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THE EFFECTS OF CREATIVE DESTRUCTION ON INDUSTRY-SPECIFIC PRODUCTIVITY GROWTH

Creative destruction during economic shocks

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1 INTRODUCTION

1.1 Background and context of study

Productivity and productivity growth have lately become central themes in the Finnish public discussion. The slowdown in productivity growth has been often associated with the growth of unit labor costs, and the two have been mentioned as central reasons for the country's current economic distress. Among the Western countries, in which the recent financial crisis has slowed both economic and productivity growth, Finland has been diagnosed to suffer particularly harshly from stagnant productivity growth.

This thesis studies the dynamics of industry-specific microstructural changes in labor productivity. The data used has been decomposed following the Diewert-Fox decomposition as presented in chapter 4.1. A shift-share analysis is conducted, in which the focus is especially on the between component of labor productivity in Finland, because it serves as the most accurate indicator of the creative destruction process. The data spans from year 1975 to 2011 and covers the principal manufacturing sectors in Finland. The study focuses on four different productivity shocks. Two economic recessions, the early 1990s depression and the Great Recession that started from the United States and hit Europe around the year 2008, are economic shocks that had consequences of considerable size on the productivity of the Finnish industries.

In a ten years period ranging from 1975 to 1985, Finland experienced a stagnant phase in terms of productivity, in which its production had become rather ineffective. This ineffectiveness of the production was compensated by extremely profitable trade with the Soviet Union, though. (Maliranta 2014b, 17.) In the end of the 1980s, trade with the Soviet Union had fallen significantly because of a decline in oil prices, and Finnish firms had to reorient themselves towards the Western markets that were known as a lot more exigent. Luckily, Finland succeeded in finding new trade partners with relative ease. (Maliranta 2014b, 31 & Maliranta, Rouvinen & Ylä-Anttila 2010, 82.) Between the early 1980s and the early 1990s, Finland was transformed in a decade from a relatively closed economy into a global market economy. The financial system, that had been both heavily regulated and bank-centric, was fully dismantled and the country was also opened up for international trade by removing restrictions on capital flows and exportation and importation. (Maliranta et al. 2010, 80–84.) The first period in which productivity is studied in this research is therefore already in the 1980s around years 1984–1985 corresponding the opening to international trade and of capital markets that lead to a productivity shock.

As mentioned, Finland suffered a deep, national scale depression soon after in the early 1990s. It was defined as the deepest economic crisis any OECD country had faced after the Second World War till the time (Maliranta et al. 2010, 80–84). This is the second productivity shock the study concentrates on. Thanks to the significant changes in opening to trade and liberalizing the capital markets that had happened in the mid-1980s, Finland recovered relatively quickly from the early 1990s depression (Maliranta et al. 2010, 80–84). While the depression left Finland with plenty of unemployment and especially with lots of highly educated labor force unemployed, the new production units that emerged thanks to the expansion of the ICT-cluster hired a major part of this unemployed labor (Maliranta 2014b, 54–58). As compared to the 1980s, the Finnish economy had experienced huge changes, and the first signs of the technological revolution had become apparent as companies started to use ICT-technology across the board (Maliranta 2014b, 54–58). By late 1990s, Finland had become a knowledge economy located on the global technology frontier and had surpassed the OECD-average R&D-intensity. (Maliranta et al. 2010, 80–84.)

Productivity growth slowed down in the mid-1990s, after the technological revolution (Maliranta 2014b, 54–58). This can be explained through the concept of national competitiveness, which is closely related to creative destruction. If national competitiveness rises to an unusually high level, ineffective companies are able to stay in the market and even effective firms tend not to commit fully to working efficiently (Maliranta 2014b, 97). Maliranta (2014b, 98) considers that it is probable that the strength of the creative destruction mechanism fluctuates according to the cost-effectiveness of Finland, which in turn determines the evolution of exports.

Finland went through a stagnant phase preceding the latest economic downturns in 1995–2005, because its national competitiveness was boosted by a single firm which turned out to be a growth miracle, the ICT-company Nokia, and the growing technology cluster that was formed around it. (Maliranta 2014b, 17.) The creative destruction process that followed was, however, not limited to the ICT-cluster but rather affected a wide range of different industries. (Maliranta 2014b, 17.) Once the creative destruction process reawakened, there was also a significant change in production unit structures in large industrial firms in Finland in the beginning of the millennial, and companies expanded effective productive units while reducing the size of the less productive ones (Maliranta 2014b, 39). The ICT-cluster led by Nokia also collapsed in the later years, but this was not the only affected sector and the problems originated already from the early 2000s, when the Finnish cost-effectiveness had started to decline (Maliranta 2014b, 103). The so-called dot-com bubble that burst out around the end of the 1990s and in the early 2000s is the third productivity shock the study focuses on.

