outweighed by the mobility of the sector due to changed in the proportional position between sectors. If $\beta > \rho$ the degree of specialization has increased, conversely if $\beta < \rho$ the degree of specialization has decreased. With $\beta = \rho$ the dispersion of the distribution is unchanged. The interpretation is that an increase in the dispersion conducts to a more 'narrow' specialization pattern, and a decrease in the dispersion conducts to a more 'broad' pattern. Still, the results based on the magnitude of β/ρ must be interpreted taking in account both the regression and mobility effects. Countries can exhibit low values for β (the regression effect) and low values for ρ (the mobility effect) still resulting in a $\beta/\rho > 1$. In these circumstances, the individual results (β and ρ) suggest that there was a considerable change in export/technological specialization and, by consequence, an increase in the degree of export/technological diversification. Therefore the assessment of the results of the galtonian regressions should not be based on the comparison of the ratio (degree of specialization) of both values, but rather on the individual indicators for the regression and the correlation. For further information see Hart (1976).

5.3 Results for the technological and export pattern of countries

Using the concept of comparative advantage explained above we obtained the RSCA and RSTA for three cohorts: cohort 1 (1976 to 1980), cohort 3 (1986 to 1990) and cohort 5 (1996 to 1999/2000). In a second step we applied the galtonian regressions to these cohorts. The final results are demonstrated Table 10. It shows the technological and export specialization indices for the countries based on the technological and export patterns between two cohorts, with the pattern in the older cohort being the predictor for the pattern in the newer cohort. The analysis was originally performed for the relation between the three time periods for which the RSCA and RSTA were available, namely: i) the influence of cohort 1 on cohort 3, ii) the influence of cohort 3 on cohort 5 and iii) the influence of cohort 1 on cohort 5. The first two relations cover an equivalent time period (the time interval between 1 and 3 is the same as the time interval between 3 and 5), while the last analysis covers a longer time period. The results from these three analyses have shown that the results for the first two analyses were quite similar. Therefore it was decided to leave one set of results out of the description (as it would be rather redundant information) and report the results of only one of the time periods, namely that of the relation between the cohort 3 and the cohort 5. The analysis of this shorter time interval does therefore complement the analysis of the longer time interval: the relation between cohort 1 and 5.

The results in Table 10 describe the results for two analyses: the influence of the specialization pattern of 1986-1990 (cohort 3) on the specialization pattern of 1996-1999 (cohort 5) and the influence of the specialization pattern of 1976-1986 (cohort 1) on the specialization pattern of 1996-1999 (cohort 5). The first period is indicated by 3 – 5 and covers a shorter time span, while the second period is indicated by 1 – 5 and covers a longer time span. The choice for applying the regression on two time periods is based on the assumption that specialization patterns will get weaker over longer periods, as also found by Laursen (2000) and Amendola et al (1998). The first two columns of the table indicate the country and time period. There next four columns give the results for the technological specialization pattern. The last four columns show the results for the commercial specialization pattern. The given results comprehend the coefficient of the regression (including t-test results and significance), the value of R^2 which indicates how much of the variance of the dependent is explained by the independent, the correlation factor (including significance) between the specialization patterns of both periods and finally the degree of specialization which is the ratio of the regression coefficient and the correlation coefficient.

	Time span	Technological specialization pattern β	R^2	ρ	D.Sp.	Export specialization pattern β	R^2	ρ	D.Sp.
USA	3 – 5	0,88 (8,22)***	0,75	0,86***	1,02	0,79 (10,32)***	0,82	0,91***	0,87
	1 – 5	1,05 (4,73)***	0,49	0,7***	1,50	0,67 (9,28)***	0,79	0,89***	0,75
Germany	3 – 5	1,27 (19,44)***	0,94	0,97***	1,31	1,02 (16,08)***	0,92	0,96***	1,06
	1 – 5	1,34 (8,32)***	0,75	0,87***	1,55	0,79 (5,53)***	0,57	0,76***	1,05
France	3 – 5	0,96 (4,84)***	0,5	0,71***	1,35	0,92 (11,4)***	0,85	0,92***	1,00
	1 – 5	0,8 (4,54)***	0,47	0,69***	1,16	0,5 (3,65)***	0,37	0,61***	0,83
UK	3 – 5	1,1 (5,62)***	0,58	0,76***	1,45	0,92 (11,98)***	0,86	0,93***	0,99
	1 – 5	0,77 (3,87)***	0,39	0,63***	1,23	0,69 (5,87)***	0,6	0,77***	0,89
Italy	3 – 5	1,02 (9,76)***	0,81	0,9***	1,14	1,05 (11,62)***	0,85	0,92***	1,14
	1 – 5	0,87 (5,51)***	0,57	0,75***	1,15	0,82 (4,62)***	0,48	0,69***	1,18
Switzer-land	3 – 5	1,15 (12,94)***	0,88	0,94***	1,23	1 (19,96)***	0,95	0,97***	1,03
	1 – 5	1,11 (6,58)***	0,65	0,81***	1,37	0,89 (8,56)***	0,76	0,87***	1,02
Sweden	3 – 5	0,69 (6,15)***	0,62	0,79***	0,88	1 (11,82)***	0,86	0,93***	1,08
	1 – 5	0,7 (4,72)***	0,49	0,7***	1,00	0,87 (6,61)***	0,65	0,81***	1,08
Nether-lands	3 – 5	0,72 (6,53)***	0,65	0,81***	0,89	0,9 (11,38)***	0,85	0,92***	0,98
	1 – 5	0,69 (4,88)***	0,51	0,71***	0,97	0,62 (4,12)***	0,43	0,65***	0,95
Austria	3 – 5	1,13 (9,06)***	0,78	0,88***	1,28	0,92 (11,69)***	0,86	0,93***	0,99
	1 – 5	0,81 (5,08)***	0,53	0,73***	1,11	0,61 (5,01)***	0,52	0,72***	0,84
Norway	3 – 5	0,98 (7)***	0,68	0,82***	1,19	0,94 (12,94)***	0,88	0,94***	1,00
	1 – 5	0,79 (3,9)***	0,4	0,63***	1,25	0,83 (5,8)***	0,59	0,77***	1,08
Canada	3 – 5	0,95 (7,97)***	0,73	0,86***	1,11	0,85 (13,94)***	0,89	0,95***	0,90
	1 – 5	1,05 (7,25)***	0,7	0,83***	1,26	0,6 (6,11)***	0,62	0,79***	0,76
Australia	3 – 5	0,96 (8,51)***	0,76	0,87***	1,10	0,87 (14,45)***	0,9	0,95***	0,92
	1 – 5	0,89 (4,21)***	0,43	0,66***	1,35	0,85 (11,39)***	0,85	0,92***	0,92
Belgium	3 – 5	0,68 (4,21)***	0,44	0,66***	1,03	1,04 (15,96)***	0,92	0,96***	1,09
	1 – 5	0,8 (6,53)***	0,65	0,81***	0,99	0,87 (6,81)***	0,67	0,82***	1,06
Spain	3 – 5	0,71 (4,84)***	0,5	0,71***	1,00	1,01 (12,51)***	0,87	0,93***	1,08
	1 – 5	0,7 (4,72)***	0,49	0,7***	1,00	0,72 (5,47)***	0,57	0,75***	0,96
New Zeal-and	3 – 5	0,66 (4,99)***	0,52	0,72***	0,92	0,94 (18,68)***	0,94	0,97***	0,97
	1 – 5	0,35 (2,34)**	0,19	0,44**	0,80	0,85 (11,99)***	0,86	0,93***	0,92
Denmark	3 – 5	1,01 (5,83)***	0,6	0,77***	1,31	0,96 (22,31)***	0,96	0,98***	0,98
	1 – 5	1,1 (4,34)***	0,45	0,67***	1,64	0,85 (6,52)***	0,65	0,81***	1,06
Finland	3 – 5	0,63 (4,52)***	0,47	0,69***	0,92	0,94 (11,41)***	0,85	0,92***	1,02
	1 – 5	0,59 (3,61)***	0,36	0,6***	0,98	0,65 (5,07)***	0,53	0,73***	0,89
Israel	3 – 5	0,77 (4,68)***	0,49	0,7***	1,10	0,88 (7,68)***	0,72	0,85***	1,04
	1 – 5	0,37 (2,66)**	0,24	0,49**	0,76	0,72 (4,72)***	0,49	0,7***	1,03
Ireland	3 – 5	0,18 (0,62)	0,02	0,13	1,39	1,03 (10,25)***	0,82	0,91***	1,14
	1 – 5	-0,12 (-0,81)	0,03	-0,17	0,76	1,03 (6,44)***	0,64	0,8***	1,28
Korea Rep.	3 – 5	0,69 (3,88)***	0,4	0,63***	1,10	0,52 (4,31)***	0,45	0,67***	0,78
	1 – 5	-0,18 (-1,28)	0,07	-0,26	0,70	0,27 (2,14)**	0,17	0,41**	0,66
Singapore	3 – 5	0,28 (2,13)**	0,16	0,41**	0,69	1 (10,1)***	0,82	0,9***	1,11
	1 – 5	-0,05 (-0,26)	0	-0,05	1,00	0,44 (2,36)**	0,2	0,44**	1,00
Japan	3 – 5	1,05 (16,06)***	0,92	0,94***	1,12	0,9 (14,97)***	0,91	0,95***	0,95
	1 – 5	1,09 (12,56)***	0,87	0,93***	1,17	0,78 (7,73)***	0,72	0,85***	0,92
Taiwan	3 – 5	0,78 (8,78)***	0,77	0,88***	0,89	0,79 (9,32)***	0,79	0,89***	0,89
	1 – 5	0,64 (5,35)***	0,55	0,74***	0,86	0,6 (4,86)***	0,51	0,71***	0,84
Hong Kong	3 – 5	0,75 (5,12)***	0,53	0,73***	1,03	0,94 (14,46)***	0,9	0,95***	0,99
	1 – 5	0,52 (4,42)***	0,46	0,68***	0,77	0,81 (13,76)***	0,89	0,94***	0,86
India	3 – 5	0,65 (4,99)***	0,52	0,72***	0,90	0,97 (16,38)***	0,92	0,96***	1,01
	1 – 5	0,63 (4,41)***	0,46	0,68***	0,93	0,93 (13,32)***	0,89	0,94***	0,99
China	3 – 5	0,3 (2,31)**	0,19	0,43**	0,69	0,8 (6,43)***	0,64	0,8***	1,00
	1 – 5	-0,09 (-0,83)	0,03	-0,17	0,53	0,36 (1,86)*	0,13	0,36	1,00
Malaysia	3 – 5	0,26 (1,56)	0,1	0,31	0,84	0,74 (6,42)***	0,64	0,8***	0,92
	1 – 5	0,1 (0,46)	0,01	0,09	1,11	0,47 (3,36)***	0,33	0,57***	0,82
Thailand	3 – 5	0,46 (2,24)**	0,18	0,42**	1,09	0,66 (8,1)***	0,74	0,86***	0,77
	1 – 5	0,22 (0,81)	0,03	0,17	1,29	0,24 (1,77)*	0,12	0,35	0,69

	Time span	Technological specialization pattern				Export specialization pattern			
		β	R^2	ρ	D.Sp.	β	R^2	ρ	D.Sp.
Brazil	3 – 5	0,7 (5,58)***	0,58	0,76***	0,92	1 (10,82)***	0,84	0,91***	1,09
	1 – 5	0,24 (1,29)	0,07	0,26	0,92	0,84 (4,68)***	0,49	0,7***	1,20
Venezuela	3 – 5	0,5 (2,84)***	0,26	0,51***	0,98	1,01 (18,49)***	0,94	0,97***	1,04
	1 – 5	0,19 (1,05)	0,05	0,21	0,90	0,82 (4,67)***	0,49	0,7***	1,18
Chile	3 – 5	0,26 (1,15)	0,05	0,23	1,13	0,99 (26,74)***	0,97	0,98***	1,01
	1 – 5	0,3 (1,5)	0,09	0,3	1,00	0,97 (16,41)***	0,92	0,96***	1,01
Mexico	3 – 5	0,8 (6,04)***	0,61	0,78***	1,02	0,78 (6,48)***	0,65	0,8***	0,97
	1 – 5	0,63 (3,67)***	0,37	0,61***	1,04	0,44 (2,68)**	0,24	0,49**	0,90
Argentina	3 – 5	0,61 (3,78)***	0,38	0,62***	0,98	0,85 (7,18)***	0,69	0,83***	1,02
	1 – 5	0,57 (3,7)***	0,37	0,61***	0,93	0,72 (4,21)***	0,44	0,66***	1,09

Table 10 – Assessment of the persistence of technological and export patterns for countries

Source: own calculations based on USPTO data

Note 1: period 3 – 5 correspond to the influence of the period 1986-1990 on 1996-1999, while period 1 – 5 correspond to the influence of period 1976-1980 (independent) on 1996-1999 (dependent).

Note 2: Technological specialization = Bèta/correlation (when both are significant at the 0,05 level)

Note 3: Values for t-test are given between brackets, significance values as follows:

*** significant at the 0,01 level (two-tailed distribution for the correlation figures); ** significant at the 0,05 level (two-tailed distribution for the correlation figures); * significant at the 0,1 level (two-tailed distribution for the correlation figures)

The examined countries are ordered according to the same taxonomy as applied in the analysis of chapter 4. The first and second sub table can be interpreted together, as the results are similar. The first table lists the developed countries that experienced a decrease in technological participation; the second table those who experience an increase in technological participation. Almost all of these countries experienced a decrease in the participation in worldwide exports. They have also not undergone major structural change (Figure 1, page 34). The first observation is that the galtonian regressions indicate that these countries all experienced the persistence characteristics as we expected. All regressions and correlations are significant at the 0,01 level. For the technological specialization pattern one observes that most values of the degree of specialization are higher than one. This is interpreted as an intensification of further specialization by the countries. Further examination shows that over the longer time interval both the values of the coefficient β as well as of the correlation ρ are lower than the respective values in the shorter time interval. This is an indication for the broadening of the specialization pattern is broadening. One also observes that for the shorter time span the values of R^2 are higher for most cases, which demonstrates that the explanation power of the first technological/export pattern on the last technological/export is stronger when the time interval between both is shorter. The strength of the past technological pattern on the posterior technological pattern is demonstrated by the coefficients for Switzerland and Germany, two countries strong in technologically advanced products: the specialization pattern at cohort 3 explains respectively 88% and 94% of the variance in the specialization pattern of cohort 5. For the longer time span the R^2 values are structurally lower, as would be expected due to the longer time interval between both periods. From this data it is clear that technological patterns are persistent and can be explained mostly by the initial technological pattern, although this explanation factor decreases its importance over time. In the last four columns we observe the results for the export specialization patterns, whose interpretation is similar to the technology specialization pattern. Comparing the technological and export patterns it is hardly possible to tell which is more persistent. The degree of specialization of technology is almost always higher than the corresponding (country and time span) degree of export specialization, whereas for the export specialization the R^2 values are higher than for the technological specialization. An overall and important conclusion is that the results present enough evidence for the existence of a persistent 'national' profile, for both technological as well as export capabilities.

In the third sub table we have a mix of developed western countries and the Asian countries that experienced an increase in technological activities (the Asian countries also experienced an increase in export activities) by entering new sectors. The results of the regressions for the technological indicator demonstrate some significant results. This seems to contradict the earlier assessed relatively high reallocation experienced by Finland, Denmark, and Israel, still we observe that the explanation power (R^2) of these regressions is considerably lower when compared to the explanation power of the regression performed on the first and second group of countries. For the Asian countries and for Ireland there are even non-significant values, which indicate that we cannot find patterns of persistence in these countries (for the longer run).

The fourth group consists of the developing 'late-comers'. Hong Kong and India present the most stable pattern of persistence for both technology as well as exports. China and Thailand experienced a persistence path in the shortest period. The values for the coefficient β and the correlation ρ are, however, relatively low when compared to the earlier values seen for developed countries. This indicates that, although the past pattern influenced the nowadays pattern, there were also other factors influencing the technological pattern of these countries.

The last sub-table represents the Latin American countries. The export pattern of these countries was subject to little change, what can be observed by the high values for the degrees of specialization. With the exception of Mexico all values are above 1, indicating that these countries further specialized in their initial export patterns. The lower coefficients for Mexico can be explained by the shifts in export shares due to the strong 'maquila' industry in this country. This was already observed in the trade decomposition analysis, which showed that Mexico was the only major Latin American country which increased trade during the period of this study (Table 8, page 47). The technological patterns of the Latin American countries are mixed. Mexico and Argentina present persistent patterns for both the short and the long period, while Brazil and Venezuela only show significant persistency in the short period. The technological pattern development of Brazil, Venezuela and Chile cannot be explained by the persistency theory over the long time period.

The results presented in this table have shown that according to the technological persistence countries can be divided into two large groups. The first group consists of the countries that demonstrated persistency throughout the period: these were mostly the rich developed countries, India, Mexico and Argentina. On the other hand we have also found a small subset of countries that did not experience persistency as defined in this chapter. These countries are Ireland, Korea, Singapore, China, Malaysia, Thailand, Brazil, Venezuela and Chile. Does the theory of technological change not apply for the development processes of these countries, or is it just the form of assessment that is not able to explain the influence of technological change? For this question we will give a tentative answer in the following chapter.

Staring at the results for the assessment of the exports profile one finds that all countries present a significant result for the persistency hypothesis. Does this mean that changing a country's technological endowments will not have an impact on the posterior exports, and that therefore all efforts made in the technological field will never pay off as the export figures will not change? This was already observed by Amendola et al. (1998) and explained by a relatively easier possibility to change the technological endowments of the country, for example through active (government led) policies to foster certain technological fields. We take Finland as an example: it was demonstrated that Finland had a weak technological base at the start of the period (indicated by the low value for the structural technology effect in Table 6, page 39). In the time interval covered by this study Finland experienced massive investments in the ICT sector, which resulted in USPTO patents concentrated in sectors related to ICT. It is fair to assume that some of this technological capabilities also reflected into posterior exports (the technology-gap model), still these exports are then in addition to the existing exports (exports in other sectors that were already performed prior to the growth of the technological capabilities). The country experienced a very concentrated technological specialization, but this only influenced a part of the exports. Secondly, looking into the coefficients of the regressions we observe that the persistency figures for the exports of the dynamic countries are consistently lower than the same figures for the developed countries. This indicates that, even though significant, there is a less persistent pattern observed in the exports of these dynamic countries, which are therefore reallocating exports shares between sectors.

5.4 The co-influence of export and technological capabilities

The technology-gap literature indicates that technological advantage precedes trade advantage in that a country first needs to develop the technology to the point that it can be employed for the production of price competitive products that are then exported. This assumption can be checked with the data available, employing the development of RSCA as measure of competitiveness for trade and RSTA as a measure for technological development. In recent work Uchida and Cook (2005) found that the traditional economic idea from technological advantage to trade advantage does not apply for some recent periods for South Korea, Taiwan and Singapore, countries that first developed trade advantage to subsequently develop technological advantage in a certain sector. This feedback effect between both is also mentioned by Lall (2000). With the data available for this research the same can be tested (Uchida and Cook, 2005, used a different concordance between trade and technology). To test the two-way feedback we apply two regressions.

$$\mathrm{RSCA}_{sc}^{t} = \propto_s + \ \beta_i \mathrm{RSTA}_{sc}^{t-1} + \ \varepsilon_{sc} \quad (23)$$

$$\mathrm{RSTA}_{sc}^{t} = \propto_s + \ \beta_i \mathrm{RSCA}_{sc}^{t-1} + \ \varepsilon_{sc} \quad (24)$$

Equation [23] will be employed to assess the influence of a prior technological specialization pattern on the export specialization pattern of a country. This measurement assesses the existence of the technology-gap, in that a technological specialization is a predictor for a posterior export specialization. Equation [24] will be employed to assess the inverse pattern: that the export specialization pattern will predict the posterior technological pattern. This is expected to be more frequent among the dynamic developing countries whose technological capabilities are built up through imitation. This is not a test of persistency, but rather of the direction of causality to indicate if a specialization pattern in technology lead to a subsequent patent in exports, or vice versa.

In Table 11 we see the results for the application of equation [23] and [24] to the relations between technological specialization and export specialization. More specifically, how the technological/export specialization pattern at the first time period influences the respective export/technological pattern of the last time period. In the remainder of this work we call the influence of technology on posterior export capabilities the 'technology-gap relation', while the influence of export capabilities on posterior technological capabilities is called the 'catch-up relation', in reference to the third hypothesis of the technology gap model as presented in § 2.3 (page 10). For each country two periods were analyzed: the influence of the technological/trade pattern of the period 1976 to 1980 on the trade/technological pattern of 1986 to 1990 (period 1 – 3), and the influence of the technological/trade pattern of the period 1986 to 1990 on the trade/technological pattern of the period 1996 to 1999 (period 3 – 5). Both analysis cover the same time interval measured in the number of years: for the first analysis the first cohort starts in 1976 and the last cohort 10 years later, in 1986; for the second analysis the first cohort starts in 1986 and the last cohort in 1996, 10 years later as well. The analysis is therefore actually performed once for the first half of the total period under study, and once for the second half. The choice to divide it as this is based on the assessment of possible changing dynamics of countries between the two time periods. Verspagen (2001) and Cimoli and Dosi (1995) comment that a catching-up country will have to change from an imitation to an innovating strategy. In this analysis this may be revealed by a 'catch-up relation' in the first time period indicating the imitation and a 'technology-gap relation' in the second period, demonstrating that it caught-up and is innovating instead of imitating.

Country	Time span	Catch-up relation B	ρ	R^2	D.Sp.	Technological-gap relation B	ρ	R^2	D.Sp.
USA	3 – 5	-0,08 (-1,12)	-0,23	0,05	0,35	-0,32 (-0,63)	-0,13	0,02	2,46
	1 – 5	-0,08 (-1,25)	-0,25	0,06	0,32	-0,11 (-0,13)	-0,03	0	4,10
Germany	3 – 5	0,42 (1,79)*	0,35	0,12	1,20	0,5 (2,29)**	0,43**	0,19	1,16
	1 – 5	0,1 (0,54)	0,11	0,01	0,90	0,34 (1,34)	0,27	0,07	1,26
France	3 – 5	0,13 (0,77)	0,16	0,03	0,82	0,48 (1,49)	0,3	0,09	1,61
	1 – 5	0,01 (0,15)	0,02	0,77	0,49	0,26 (0,93)	0,19	0,04	1,37
UK	3 – 5	0,21 (1,31)	0,26	0,07	0,80	0,78 (2,27)**	0,43**	0,18	1,82
	1 – 5	0,09 (0,93)	0,19	0,04	0,47	0,14 (0,45)	0,09	0,01	1,50
Italy	3 – 5	0,37 (2,05)*	0,39	0,15	0,94	0,64 (2,51)**	0,46**	0,21	1,38
	1 – 5	0,19 (1,12)	0,23	0,05	0,83	0,16 (0,64)	0,13	0,02	1,21
Switzer-	3 – 5	0,24 (1,53)	0,3	0,09	0,79	0,58 (1,87)*	0,36	0,13	1,59
land	1 – 5	0,16 (1,24)	0,25	0,06	0,64	0,45 (1,29)	0,26	0,07	1,74
Sweden	3 – 5	0,16 (1,31)	0,26	0,07	0,61	0,67 (2,31)**	0,43**	0,19	1,54
	1 – 5	0,16 (1,1)	0,22	0,05	0,71	0,95 (3,43)***	0,58***	0,34	1,63
Nether-	3 – 5	0,31 (1,77)*	0,35	0,12	0,89	0,41 (2,26)**	0,43**	0,18	0,96
lands	1 – 5	0,4 (2,14)**	0,41**	0,17	0,98	0,22 (0,99)	0,2	0,04	1,09
Austria	3 – 5	0,38 (1,87)*	0,36	0,13	1,04	0,68 (3,16)***	0,55***	0,3	1,24
	1 – 5	0,15 (1,06)	0,22	0,05	0,70	0,22 (1)	0,2	0,04	1,08
Norway	3 – 5	0,31 (1,71)	0,34	0,11	0,92	0,37 (1,46)	0,29	0,08	1,27
	1 – 5	0,18 (1,07)	0,22	0,05	0,83	0,26 (0,95)	0,19	0,04	1,34
Canada	3 – 5	0,07 (0,51)	0,11	0,01	0,66	0,73 (2,48)**	0,46**	0,21	1,59
	1 – 5	0,04 (0,38)	0,08	0,01	0,50	0,47 (1,15)	0,23	0,05	2,01
Australia	3 – 5	0,21 (1,41)	0,28	0,08	0,74	0,31 (1,12)	0,23	0,05	1,36
	1 – 5	0,03 (0,24)	0,05	0,00	0,61	0,16 (0,44)	0,09	0,01	1,75
Belgium	3 – 5	0,02 (0,09)	0,02	0,00	1,04	0,36 (1,91)*	0,37	0,14	0,98
	1 – 5	0,38 (1,8)*	0,35	0,12	1,08	0,08 (0,42)	0,09	0,01	0,91
Spain	3 – 5	0,89 (5,42)***	0,75***	0,56	1,19	0,56 (3,78)***	0,62***	0,38	0,91
	1 – 5	0,49 (2,5)**	0,46**	0,21	1,06	0,46 (3,2)***	0,56***	0,31	0,83
New Zeal-	3 – 5	0,46 (3,87)***	0,63***	0,39	0,73	0,63 (2,98)***	0,53***	0,28	1,19
and	1 – 5	0,4 (2,95)***	0,52***	0,27	0,76	0,18 (0,83)	0,17	0,03	1,06
Denmark	3 – 5	0,45 (2,47)**	0,46**	0,21	0,98	0,9 (4,58)***	0,69***	0,48	1,30
	1 – 5	0,53 (4,19)***	0,66***	0,43	0,81	0,97 (3,46)***	0,59***	0,34	1,66
Finland	3 – 5	0,31 (1,94)*	0,37	0,14	0,83	0,34 (1,53)	0,3	0,09	1,12
	1 – 5	0,24 (1,53)	0,3	0,09	0,79	0,43 (1,84)*	0,36	0,13	1,20
Israel	3 – 5	0,25 (2,09)**	0,4**	0,16	0,63	0,69 (2,02)*	0,39	0,15	1,78
	1 – 5	0,23 (2,13)**	0,41**	0,17	0,57	0,25 (1,02)	0,21	0,04	1,20
Ireland	3 – 5	0,25 (1,55)	0,31	0,09	0,81	0,59 (1,54)	0,31	0,09	1,93
	1 – 5	0,32 (2,7)**	0,49**	0,24	0,65	0,15 (0,82)	0,17	0,03	0,89
Korea Rep.	3 – 5	0,44 (2,92)***	0,52***	0,27	0,85	0,54 (2,98)***	0,53***	0,28	1,02
	1 – 5	0,34 (2,91)***	0,52***	0,27	0,66	0 (0)	0	0	0,00
Singapore	3 – 5	0,58 (3,28)***	0,56***	0,32	1,03	-0,01 (-0,05)	-0,01	0	0,90
	1 – 5	0,14 (0,52)	0,11	0,01	1,30	-0,09 (-0,54)	-0,11	0,01	0,81
Japan	3 – 5	0,33 (2,52)**	0,47**	0,22	0,71	0,66 (2,42)**	0,45**	0,2	1,46
	1 – 5	0,25 (2,1)**	0,4**	0,16	0,62	0,66 (2,09)**	0,4**	0,16	1,65
Taiwan	3 – 5	0,41 (3,14)***	0,55***	0,3	0,75	0,28 (1,33)	0,27	0,07	1,05
	1 – 5	0,39 (2,7)**	0,49**	0,24	0,79	0,51 (2,35)**	0,44**	0,19	1,16

Country	Time span	Catch-up relation B	ρ	R^2	D.Sp.	Technological-gap relation B	ρ	R^2	D.Sp.
Hong Kong	3 – 5	0,39 (3,02)***	0,53***	0,28	0,73	0,79 (3,37)***	0,57***	0,33	1,38
	1 – 5	0,33 (3,04)***	0,54***	0,29	0,62	0,52 (2,83)***	0,51***	0,26	1,02
India	3 – 5	0,4 (2,11)**	0,4**	0,16	0,99	0,3 (1,64)	0,32	0,11	0,93
	1 – 5	0,19 (0,86)	0,18	0,03	1,08	0,46 (2,65)**	0,48**	0,23	0,95
China	3 – 5	0,08 (0,6)	0,12	0,02	0,65	0 (-0,01)	0	0	0,00
	1 – 5	0,11 (0,62)	0,13	0,02	0,85	0,11 (0,61)	0,13	0,02	0,87
Malaysia	3 – 5	0,19 (0,98)	0,2	0,04	0,95	0,19 (1,16)	0,23	0,06	0,81
	1 – 5	0,37 (1,86)*	0,36	0,13	1,02	0,37 (1,69)	0,33	0,11	1,12
Thailand	3 – 5	0,42 (2,08)**	0,4**	0,16	1,05	0,15 (0,91)	0,19	0,03	0,81
	1 – 5	-0,06 (-0,34)	-0,07	0,01	0,85	-0,26 (-1,03)	-0,21	0,04	1,24
Brazil	3 – 5	0,25 (1,27)	0,26	0,07	0,98	0,41 (2,05)*	0,39	0,16	1,04
	1 – 5	0,05 (0,21)	0,04	0	1,15	0,14 (0,72)	0,15	0,02	0,94
Venezuela	3 – 5	0,48 (2,28)**	0,43**	0,18	1,12	0,4 (2,32)**	0,44**	0,19	0,92
	1 – 5	0,51 (2,07)**	0,4**	0,16	1,29	0,01 (0,07)	0,01	0	0,71
Chile	3 – 5	-0,07 (-0,36)	-0,07	0,01	0,94	0,28 (1,21)	0,25	0,06	1,14
	1 – 5	0,22 (1,24)	0,25	0,06	0,88	0,21 (1,03)	0,21	0,04	1,00
Mexico	3 – 5	0,01 (0,04)	0,01	0	1,07	-0,21 (-1,32)	-0,27	0,07	0,79
	1 – 5	-0,12 (-0,49)	-0,1	0,01	1,18	-0,07 (-0,43)	-0,09	0,01	0,78
Argentina	3 – 5	0,35 (1,5)	0,3	0,09	1,17	0,15 (0,84)	0,17	0,03	0,87
	1 – 5	0,44 (1,77)*	0,35	0,12	1,27	0,12 (0,72)	0,15	0,02	0,80

Table 11 – The co-influence of trade specialization and technological specialization

Source: own calculations based on USPTO data

Note 1: period 3 – 5 correspond to the influence of the period 1986-1990 on 1996-1999, while period 1 – 3 correspond to the influence of period 1976-1980 (independent) on 1986-1990 (dependent).

Note 2: Technological specialization = Bèta/correlation (when both are significant at the 0,05 level)

Note 3: Values for t-test are given between brackets, significance values as follows:

*** significant at the 0,01 level (two-tailed distribution for the correlation figures); ** significant at the 0,05 level (two-tailed distribution for the correlation figures); * significant at the 0,1 level (two-tailed distribution for the correlation figures)

Table 11 is divided into cohorts of countries as also used in the previous tables. The first set consists of developed countries where the significant results do basically show the technology gap relation: that technology precedes exports. This is demonstrated by the figures for the influence of technology on export (second column) that have a higher R^2 value as well as a higher correlation figure (in the cases of Germany, Italia and Austria and the second period for the Netherlands). For the first period the Netherlands presents the inverted path, in that export advantage precedes technological advantage.

In the remaining four groups one can hardly distinguish 'group patterns'. Each group has a mix of patterns. We will start with the countries that experience mostly a co-influence of technological and export activities on each other. This conclusion is based on the similar figures for the R^2 values as well as the correlations between the two activities within the referent time period. The technological pattern of 1976-1980 influenced the export pattern of 1986-1990 while the export pattern of 1976-1980 influenced the technological pattern of 1980-1990. The same applies to the posterior period, the influence of 1986-1990 on 1996-1999. This co-influence pattern is observed Spain, Denmark, Japan, and Hong Kong. For Denmark and Spain all figures are significant, but one observes that in the first time period Denmark's technological pattern had a stronger influence (R^2 = 0,43; correl = 0,66) on the posterior trade pattern than the other way around (R^2 = 0,34; correl 0,59). In the second time period this pattern inverts, in that the technological pattern explains more of the trade pattern than the other way around (R^2 = 0,48; correl = 0,69 versus R^2 = 0,21; correl = 0,46). For Spain this pattern is inverted, in the first period technology's influence on exports was stronger than the other way, while in the second period this reversed: exports explained the technological pattern.

For Japan and Hong Kong the figures are close, indicating that these countries underwent a co-influence of technology and exports.

Among the countries in this group we also observe some cases of the 'catch-up relation': New Zealand, Israel, Ireland, Korea, Singapore, Thailand and Venezuela developed the 'catch up relation'. Taiwan experienced a mutual influence in the first period, but the figures are stronger for the 'catch up relation', while for the second period only the 'catch up relation' is significant. Korea experience the opposite: in the first period the exports led to technology, while in the second period the influence of both patterns are almost as strong, which puts Korea's experience close to that of Japan and Hong Kong. This same pattern 'catch up relation' in the first period and mutual influence in the second period is also observed for New Zealand, Israel and Venezuela. Singapore, Thailand and Malaysia seem to be on the same path as Korea, only delayed by a period of 10 years. This is based on the patterns demonstrated by those three countries in the second period, which are the same as the pattern of Korea in its first period. Still it is known that the development strategies adopted by the latter countries are based on FDI, while from the earlier countries (Japan, Taiwan, Korea) are based on strong national endowments (Archibugi and Pietrobelli 2003). It is therefore possible that in these 'delayed' countries the patents are being issued to multinational companies that are also patenting locally achieved innovations. These patents would then not be coming from local research, contrary to what happened in Japan, Taiwan and Korea. Future research on the newest data on patenting could indicate if those countries also experienced the reverse situation. Finally India presents a rather awkward pattern. In the first period it experiences the traditional technology gap direction of capabilities development, while in the second period it shares itself with the earlier mentioned FDI receiving countries. The pattern of the second period could be explained by the strong ICT sector of India that came up during the second period of the study, and started selling their services to foreign markets generating export advantages, while posterior patenting this acquired technological capabilities.

From this analysis we learn that the developed countries (first group of Table 10, page 58) experienced the expected technological gap relation. A second group of countries, which can be seen as the earlier upcoming 'developing' countries and that are now for a long time OECD members experienced a mixed pattern, or two-way feedback: the exports of products led to technological advantage in those products, while at the same time earlier technological efforts lead to subsequent exports of those products. These figures are an evidence for the importance of the learning by imitating experiences in obtaining posterior technological advantage, as well as the need for investments in high-end technology to attain posterior export advantages. Most probably they co-influenced each other: learning from imitating combined with research that eventually led to advantage in both technology as well as exports. Finally there is a group of countries with a recent catch-up which demonstrates only the relation from export capabilities leading to technological capabilities.

In comparison to the persistency analysis performed in Table 10 we observe that the above exercise did present fewer significant results, although the studied relations are suggested by existing theories, such as the technology gap model. The first interpretation for this phenomenon is the apparent lack of significant relationship between the technological activities and the export activities for most countries. Still we believe that the answer is more elaborate. When one performs the persistence analysis for the technological pattern or for the export pattern one deals with respectively patents and trade data. This data has been continuously processed by the respective agencies, which continuously took care that all similar patents were filed in the same technological class as well as that all exported products were assigned to the same product class throughout the period. Therefore one can expect that the patents by a certain industry will be continuously assigned to the same technological classes throughout the period. One can also expect that the same exported products of a country will be assigned to the same product class. The sum of the activities of the industries forms the country's output. If all industries keep patenting and exporting persistently one will eventually have a persistent pattern for the country, as assessed by the galtonian regressions. The nature of regressions, in that it assigns the change to only one predictor, is not the best indicator for the relation between technological efforts and export successes (or vice versa). As was discussed in chapter 3 'Description of the data', there is no possibility for a perfect concordance between technology (as revealed by patents) and trade (as revealed by exports). The basic argument is that one technology can be employed for multiple products (electronics are used in PC's, cars, airplanes, mechanical instruments) while on the other hand a single product may require multiple technologies (a car requires mechanical, electronical, and chemical technologies to be produced). The use of a relatively small set of technological sectors does account for this somehow, but it still cannot assure perfect correspondence. Acknowledging the above one can assume that (some of) the technological efforts by a country are assigned to one of the 25 sectors, while the resulting commercial advantage is registered by another of the 25 sectors. A possible example is that a country is investing in the development of turbines for airplanes which are registered in the technological class 'Rotary machines and mechanical power', while the subsequent export of turbines is credited to the technological class 'Vehicles and transportation', as the turbines are used for the assembling of transportation means (airplanes). Application of the galtonian regressions to the case above would not reveal a positive influence of the technological development in sector 'rotary machines and mechanical power' on the export performance of the country as both sectors are, for the galtonian regression, unrelated. This may explain why there are less significant results for the cross-analysis.

5.5 Conclusions

In chapter 4 we identified the dynamics of the countries at a macro-level. We have observed the dynamics caused by the reallocation of countries endowments and performed an assessment based on shrinking and expanding sectors. This chapter presented an analysis at the meso-level, analyzing the influence of the earlier specialization pattern formed by the 25 sectors on the posterior performance of the country. The hypothesis tested in this analysis is that the patterns are persistent, so all significant results indicate persistency of specialization. In chapter 4 we found that most countries barely experienced a reallocation in their endowments. This finding is confirmed in the above analysis: most countries presented rather stable patterns of specialization, with the newer assessed specialization patterns firmly influence by the older specialization patterns. These findings corroborate the theory of the evolutionary school of economics in that technological change is of a cumulative nature. Therefore it build up on prior capabilities, and that they are relatively immune to economical stimulus/rationality.

Both analyses have also shown that there are some countries that did not follow the persistent pattern. This rather small set of countries, consisting of Ireland, Korea, Singapore, China, Malaysia, Thailand, Brazil, Venezuela and Chile, underwent a relatively high reallocation of their exports and technological capabilities (chapter 4). This reallocation is a strong indicator for the structural change of these countries. In this chapter we found that the persistent theory as explained here does not explain the development underwent by these countries. The interpretation of this finding is that the null hypothesis: 'there is no persistency in countries', could not be rejected. These results show evidence for the existence of structural change that is not explained by the definition of persistency employed in this chapter. This definition is based on intrasectoral cumulativeness, that is, the technological paradigms and trajectories would only explain the further development of technology in the same class. In the next chapter we do therefore argue for intersectoral cumulativeness, that is, technological paradigms and trajectories can also build upon capabilities developed in other sectors. The further characteristics of these intersectoral trajectories are presented in chapter 6.

6 The determinants and characteristics of structural change

In chapter 2 - Theory and background – we described the influence of the characteristics of technological change as explained by the evolutionary school of economic thought on the development of technological and export capabilities of countries. The literature described the influence of past technological specialization of the country on the further development of the country. The findings described in chapter 4 and 5 have corroborated the existence of cumulativeness and persistence in the technological and export patterns of most countries. Therefore there is both theoretical and empirical evidence that the past characteristics of a country influence future developments of the technological capabilities of that country. Still it was also shown that countries underwent changes in the export and technological capabilities. In the analysis of chapter 5 it was demonstrated that the explanation power of the initial specialization profile on the end specialization profile got weaker as the time between both intervals increased. Besides there was also a small set of countries that underwent drastic reallocation of their export and technological capabilities, indicating structural change (chapter 4). In the further analysis towards persistence performed in chapter 5 it was shown that we could not reject the null-hypothesis ‘there is no persistency’ for these countries. Does that mean that the technological change characteristics as explained by the evolutionary school do not apply to these countries? We do not believe that, therefore we will argue in this chapter that the theories on technological paradigms and trajectories can also explain the changing specialization pattern of the country. To accomplish this we propose a methodology to assess the influence of an initial specialization pattern of a country on a later specialization pattern, not intrasectoral as the previous exercise, but between sectors. With this analysis we aim to answer the third sub-question of our research proposal:

> Can the cases of ‘structural change’ be explained by the theory on technological paradigms and trajectories?

Earlier research did not explain all variance based on the simple regression applied, and in some cases it did not even present a significant value. It was also observed that over longer time spans the relations got weaker, indicating a slowly changing pattern of the country’s technological profile. This is mostly the case for countries that experience a thorough change of their technological as well as production structure. The earlier research failed to observe where the changes in the upcoming sectors came from. Therefore we find it necessary to add additional explaining variables to explain the change of a country’s structure. We do this in this chapter by assuming that the different sectors are related as to their ‘likeliness’: some are closer (more alike) while others are apart (less alike). We further assume that a strong sector may spill over some of its technological content to a close sector, and that therefore there can also be what we will call intersectoral trajectories: trajectories based on the relation between different technologies. The background, definition and interpretation of these intersectoral trajectories will be explained in the next paragraphs of this chapter.

The observations by earlier researchers about the persistence of technological and export patterns are based on the regressions between the technological profiles of a country at two different points in time (galtonian regressions). The outcomes of these regressions demonstrate if the profile at the start of the period was further intensified, remained stable, or weakened. In this analysis the sectors characteristic at the end of the period is only based/influenced on the characteristic of this sector at the start of the period. In other words, one assumes that it is only sector ‘X’ in the first cohort that had an influence sector ‘X’’s changes in the last cohort. Based on the reviewed literature this is fair argument, as it was seen that technological change is based on past characteristics of that same technology. In other words, the sector can find a great deal of support for further expansion on its intrinsic capacities. Besides the evidence provided in the earlier literature, Table 12 from this chapter demonstrates that most patent citations occur between patents belonging to the same class, which supports the arguments presented above. This work will not try to change that view, actually we build further on the idea that past specialization patterns define nowadays patterns. This work tries to complement the existing literature by studying the expansion of a sector as dependent on its relation to the other sectors combined with the dynamic of those sectors.

6.1 The relation between the technological sectors: the technological space

In the previous assessment we assumed that a sector's strength does influence its future development. In this chapter we assume that in a process of structural change a strong sector can influence an initially weak sector, and that this influence is proportional to the similarity of both sectors. Therefore one needs a measure of the similarity of technological sectors. For this research the proximity between technological sectors will be based upon the citations between patents aggregated to technological classes. In the description of the patents (chapter3.1, page 17) it was described that for legal purposes each patent has to refer to earlier patents to support the claimed improvements. These citations have been extensively used as indicators of knowledge flow and technological relationship between the cited patents. The citations from a patent are made to older patents. All patents are assigned to technological classes, generating a list containing, for each patent, the citing USPTO class (pertaining to the patent) and the cited USPTO classes. The original 411 UPSTO classes are reassigned to 25 broader technological sectors. All citations between patents are therefore aggregated to citations between the 25 broad technological sectors. The data employed for this research consists of all patents as well as the citations assigned in the period 1976 to 1999 by the USPTO. In total 2.061.354 patents were issued in this period, and those patents made 11.803.154 citations, of which 2.832.776 (about 24%) are of intrasectoral nature. The citations made between all patents of the USPTO database are converted to citations between these 25 sectors: that is, if patent 'A' of class '1' refers to patent 'B' of class '2' the citation A->B will become 1->2. It is possible that a patent from sector '1' refers to another patent in sector '1', which results in an intrasectoral citation. Besides, multiple intersectoral citations may happen: two or more patent from class '1' cite two or more patents from class '2': the amount of pairs will be summed to an intersectoral total. Finally a patent from class '2' may cite a patent from class '1', that is, the other way around. This will lead to weighted (number of citations) and directed ('1' to '2' is different than '2' to '1') citations between the technological sectors (TSs). Those characteristics form a network of nodes (the TSs) and linkages (citations) that allow one to calculate figures as proximity of TSs (proximity is proportional to the number of citations). Proximity is interpreted as a measure for 'local' (by Cimoli and Dosi, 1995): the closer two TS are, the easier a country specialized in one can move to the other. As indicators of knowledge flows, the intrasectoral citations show cumulativeness of knowledge, intersectoral citations how similar two technological classes are.

Although most citations are directed to patents within the same technological sector, a considerable amount of citations is also made to patents from other technological sectors (Table 12). The results show that the average percentage of interclass citations grew throughout the period, from 27% to 33%: while most technological sectors experimented a growth of outward citations, the 'Biochemistry' and 'Surgery-body care-cosmetics' sectors actually decreased their percentage of outward citations. Furthermore one observes that there is a wide dispersion between the technological classes about their propensity to cite other classes: one case (textiles and apparel in the period 1996-1999, highlighted) had more interclass citations than intraclass citations, while sectors 13, 34 and 47 have interclass citations figures that are closer or less than 20%.

Code and description of the sector		Percentage of intraclass citations (in %) for cohort 1976 to 1980	1981 to 1985	1986 to 1990	1991 to 1995	1996 to 1999	Average
11	Tools–hardware–pipes–joints	30	34	35	36	39	35
12	Receptacles–containers–supports–partitions–furniture	26	27	26	26	27	26
13	Motors–engines–pumps	16	18	19	19	23	19
14	Manufacturing–assembling–metal working	27	31	31	32	38	32
15	Rotary machines and mechanical power	20	21	22	23	25	22
16	Machining and cutting	38	41	43	46	48	43
21	Material or article handling	28	30	31	30	34	31
22	Earthworking and civil engineering	18	21	22	23	23	21
23	Heating–cooling–buildings–fluid/gas handling	24	23	27	30	34	28
24	Vehicles and transportation	22	23	24	24	26	24
25	Office devices–paper handling–coatings	30	33	37	39	47	37
26	Textiles and apparel	33	32	38	45	53	40
31	Biochemistry	43	35	31	30	28	33
32	Chemical engineering	34	35	36	39	43	37
33	Organic chemistry	23	27	31	32	41	31
34	Surgery–body care–cosmetics	18	18	17	14	14	16
35	Materials–compositions–explosives	37	39	41	44	48	42
36	Agriculture and farming	28	27	26	28	33	28
41	Computing and data processing	27	29	28	25	25	27
42	Electricity and electric power	24	24	27	29	32	27
43	Electronics and components classes	31	30	29	27	28	29
44	Optics–radiant energy–photography	20	22	22	24	26	23
45	Communications and networking	24	25	25	24	25	25
46	Other science and engineering, measurement, nuclear	28	30	32	33	40	33
47	Music–education–games	15	17	20	17	20	18
	Average for the period	27	28	29	30	33	29
	Stand deviation for the period	7	7	7	8	10	7
	Maximum	43	41	43	46	53	43
	Minimum	15	17	17	14	14	16

Table 12 – Interclass citations (citations to other technological sectors) in %
Source: own calculations based on USPTO data

Table 12 shows that most citations are of intrasectoral nature, an indication that technology trajectories build upon past knowledge (paradigms) belonging to the same technological sector. The relation between intrasectoral (within sector) and intersectoral (between sectors) are different. This could be an indicator of the differences in self-sufficiency of patent classes. It is interesting to note that sectors 31 and 34 experienced both a fast growth of patenting as well as a reduction of intersectoral citations, that is, fewer citations were made and/or received from other patent classes. It seems that they built upon their own technological content. From the expanding sectors the sectors related to electronics have a considerable and stable amount of citation to other classes.

The intra- and intersectoral citations between the 25 technological sectors are represented in citation matrixes, from which a general example is shown in Figure 4. For the sake of simplicity (and space saving) of the representation we use one column and row to indicate the sectors 3 to sector 24, but in fact there are 25 rows and 25 columns, resulting in a matrix containing 625 cells. As can be seen, all sectors are given in both the rows and columns. This allows one to separately present the citations made and received by each sector. Each row of the table represents the citations made by the respective sector, given in the first cell of the row, while each column represents the citations received by the sector given in the first cell of the column. Those cells (not shaded) amount to a total of 600, which corresponds to the number of directed citations possible between 25 nodes, as given by equation [n*(n-1)], where n is the number of nodes. The group of shaded cells, in the diagonal of the matrix, represents the intrasectoral citations, that is, the citations made between patents belonging to the same sector. This gives a total of 25 cells, one for each sector.

Citing sector	Cited sector: Sector 1 (S1)	Sector 2 (S2)	Sec 3 (S3) to sec 24 (S24)	Sector 25 – S25
Sector 1	Number of citation made by S1 to S1	Number of citation made by S1 to S2	Number of citation from S1 to S3…S24	Number of citation from S1 to S25
Sector 2	Number of citation received by S1 from S2	Number of citation made by S2 to S2	S2 cites S3…S24	S2 cites S25
Sect 3 … Sect 24	Number of citation received by S1 from S3…S24	S3…S24 cite S2	Number of citation made by S3…S24 to S3…S24	S3…S24 cites S25
Sector 25	Number of citation received by S1 from S25	S25 cites S2	S25 cites S3…S25	Number of citation made by S25 to S25

Figure 4 – Citation matrix indicating intra- and interclass citations.

The citation matrixes is used as basis to build the technology space, which consists of the 25 technological sectors that are related to each other through the interclass citations made by the patents within each of the technological sectors to patents pertaining to other technological sectors. The number of citations between technological sectors is assumed to be proportional to the proximity of the two sectors: the more citations, the more two sectors are related. To transform the citation matrixes into a technological space some additional techniques are necessary, and described in the next paragraphs.

The citation matrixes for each year were symmetrised by addition, that is, the directed citations between a pair of technological sectors were added, forming an undirected relation between both. The citations "n" made by sector 1 to sector 2 were added to the citations "m" made by sector 2 to sector 1, obtaining a total of n+m citations between both sectors. The matrixes of each year were summed for an overall matrix covering the whole period of 1976 until 1999. Based on this cumulative citation matrix the distances between each pair of technological classes are calculated using cosine distances. The cosine distance is derived from cosine measure (cosine values of the angle between two technological sectors) by applying equation [25] to the data. The cosine distance makes the relation between the sectors more consistent by calculating the distance between sectors accounting for the relation to all other sectors.

$$C_{ij} = \cos\theta = \frac{\sum_k x_{ik} x_{jk}}{\sqrt{\sum_k x_{ik}^2 \sum_k x_{jk}^2}} \qquad (25)$$

Where:

C = distance between two sectors
j = subscript that refers to first sector

i = subscript that refers to second sector
k = subscript that refers to the set of sectors

The distance figure obtained by this method varies between 0 and 1, with higher values indicating a higher similarity between sectors. The distances obtained are now more consistent[9], but it will be hard, if not impossible, to allocate all sectors in a two-dimenstional space by employing the obtained distances as ratio data. So, even though we obtained a matrix with an indicator for the distances between the technological sectors, these distances consist of quantitative/ratio data. This problem is better illustrated with an example. Consider three sectors, A, B and C with the distances (number of citations) between sectors A and B as being 1, and the distance between sector A and C is 2. The maximum and minimum possible distances between B and C are respectively 3 and 1. If the distance B-C is smaller than 1 or larger than 3 a metric disposition of sectors will not work. Let's assume that the distance between sectors B and C is equivalent to 4. We have A-B = 1, A-C = 2 and B-C = 4, a situation that could not be plotted on a metric map. A possible solution for this situation is to downgrade the data from their ratio scale to an ordinal scale. Ratio scale data tells what the relation (ratio) is between the measurements (eg: distance B-C is twice the distance A-C and four times the distance A-B), while the ordinal data does only l classify sectors on a scale of 'closer to more apart' (eg: distance B-C is larger than distance A-C which is larger than distance A-B). Plotting this characteristics on a map could result in a solution where, for example, the distance of A-B is 1, of A-C is 2 and B-C is 2,8. This example already demonstrates that the results get distorted, in that the distance of B-C got 'shorter'. With an even larger number of sectors this disposition gets even more difficult. To accomplish the creation of the technological space we employed techniques of Multi Dimensional Scaling with a software by Heady (2008). More specifically, we use an algorithm based on non-metric data. This algorithm treats the inputs originated by the cosine distance measure as ordinal data. The algorithm shift sectors over a two-dimensional map in order to achieve a disposition where the sector position correspond to the input data. This map is entitled as the technological space, in that it reveals how technologies are related to each other (Figure 5).

Figure 5 shows the technological space based on the aggregated data over the whole period (1976 until 1999). The map shows the 25 technological sectors identified by their corresponding number. These 25 technological sectors were originally further aggregated into four broad technological fields. For the ease of assessment in the MDS the first digit of the sectors classification code refers to the broad technological field: mechanical engineering has number 1, engineering (general) has number 2, chemical engineering has number 3 and finally electronic engineering has number 4. The second digit refers to the subdivision within the broad technological class. An expected outcome is that the sectors with the same first digit (belonging to the same broad technological sector) will group together. This can be seen to happen in the technological space, as the sectors are actually grouped according to their broad technological class.

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[9] As an alternative to the cosine distance calculations we also entered the number of citations between sectors straight into the MDS software, resulting in a highly stressed graph. This is an indication that the MDS could not handle the citations right away, and that cosine distances did indeed make the data more consistent for further processing with MDS. Therefore one may consider the cosine distance as a pre-processing tool for data.

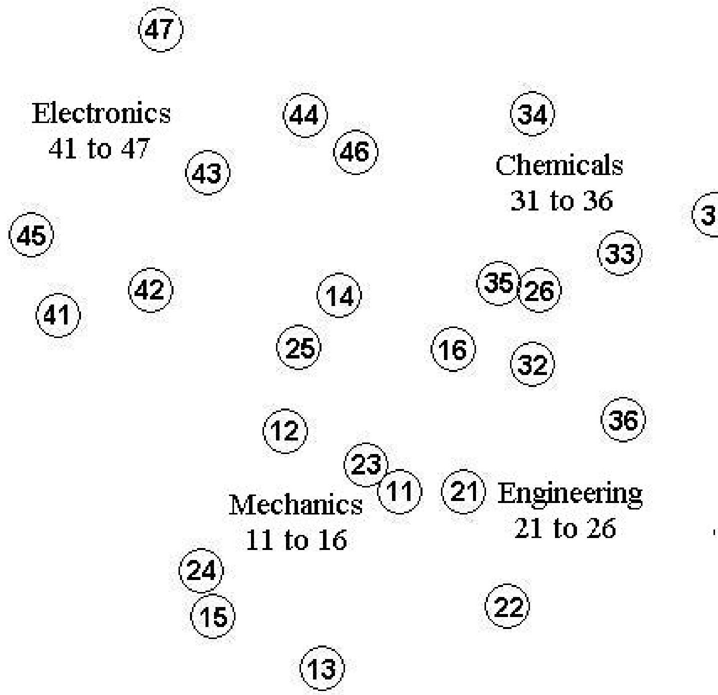

Figure 5 – The technological space indicating the position of sectors based on citations
Source: own calculations based on USPTO data from 1976 to 1999
Note: Numbers indicate the corresponding technological sector: , 11 - Tools, hardware, pipes, joints; 12 - Receptacles, containers, supports, partitions, furniture; 13 - Motors, engines, pumps; 14 - Manufacturing, assembling, metal working; 15 - Rotary machines and mechanical power; 16 - Machining and cutting; 21 - Material or article handling; 22 - Earthworking and civil engineering; 23 - Heating, cooling, buildings, fluid/gas handling; 24 - Vehicles and transportation; 25 - Office devices, paper handling, coatings; 26 - Textiles and apparel; 31 - Biochemistry; 32 - Chemical engineering; 33 - Organic chemistry; 34 - Surgery, body care, cosmetics; 35 - Materials, compositions, explosives; 36 - Agriculture and farming; 41 - Computing and data processing; 42 - Electricity and electric power; 43 - Electronics and components classes; 44 - Optics, radiant energy, photography; 45 - Communications and networking; 46 - Other science and engineering, measurement, nuclear; 47 - Music, education, games

In the upper left corner we have the electronics sectors, at the upper right we have the chemical sectors and in the bottom we have the mechanical engineering related sectors. The sectors belonging to engineering general are somewhat more spread. Sector 26 (textiles and apparel) is positioned among the chemical engineering sectors. Sector 25 (Office devices–paper handling–coatings) is positioned among the mechanicals and electronics (probably due to the inclusion of office equipments as computers, printers etc that have both an electronic as well as mechanical input). Sector 24 contains all patents on vehicles and transportation, which explains it positioning between the mechanical sectors, especially to sector 15 (rotary machines and mechanical power). The overall sectors of engineering (general) are located among the mechanical engineering sectors. Even though the sectors are grouped in their broad technological classes it can be seen that for example sectors 46 is closer to sector 14 and 34 than to the group of sectors 41, 42 and 45. In the same way some of the mechanical sectors (12 and 14) are closer to some of the electronic sectors than to other mechanical sectors. So while there are some sectors that are hidden in the edges and hardly have contact to other sectors, even in the same technology, there are also sectors that are really close to other technology kind of sectors. This proximity is believed to influence a country's capability of moving to that sector, both to sectors in the same broad technological group as well as to sectors belonging to other technological groups.

6.2 The intersectoral trajectories and the technological opportunities

Figure 5 shows the technological space as used in this analysis. Before diving into its use, we will refer to some economic theory and its relation to the technological space.

In (older streams of) the neo-classical economical theory it is assumed that technology can be obtained from a large pool of knowledge which is equally available to all persons and firms. It is further assumed that all persons and/or firms are informed of all technologies available in this knowledge pool. Consequently, they are able to make rational choices on which technology is better suited for their needs. A firm in a developing country can choose for a low-tech cheap technology that requires plenty of cheaply available labor, while a firm in a developed country can choose from a high-tech expensive technology that requires few labor. In other words: the output of a production process is determined by technological input and labor intensity, and one can swap one item for the other, creating an infinite range of possible combinations of technology and labor that will eventually offer similar outputs regarding quality, price, etc. Atkinson and Stiglitz (1969) presented a 'new view on technological change' that defended that this sort of 'swapping' technology for labor or vice versa was not possible. Evolutionarists took this assertion as a basic characteristic of their models, therefore considering that there is only one or a limited set of technologies optimized for a production process (Cimoli and Dosi 1995). In practice this is reflected in the fact that developing countries should operate their production processes employing expensive imported hi-tech production lines and are not able to explore the cheaply available labor source (Szirmai 2005). The earlier presented technological space can be said to represent the worldwide knowledge pool. This assertion relies on the fact that the technological space is based on the patents issued by the USPTO between 1976 and 1999 and the citations they make to prior patents. An essential condition to acquire a patent is to make full disclosure of the content of the patent so that it can be added to the general stock of knowledge. And this is true as simple search mechanisms freely available at the World Wide Web do allow one to obtain access to all contents revealed in the more than two million patents issued in the period of this study. Therefore apparently only the persons deprived from a microcomputer with access to internet cannot have access to this information. What neo-classical economists fail to observe is that this information is very extensive with more than two million documents, and very complex: the USPTO patent examiners are highly trained in a limited number of technological classes to be able to identify new knowledge and consequently assign a patent. We have also seen in the theoretical chapter that within a technological paradigm one works with a set of information which is accepted by the group, and the overall information is mostly rejected. The information may be available, but it is not automatically employed by scientists, researchers or engineers. Authors from the evolutionary school have written about it, describing the central actor in an innovation system as having limited knowledge. Dosi et al (1990) use the technological paradigm and technological trajectories as explanation factor for the possibilities offered to a firm to achieve technological advancements. They refer that the development of the technological capabilities of a firm are mostly influenced by the conditions offered by the country in which this firm is active. Those conditions involve the availability of knowledge, the incentives and opportunities created by positive feedback, the institutional context and economics signals faced by the firms.

In order to apply these constraints to the technological capabilities development of firms within a country we impose a limit to the knowledge available to these firms. The boundary chosen is the country in which the firm is active. That is, a Brazilian firm (or better, all Brazilian firms) can only build upon the prior knowledge produced by other Brazilian firms. This allows us to make the assessment at a more aggregate level as we define that all technological development of Brazil can only be built upon prior technological capabilities owned by Brazil. This assessment was also made in the galtonian regressions, where one analyzed the dependence of a technological pattern on an earlier technological pattern for each individual country.

In this chapter we are, however, interested in the structural change of countries. In the process of structural change countries do break free of older patterns, they build up capabilities in areas where they had prior weak capabilities, while former stronger sectors may become weaker. The technological paradigms and technological trajectories story hold that countries develop capabilities conducted by their past experiences and past capabilities. In this work we stretch this view of the paradigms and trajectories by assuming that this development of capabilities do not happen only on the exact same prior technology, but they can also be influenced by prior capabilities in similar technologies. This assumption corresponds to the view that learning is of local character and expected to be based on closely located sectors (Cimoli and Dosi 1995). Earlier empirical research based on export data (Hidalgo et al. 2007) suggest that countries undergoing structural change in exports do have a higher propensity to move to the export of products that are similar to products that are already exported by the country.

The similarity between technologies was not yet used or even given in the prior methodologies; therefore we created the technological space as described. For this research we use these similarities as determinants for the relationship between technologies: if two technologies have a small distance between them they are said to be similar, conversely, if two technologies are distant from each other, they are said to be dissimilar. The spillover between technologies is expected to be dependent on these distances: the closer two sectors, the higher the propensity to accomplish a technological spillover. The technological space does therefore indicate similarities of technological sectors, but countries have different initial positions in the different technological sectors. For example the similarity of electronics and ICT is equal to all countries, but in the 1980's Japan may have had a better initial position in electronics than Brazil, and was therefore able to successfully move to the ICT sector, while Brazil failed (even though massive investments were made by this country).

Now that we have defined the relation/distances between technological sectors we still need to define a methodology that allows one to measure the influence of the surrounding sectors on the expansion of a central sector of a country. We want to obtain a measure of the 'technological opportunity' around each of the technological sectors of a country. The employed methodology should therefore take two factors in account: i) the technological specialization pattern of the country and ii) the technological space. This measure of technological opportunity is then used as a predictor of the growth experienced by a sector in a country.

The hypothesis to be tested is that the development (measured as the change in share) of each of the 25 technological sectors of a country is dependent on the past technological specialization pattern of the country and on the technological space. With the initial pattern of specialization we refer to the shares of patents of each technological sectors of the country (that is, a characteristic determined by the country's patents portfolio), while the technological space refers to the relation (proximity) of the technological classes on the worldwide.

The technological space is a network consisting of 25 nodes (the technological sectors) and 300 non-directed links between them as indicators of the relationship between sectors. Therefore we define that the most adequate measurement tool for technological opportunity around a sector should come from the field of complex network analysis. More specifically, we want to obtain the technological opportunity experienced by each sector of each country, that is, how much opportunity does each sector have to grow. This implies in the analysis of an individual central sector and how it is influenced by its surroundings. The available data suggest that this measurement can be taken for each sector individually, as for each sector (called ego) there is information as to its distance to all other 24 sectors (called alters): this data is obtained from the technological space. Therefore we opt for a measurement based on the centrality of the sector. Centrality is a measure that uses the information on the weighted linkages to define how central the actor under study is positioned in the network. A central position means that it is close to (most of) the alters, while a peripherical position means that it is far away from (most of) the alters. The centrality measure therefore defines how central the sector is positioned based on its surroundings, which is exactly what we want to analyze in this study. As centrality is calculated for every node in the network at the end one can compare relative centrality between nodes. As said above, in the centrality measurements one uses the information on the weighted linkages of the ego to the alters. Those linkages are available, consisting of the distances between sectors. Standard centrality measurement methods do, however, not account for differences in the characteristics of the alters (Wasserman and Faust 1994). This is a limitation of the proposed centrality methods, as we have the information on the weights of the alters (given as the shares of patents of the alters) and we expect that those weights – in combination with the distance – influence the development of the ego.

The available information consists of the distances from the ego to each of the alters and the shares of patents owned by the country at the start of each time-period. Based on the shares one can calculate the change of shares between two time periods, observing the sectors that experienced expansion and shrinking over the analyzed time period. It is hypothesized that a high proportion of close sectors having high values for the shares of patents shall lead to a high technological opportunity for the ego. This implies that both the shares as well as the closeness to the ego are proportional do the technological opportunity: the higher the share and the higher the proximity of an alter-sector, the higher the influence of this alter in the technological opportunity of the ego-sector. The shares are already proportional to the opportunity, and therefore need no correction, but the proximity is not yet proportional as the measure available from the technological space is the distance between sectors, where high values stand for large distances, and conversely low values for low distances (high proximity). Therefore the values of distances should be somehow converted to reflect proximity. The option employed in this work was to use the inverse value of the distance, namely (1/distance) = proximity. With the above considerations in account we eventually defined equation [26] to calculate the technological opportunity for each sector of each country.

$$TO_{sc} = \sum_{\mathrm{sc}}^{\mathrm{S_A}} [prox\ (s, S_A) * (share\ S_{patA}^{t})^2] \tag{26}$$

where:

TO = the technological opportunity
s = subscript that refers to sector
t = superscript to indicate the cohort employed for the shares
c = subscript that refers to the country
S_A = refers to the alter sectors
$prox\ (s, S_A)$ = proximity of the ego sector (s) to the alter sector (S_A)
$share\ S_{patA}^{t0}$ = share of patents belonging to the alter sector (S_A) at time 0

With equation [26] the technological opportunity is accessed for all 25 sectors of a country for a given time interval. Note that we use the values of the share squared. This procedure accentuates the results, leading to a higher differentiation between countries for the values obtained for the technological opportunities. The opportunities are expected to influence the posterior dynamics of the sectors, where a larger opportunity faced by a sector will lead to an expansion of its shares. This relation is assessed through a simple linear regression where the technological opportunity is used as the predictor (independent) for the dynamics of the sectors (dependent). The dynamics of the sectors are determined by the measured change in share between two cohorts.

$$\Delta\, share\ PAT_{sc}^{tb-ta} = \propto_{\mathrm{s}} + \ \beta_{\mathrm{i}} TO_{sc} + \ \varepsilon_{\mathrm{sc}} \qquad (27)$$

where:

s = subscript that refers to the ego sector
c = subscript that refers to country
$tb - ta$ = superscript to indicate the timespan for the assessment of the ego sector's dynamics
$\Delta\, share\ PAT$ = change in share of patents of the ego sector
TO = the technological opportunity
$\propto_{\mathrm{s}}$ = constant
$\varepsilon_{\mathrm{sc}}$ = residual

The five cohorts used in this work are based on the cumulative amount of patents and exports accomplished over the following years: 1976-1980 (1), 1986-1990 (3) and 1996 to 1999 (5). Therefore 1976-1980 is not an indication of changes that happened between 1976 and 1980, but rather an accumulation of the patents/exports accomplished in this period. In the posterior analysis we will use the corresponding numbers to facilitate interpretation, for example 1 – 3 represents the changes in the shares from the values obtained for all patents between 1976 and 1980 to the values obtained for all patents between 1986 and 1990. It is important to note that the dependent variable is based on the changes of shares, which can only be calculated between two cohorts. Therefore we will always refer to two periods when accessing the change of shares of the sectors.

As we have five time cohorts in this analysis it is possible to do a rather extensive set of studies towards the relation between the opportunities and the posterior dynamics. As an example: we can assess the opportunity employing data from cohort 1 and use this as predictor for the dynamics between the cohorts 1 and 2, between cohorts 1 and 3, cohorts 1 and 4, cohorts 2 and 3… up to 4 to 5. For the matter of space saving we assessed only a limited number of combinations of technological opportunities and posterior sector dynamics, still the data is available from the author so that further analysis can be performed.

The combinations chosen for the assessments performed and described in this work are the following:

1. The opportunities generated in cohort 1 on the dynamics between cohorts 1 and 5
2. The opportunities generated in cohort 1 on the dynamics between cohorts 3 and 5
3. The opportunities generated in cohort 3 on the dynamics between cohorts 3 and 5

We have performed the analysis for all countries. For most countries the results turned out to be insignificant, with the exception of the results described in Table 13.

	Opportunity generated in cohort…	Dynamics assessed between cohorts…	β (t-test)	R^2 adjusted
Thailand	1	5 and 1	0,13 (0,07)*	0,12
	1	3 and 1	0,18 (0,11)*	0,10
	3	5 and 3	0,09 (0,05)*	0,12
Singapore	1	5 and 1	0,15 (0,07)**	0,16
	1	3 and 1	0,13 (0,06)**	0,16
	3	5 and 3	0,01 (0,31)	0,00
Korea	1	5 and 1	-0,24 (0,16)*	0,09
	1	3 and 1	-0,16 (0,12)	0,07
	3	5 and 3	0,44 (0,12)***	0,37
Hong Kong	1	5 and 1	0,24 (0,14)*	0,10
	1	3 and 1	0,34 (0,16)**	0,16
	3	5 and 3	0,03 (0,07)	0,01
Chile	1	5 and 1	0,08 (0,09)	0,03
	1	3 and 1	0,19 (0,16)	0,06
	3	5 and 3	0,19 (0,11)*	0,12
Venezuela	1	5 and 1	-0,09 (0,38)	0,00
	1	3 and 1	-0,26 (0,36)	0,02
	3	5 and 3	0,03 (0,02)*	0,09

Table 13 – The influence of the technological opportunity on the growth of sectors

Source: own calculations based on USPTO data

Note 1: period 3 – 5 correspond to the influence of the period 1986-1990 on 1996-1999, while period 1 – 5 correspond to the influence of period 1976-1980 (independent) on 1996-1999 (dependent).

Note 3: Values for t-test are given between brackets, significance values as follows:

** significant at the 0,05 level (two-tailed distribution for the correlation figures); * significant at the 0,1 level (two-tailed distribution for the correlation figures)

Table 13 shows the results for the influence of the opportunity generated in the given cohort (2nd column) on the posterior dynamics of the countries: the change in shares measured between two subsequent cohorts (3rd column). Three analyses are performed for each country according to the combinations of 'opportunity' and 'dynamics' as given above (under 1, 2, and 3). The outputs consist of the coefficient of the regression (and t-test) and the R^2 value. The results show that the proposed methodology is able to explain some cases where the development of a sector is influenced by a strong opportunity at the start of the period. In other words, the sectors that were close to prior strong sectors expanded faster. We observe that most results have the expected positive sign, demonstrating the relation between higher opportunity and posterior expansion[10]. Thailand demonstrates the expected (and at the 0,1 level) sign in all the periods assessed. For Singapore it was mostly the pattern of the first cohort that influenced the posterior development, what is demonstrated by the significant results in the first two lines. Korea demonstrates the reverse pattern at the start: the pattern at cohort 1 is negatively related to the expansion of the sectors assessed over the longer period (5 to 1) and the short period (3 to 1). However we do observe that the pattern at the middle cohort has a strong influence on the posterior development of the sectors. Hong Kong demonstrates the most interesting result at the start of the period: the technological opportunity generated in cohort 1 explains the development over the period 1 to 3, and to less extension also the development over the period 1 to 5. The third regression: the influence of the opportunity in cohort 3 on the posterior performance does reveal the expected sign, but is it not significant. Our interpretation is that at this point the country may already have entered the rather persistent pattern and not have presented a large structural change anymore. Chile demonstrates the

[10] While in the galtonian regressions the value of the coefficient indicated the 'strength' of the influence of the first period on the last period, the coefficient obtained in this exercise does not have such explaining power.

expected sign throughout the period, observing the increase in R^2 values we can conclude that the influence of the technological pattern increased throughout the period. Finally Venezuela demonstrates the inverse pattern in the first period, but in the last period it also does develop their sectors based on the existing prior capabilities.

The above countries did have weak results for the assessment of persistency as performed in chapter 5. The explanation for this weak performance relied on the high structural change which these countries underwent in the period of this study. Therefore the initial technological patterns could not explain the final technological patterns. Due to this failing of the persistency model based on intrasectoral characteristics we presented a possible complementing assessment tool to assign the development of the technological capabilities to the prior capabilities of the country. The results of the analysis did show the expected and significant results for some of the countries that had previously been identified as having undergone a major reallocation in their technological and export structure which could – expectedly – not be explained by the persistence of specialization within sectors. The countries that underwent reallocation of capabilities did not develop the new capabilities in random sectors, but rather in sectors which were close to sectors where the country was already strong at the start of the period. This finding confirms that the growing technological sectors rely at least partially on the capabilities that were already present in similar technological sectors. Therefore the process of reallocation of endowments is influenced by the past capabilities of countries.

7 Conclusions and recommendations for further work

The central question throughout this research was the validity of the concepts of technological paradigms and trajectories to explain the dynamics of the development of technological and export capabilities by countries. Our curiosity in studying the dynamics of structural change is that it offers the possibility to a country to achieve economic development through the replacement of a country's endowments towards higher productive sectors. In the preceding three chapters we performed a series of analysis to study the characteristics of technological and export change underwent by countries in the period 1976 until 1999. The empirical study was opened with a very illustrative graph (Figure 1, page 34) showing the dynamics of the countries, measured as the total reallocation (changes in shares) between the 25 sectors that form the technological and exports portfolio of the country. The assessed reallocation was employed as an indicator for the structural change of countries. Two characteristics of the structural change were demonstrated: i) the extent of structural change in exports and structural change in technology are strongly related, and ii) the extent of structural change and the growth of the country's technological and exports output are related. Two important conclusions can already be drawn: i) a country that is willing to increase its share in the worldwide market of technology and exports should be dynamic, and ii) higher success rate is obtained if the country develops both the technological and export capabilities. Using the definitions by Bell and Pavitt (1993), a country should develop the technological capabilities to understand, apply and further develop technologies as well as the technological capacities to be able to produce and sell the output at worldwide competitive prices.

Achieving structural change is, however, not an easy task according to the theory of technological change as presented by the evolutionary school of economic thought: technological change is rather achieved by an accumulation of knowledge within the already strong sectors instead of a constant shift from endowments between technological sectors. The explanation for this cumulative characteristic can be found in the micro-processes of innovation as deployed by the involved professionals. The activities of these professionals are guided by their past experience, formal and tacit knowledge and the environment in which they operate.

The different chapters of the empirical part explain the observed dynamics. Table 14 eventually summarizes the results, giving an overview of the development of the exports and technological capabilities of the countries throughout the period. As such it acts as a taxonomy to allocate the 33 countries to specific groups. The lost of individual characteristics due to the generalizations needed for categorization are kept to a minimum. The table lists all 33 countries in column 1. The results of the different analyses are divided over the columns. The results obtained from chapter 4 are given in column 2, 3 and 4. Column 2 indicates the degree of structural change as obtained from the analysis related to Figure 1 (page 34). Column 3 indicates the different components of the decomposition of the participation of countries in worldwide technological output (Table 6, page 39). Column 4 does the same, but for the participation of countries in worldwide exports (Table 8, page 47). Columns 5 and 6 demonstrate the results obtained in the analyses of chapter 5. Column 5 shows the results of assessment of causality between the specialization in exports and the specialization in technology, observing which of these came first. If technological specialization was developed prior to commercial specialization it is called the 'technological gap relation' (TGR), conversely, if export specialization came prior to technological specialization it was an indication for the 'catch-up relation' (CUR). The co-influence of both is indicated by COI. We assessed this relation as an initial assessment for the possibility of using export figures as indicators for technological capabilities build up through imitation activities. In the same chapter we analyzed the degree of persistence of countries for technological and exports output, according to the results obtained in Table 10 (page 58). Finally column 7 indicates the results obtained for the assessment of structural change explained by the 'opportunity' methodology, described in chapter 6.

		Column 1	C2	Column 3			Column 4			Col 5	Column 6		Col 7
		Country	A	Participation in technology			Participation in exports			Assess-ment of causality	Assessment of persistence for…		Assess-ment of opportuni-ty
				B	C	D	B	C	D		Tech.	Export	
Developed western economies	Techn.advanced	USA			*								
		Germany								TGR			
		France			*								
		UK								TGR			
		Italy						+		TGR			
		Switzerland		-									
		Sweden								TGR			
		Netherlands			- *	-				TGR	+		
		Austria	-				-		-	TGR			
		Norway										+	
	Tecn.backwar	Canada								TGR			
		Australia											
		Belgium						-					
		Spain					*			COI			
		New Zealand								COI	0		
		Denmark								COI			
	Upco	Finland	0										
		Israel											
		Ireland		+									
Asian countries	Advanced	Korea Rep.				+				COI	X		+
		Singapore						+		CUR *		0	+
		Japan	1						1	COI			
		Taiwan	+				+		+	COI	0	+	
		Hong Kong	1						1	COI			+
	Upcomi	India	4		0				4				
		China						-					
		Malaysia								CUR		0	
		Thailand								CUR			+
Latin America		Brazil				-					X		
		Venezuela	3										+
		Chile	0	-			-		-			+	
		Mexico	2				2		2		0		+
		Argentina								CUR			

Table 14 – Summary of the dynamics for the analyzed countries

Source: based on results from the analysis presented in chapter 4 , 5 and 6.

Valuation on a likert-scale: '+' = agrees with assessed dynamic, '0' = middle term, '-' disagrees with assessed dynamics

Notes: A – Degree of structural change underwent by the countries as obtained from Figure 1, page 34

B – Overall result for the technological/export performance: increase or decrease of worldwide participation?

C – The influence of the initial pattern in the technological/export performance: good starting profile?

D – The influence of reallocation throughout the period: changes in agreement with expanding sector?

Column 6: TGR: technology gap relation; COI: co-influence; CUR: catch up relation.

* – indicates an exception for the given general assessment: for example Spain experienced an increase of exports (component B, column 4), even though it is among a group of countries which all lost shares in the period

1 – Japan and Hong Kong have not reallocated their capabilities, but the structural decomposition revealed that at the start of the period they were already located in the expanding sectors, which explained their growth in the period.

2 – Reallocation from Mexico was mostly in exports, explained by their 'maquila' industry

3 – Reallocation from Venezuela was mostly in the patents, possibly explained by the high importance of natural resources exports for this country

The performance of the country is indicated with signs arranged according to a 'likert-scale' ranging from '+' for complete agreement, through '0' for middle term up to '–' for disagreement with the assessed indicator. Whenever applicable, 'X' indicates that no significant values were obtained. For each component we defined the countries belonging to that characteristic by a common space for them (the shading is only meant for a clearer differentiation between the different clusters). Therefore the results of each component can be read on the vertical plan. One observes that from the USA until Austria all countries share the same characteristics for the components and therefore they are taken as a cohort: the characteristics of countries and cohorts should be read on the horizontal plane.

The table also indicates situations in which a country belongs to one cohort of countries for certain characteristic, and to another cohort of countries for another characteristic. An example of such a country is Finland: it has characteristics similar to dynamic Asian countries for the technological indicators of column 3, but also shares characteristics of the developed western countries when it comes to the shrinking of worldwide exports (C4) and the persistent pattern of exports (C5). This illustrates the richness of details, and at the same time the difficulty of aggregation. Eventually we obtained, grossly speaking, five cohorts of countries. The first cohort ranges from the USA until Norway, developed western economies. The second cohort ranges from Canada to Denmark, also developed western economies, but who achieved more technological growth in the period 1976 – 1999. The third cohort comprehends Finland, Israel, Ireland and 5 Asian countries. These are the countries that achieved the highest growth in technological capabilities. There is a second set of Asian countries that underwent technological and export growth, but not as far reaching as the previous group. Finally there is a set of Latin American countries whose participation in worldwide exports and technological capabilities did not change much. Further characteristics of the cohorts are described in the following paragraph. There is one large cohort of developed western countries, ranging from the USA up to Ireland. This set of countries can be divided into three subgroups: the first group ranges from the USA up to Norway. The second group ranges from Canada to Denmark. The last group consists of Finland, Israel and Ireland. The first two groups experienced a low reallocation of capabilities throughout the period (negative sign in C2). Column 6 confirms these results, by indicating the highly significant results obtained for the persistency analysis for both technology and exports. The difference between the two groups is indicated by components B and C, from respectively columns 3 and 4. The first group of countries lost participation in the worldwide shares, while the second group improved their technological participation. At the same time the first group demonstrates an export pattern that is consistent with the expanding sectors, while the last group demonstrates an export pattern that is not consistent. We interpret this pattern as a demonstration of convergence of the second group: they started from a less privileged position in the exports (negative sign in component C, column 4) and compensated this backwardness by a further improvement of their technological participation worldwide. Probably the uninteresting and backward pattern of their exports sectors stimulated programs for technological improvements, leading to the registered growth of patenting. This has, however, not resulted in large reallocation of endowments or changes in the overall structure, indicated by the persistent structure (indicated by C2 and C6). Finally we arrive at Finland, Israel and Ireland, countries with a pattern that has both characteristics belonging to the Western developed countries, such as the persistence of exports (column 5), but as upcoming countries they do also share characteristics with the upcoming Asian countries. Ireland resembles most the Asian pattern, and is therefore analyzed together with this group. The group of Asian countries is also divided in two groups. The first group does consist of the 'advanced' countries (Korea, Singapore, Japan, Taiwan and Hong Kong) and the second group of the 'upcoming' Asian countries (India, China, Malaysia and Thailand). All these countries (and Ireland) share the following characteristics: high indices for the reallocation of activities and an increase in the worldwide shares of technological capabilities and exports. At the start of the period these countries had a small technological base, which is indicated by the low values of the structural technology effect, indicated by a 0 in the component C in column 3. Due to these changes these countries were clearly not persistent in the studied time interval: this is revealed by the lack of significant result for the technological persistence and the low levels of persistence found for the export pattern. These are the most interesting countries from the development point of view, as they underwent a major transformation of their technological and economical performance. There is also an important difference between the two groups of countries: the first group (entitled 'advanced') is characterized by an increase of their technological capabilities in the economically more interesting and expanding sectors (component D, column 3). It is interesting to note that even though there are social and cultural differences between eastern and western economies, they do share common characteristics when it comes to the expansion of technological and export capabilities. Conversely the 'upcoming' Asian countries expand their technological capabilities into the shrinking sectors (negative sign in same column). The group of advanced countries already exported products in the expanding sectors at the start of the period (component C, column 4), while the upcoming countries exported products in the shrinking sectors (but started exporting products in the expanding sectors throughout the period, component D). We stress this difference by referring back to the taxonomy of development presented by Cimoli and Dosi (1995), where they describe that countries follow a temporal sequence of events in their course of development: step 1) acquisition of existing technologies; step 2) adaptation to the local environment; step 3) creation of innovative capabilities. We interpret the above findings as fitting into this taxonomy: the 'upcoming countries' are still in the first and second phase of the taxonomy, acquiring foreign technology through FDI (Archibugi and Pietrobelli 2003) and reflecting the first results of the adaptation stage by the increase of exports in the expanding sectors (which belong to the nowadays paradigm). The 'advanced' group is already in the third phase, what is indicated by their active participation in the advanced and expanding technologies.

The patterns for the Latin American have not changed much. The largest reallocation was found in Mexico possibly due to the maquila (reallocation in exports without accompanying reallocation of technological capabilities). Brazil, Venezuela and Chile did not present significant patterns for (one of) the intervals of the persistency assessment in column 5.

The results in column 6 demonstrate the assessment for the causality between technological and exports advantages. This assessment is based on the 'technology-gap model', which explains that technological capabilities precede export capabilities. The same model does also suggest that countries may catch-up by imitating technology from the developed countries. This strategy would then lead to the export advantages preceding the technological capabilities. The results demonstrate that indeed the empirical findings match the theory: the developed countries do present the technology-gap relation (TGR), while the upcoming developing countries present the catch up relation (CUR). There is also a large group of countries that experienced the co-influence relation. These countries are found in Europe and among the advanced Asian countries. We have previously observed that during the period under study their technological and export capabilities were improving towards the expanding sectors, demonstrating the catch up with the developed countries of the first group. This group is therefore consistently demonstrated to be more advanced in technology and exports than the last group, consisting of the upcoming Asian countries (China, Malaysia, and Thailand). Some of the countries in this group experienced the co-influence relation in both periods (cohort 1 to 3 and 3 to 5), while other experience the CUR in the first period (cohort 1 to 3), and the co-influence of export and technological capabilities development in the second period (cohort 3 to 5). This is an interesting outcome, that indicates that countries can indeed use imitation in the first stage of catch up, but will eventually have to deploy extensive technological activities (leading to USPTO patents) to further explore their exporting capabilities.

Column 7 demonstrates the results for the opportunity assessment: the influence of a strong sector in a country on the expansion of similar (weak) sectors. Therefore a sector is not only expected to influence its own further activities, but to also influence the activities of similar technological sectors. The results of the analysis did show the expected and significant results for some of the countries that had previously been identified as having undergone a major reallocation in their technological and export structure which could – expectedly – not be explained by the persistence of specialization within sectors. The interpretation is that the countries with persistent patterns for technological specialization as assessed in column 2 and column 6 have barely underwent reallocation, which is revealed by the non-significant results. The countries that underwent reallocation of capabilities did not develop the new capabilities in random sectors, but rather in sectors which were close to sectors where the country was already strong at the start of the period. This finding confirms that the growing technological sectors rely at least partially on the capabilities that were already present in similar technological sectors. Therefore the process of reallocation of endowments is influenced by the past capabilities of countries.

7.1 Recommendation for further research

Throughout this work we have cited a remark made by Montobbio and Rampa (2005) and Laursen (1999) about the observation that the more dynamic sectors offer a higher propensity for newcomers to enter. In the reviewed micro and macro dynamics of a country's development as described by the evolutionarists we have not observed such a remark, on the contrary, these authors prefer to maintain the explaining power of technological development based on prior capabilities of the countries. The empirical part shows somewhat conflicting results: In the analysis for the structural change underwent by countries (chapter 4, page 32) in the period 1976-1980 to 1996-1999 (based on patents) we have observed that the most dynamic sectors were basically concentrated in the electronics and the chemical engineering sectors. These would therefore be the sectors that would offer most opportunity for the upcoming countries. We observed, however, that the entrance of the dynamic countries was limited to the sectors related to electronics, so not all dynamic sectors were 'jumped on'. Additionally, we have observed that not all developing countries moved into the electronic sectors. As we have found no relation between the expansion of *all* sectors and the expansion of *all* countries, and, holding on the assumptions by the evolutionarists, we have not employed the characteristics of sectors in determining the expansion of a country, and therefore we solely explained the structural change of countries based on their prior specialization patterns. Although this is a legitimate question and research objective, one still can wonder what attracted *some* of the developing countries to *some* of the expanding sectors. According to the theory it would be expected that the electronics sectors were closer to the sectors in which those countries had prior advantages. This would also agree with the taxonomy of the development processes which say that the industrial development starts with low tech activities as textiles production and advancing through higher productivity industrial activities, such as electronics.

Another point worth of consideration for future research: The study of the influence of technological paradigms and trajectories in the technological pattern of countries was split into two analyses. Each analysis was based on the development of a central sector: the first analysis considered the past ‘strength’ of the own sector on the further expansion of this sector while the second analysis considered the influence of the neighborhood on the expansion of a sector. Therefore both analyses are rather complementary, and in this way they were used in this analysis. This complementary character of the analysis suggests that both analyses could be joined into one overall analysis with two variables: one variable for the influence of past capabilities of the sector in its further development, and a second variable for the influence of the capabilities in one sector on the development of the capabilities in the other sectors. What kept us from doing this in this current work is the different nature of the variables employed in the individual exercises. The first exercise employed the adjusted values for the comparative advantages indexes as dependent, while the second exercise was based on the change of shares throughout the periods as dependent. Future research could concentrate on a further measurement of the complementarities of both measures. This could result in a model that explains the influence of a sector on its own development and/or the development of close sectors.

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9 Appendix

9.1 USPTO granted patents and exports for each country

		Number of patents issued at the USPTO					Exports in current US$ (x1.000.000)				
		1976 to 1980	1981 to 1985	1986 to 1990	1991 to 1995	1996 to 1999	1976 to 1980	1981 to 1985	1986 to 1990	1991 to 1995	1996 to 2000
US	USA	194376	183787	219367	267624	284315	766	1078	1487	2465	3577
DE	Germany	27974	30286	38053	35200	32208	672	825	1558	1998	2540
FR	France	10322	10610	13902	14543	13177	386	472	807	1153	1427
GB	Great Britain	12680	11295	13630	12207	12115	346	460	693	988	1305
IT	Italy	3635	3972	5808	6057	5515	284	360	638	895	1133
CH	Switzerland	6443	5809	6476	5884	4758	107	135	259	360	413
SE	Sweden	4085	3631	4211	3488	4335	116	139	237	298	407
NL	Netherlands	3288	3375	4467	4294	4065	272	345	551	738	947
AT	Austria	1303	1349	1834	1668	1603	58	78	154	223	268
NO	Norway	457	401	575	592	702	55	90	128	181	244
CA	Canada	5580	5667	8203	10029	10758	247	374	522	732	1109
AU	Australia	1261	1453	2111	2173	2372	92	119	165	234	324
BE	Belgium	1282	1170	1511	1748	2338	215	251	458	613	711
ES	Spain	404	304	599	733	804	74	111	200	338	520
NZ	New Zealand	180	212	283	205	362	22	29	42	57	71
DK	Denmark	763	713	916	1006	1453	60	78	135	185	217
IL	Israel	493	687	1295	1682	2484	19	28	49	72	123
FI	Finland	537	748	1251	1654	2136	49	69	114	141	210
IE	Ireland	85	118	228	263	315	28	42	87	151	298
JP	Japan	32034	49153	85473	109037	107472	465	771	1321	1968	2275
TW	Taiwan	212	506	2330	6158	10732	64	125	292	479	665
KR	Korea Rep.	39	128	609	3821	10177	58	104	261	426	705
SG	Singapore	11	25	50	187	444	45	92	151	321	463
HK	Hong Kong	92	113	206	313	483	52	84	182	249	258
IN	India	62	46	81	140	278	33	44	81	127	198
CN	China	8	7	178	254	270	47	112	304	804	1524
MY	Malaysia	9	9	13	47	82	50	77	125	290	479
TH	Thailand	4	6	12	21	49	24	36	81	199	316
BR	Brazil	106	119	167	282	288	73	124	166	210	269
MX	Mexico	221	184	199	193	217	48	125	157	273	596
AR	Argentina	107	95	88	123	152	35	40	50	79	130
VE	Venezuela	24	53	108	130	116	52	71	69	81	122
CL	Chile	15	9	19	37	37	15	18	34	60	86

9.2 The 25 technological sectors and the related SITC and USPTO classes

Code and Description of technological class		SITC rev2 classes	USPTO patent classes
11	Tools–hardware–pipes–joints	695,628,677,678, 679,684-687,689,693	7,81,277,294,492,292,70,140,285, 16,100,279,403,72,249, 411,425
12	Receptacles–containers–supports–partitions–furniture	692,83,621,82	5,160,215,267,150,211,108,206,49,190, 217,297,248,383,220,312
13	Motors–engines–pumps	71,743	60,185,418,92,416, 91,415,123,417
14	Manufacturing–assembling–metal working	694,699,73,664-666, 671-676,681-683	29,79,163,228,271,493,270,412,53,147,164, 242,300,76,162,227, 59,157,226,266,402
15	Rotary machines and mechanical power	742	74,192,384, 188,303,173,269,464,474-477
16	Machining and cutting	696,728,24,63	30,125,234,408,483,225, 82,144,264, 51,142,241,409,451,470, 460,83,407
21	Material or article handling	744,745,749	141,198,222,406,193,187,212,232,186,209, 224,413,221,414,254
22	Earthworking and civil engineering	723	14,171,256,405,404, 37,172,299,166,175
23	Heating–cooling–buildings–fluid/gas handling	691,697,741,81	4,34,48,52,110,122,126,135,137,138,194,431, 432,15,62, 165,236, 182, 109, 169,237,454,251
24	Vehicles and transportation	722,78,79,625	104,180,246,291,298,440,296,410,105,213, 258,293,301,441,280,114,238,278,295,305, 152,244
25	Office devices–paper handling–coatings	725,726,25,641,895	101,229,400,199,283,118,276,401,453
26	Textiles and apparel	26,65,61,724,84,85	2,24,38,69,223,442,450,12,28,66,112, 8,26,57,87,245,68,139,289,19,36
31	Biochemistry	592,54	127,435,514,930,424,436,800,935
32	Chemical engineering	591,32,33,34,522, 531,532,554	23,96,196,205,366,502,510,44,134,201,208, 422,588,516,95,184,203,55,159,202,210,427, 117, 261,494,216
33	Organic chemistry	233,51,58,28,43,524,55 1,553,56	71,530,540,549,558,568,260,532,544,552,560,57 0,518,534,546,554,562,585,520-528, 536,548,556,564,987
34	Surgery–body care–cosmetics	872,667,897	27,132,512,604,623,128,482,63,433,600,606, 601,602,607
35	Materials–compositions–explosives	57,598,95,523,533, 661,662,663,688	42,86,106,156,420,501,75,102,149,65,89,148, 252,423,507, 419,428,508
36	Agriculture and farming	00-09,11,12,21,22,27, 29,232,42,721,727,41	43,56,119,231,449,54,111,168,47,99,131,239, 452,426,504
41	Computing and data processing	75	235,365,395,701,706,710,714,364,705,347, 369,901,702,707,711,380,700,360,371,902, 704,708,712,709,713
42	Electricity and electric power	35, 771, 772,773, 774, 775	136,219,313,320,333,361,392,200,310,174, 290,314,322,335,363,218,318,324,191,307, 315,323,336,373,327,337,388
43	Electronics and components classes	776,778	116,330,377,445,349,328,338,257,331,437, 505,438,439,326
44	Optics–radiant energy–photography	88	250,353,356,372,503,352,355,362,351,354, 359,378,396,385,399
45	Communications and networking	76	178,334,342,367,379,455,332,341,358,329, 340,343,370,381,348,375,382,386
46	Other science and engineering, measurement, nuclear	871,873,874	33,181,346,376,968,177,345,73,204,368,429, 976,374,430
47	Music–education–games	642, 892, 893	40,273,446,473,124,434