The period between the dot-com bubble and the global financial crisis, approximately from 2002 to 2007, serves as a period of reference and is expected to be a period of stronger growth. Around year 2008, the recent global financial crisis also known as the Great Recession, spread to Finland simultaneously with the rest of the countries in the European Union. Looking at the creative destruction mechanism, years 2005-2011 remind about years 1985-1991 corresponding the previous depression to a surprising extent (Maliranta 2014b, 17). Both of the periods were preceded by an extremely stagnant period, and both periods started economically well and nevertheless ended up in an economic crisis (Maliranta 2014b, 17). The Great Recession is the fourth and final productivity shock on which the study concentrates on.

Having reviewed the productivity shocks to be studied, it is necessary to define creative destruction shortly. Creative destruction is a mechanism, essentially the microstructural change, that happens between companies in a certain industry. The change is called microstructural, because the change happens at the micro level between single production units, and stems from resources being reallocated from less productive companies to more productive ones. As a concept, creative destruction is reviewed in more detail in chapter 2.1.

In Finland, researchers dispose of high quality, production unit specific data. The quality of the data can be fully taken advantage of by studying the structure and underlying components of productivity growth that are incorporated into it. Unfortunately, many researchers still content themselves with growth rate statistics originating from the system of National Accounts, even though this does not enable researching the structures of economy extensively. Aggregate productivity growth has been found out to correlate strongly with productivity growth within production units, and this is the principal structural component that is typically captured when looking at productivity growth statistics. Productivity growth within production units is growth created by production units that enhance their productivity internally by starting to produce products of higher quality than before or producing more products, in other words in a more productive way, in the current facilities. However, it does not account for the effects of creative destruction this study seeks to examine. Creative destruction is an interesting mechanism firstly because its effect arises with a lag and secondly because it covers the changes in productivity caused by entering, exiting and between established production units continuing in the market. Further reasons to research creative destruction are provided throughout the study, including in chapter 2.2. In short, there is a apparent need to produce research that takes advantage of the extensive microlevel firm statistics and is based on the Schumpeterian new growth theory approach. (Maliranta 2014b, 24–25.) This is also one of the fundamental reasons for performing this study.

1.2 Research questions and objectives

Theory suggests that the creative destruction process will be enhanced once technological progress augments as well as during, and directly after, economic downturns. Therefore, the study aims to determine whether there is evidence supporting the assumption that the creative destruction process accelerates during economic shocks. In this study, creative destruction is examined around the time of four important economic shocks in the past years in Finland: the financial shock on the second half of the 1980s due to changes in banking laws and market competition, the Finnish depression in the early 1990s that followed, the dot-com bubble and technological breakdown in late 1990s and by the turn of the millennium and finally the recent global financial crisis that started in 2008.

The study seeks to find out the nature of the industries that have lately benefited from creative destruction as a result of economic downturns and which type of industries have rather suffered thanks to the recent downturns and not experiencing microstructural change. It is also equally investigated, whether a distinction between R&D and ICT-intensive industries as opposed to capital and labor-intensive industries or rather between industries selling products within Finland and industries selling products abroad can be made when discussing the magnitude of creative destruction in these industries under the last few years. The study also aims to find out whether productivity growth has been reduced principally in a few important sectors driving the national productivity, which have been affected more than some other sectors, or whether the mentioned shocks have had effects on all manufacturing sectors simultaneously. The possible advantages and disadvantages that the recent evolution of productivity has had on the Finnish industries are also considered.

The following research questions are assessed in the study:

1. Does the creative destruction process accelerate due to economic shocks?

2. Which industries have most suffered productivity-wise from the two large recessions, first in the 1990s and now since 2008, and do these industries exhibit creative destruction?

3. What is the nature of the industries with strong/little signs of creative destruction?

4. Can R&D and ICT-intensive industries be dissociated from capital and labor-intensive industries in terms of creative destruction in the periods studied? Or are the differences rather accounted for by differences in the evolution of their

target markets, target markets being either international (export demand) or domestic (domestic consumption demand)?

5. Has productivity growth has been reduced principally in a few important sectors driving the national productivity, which have been affected more than some other sectors? Or have the shocks studied had effects on all manufacturing?

1.3 Limitations and study structure

The data used is from manufacturing statistics and therefore limited to the manufacturing industries and the private sector as explained in Section 4.3. Thus, the results presented might not be entirely applicable to other industries as such. As explained in the same Section 4.3, the choice of a geometric decomposition against an arithmetic or harmonic one, the choice of weighing production units as to their labor input shares instead of their nominal or real value added shares and the choice of not detrending the data though often common in the field, are decisions that might affect the obtained results in a fundamental way. It is equally important to acknowledge that there are numerous decomposition methods of which the geometric Diewert-Fox method have been chosen, and that the choice of method can also change the results dramatically. As explained in Section 4.3, ten representative combined sectors were chosen from sixty different sectors to account for all manufacturing industries, and where then classified into three different groups. Important to note, the selection of these sectors as well as the classification in use may have an influence on the outcome. Besides, some limitations are linked to the choice of productivity shocks studied: for instance, since the financial crisis is a very recent event and we possess of data spanning until year 2011, only very conservative predictions can be made regarding the recent financial crisis.

The study proceeds as follows: some central concepts and theory including significant recent studies in the field are first reviewed. Having reviewed the theoretical background of creative destruction and related fields, the decomposition method and the data are introduced, and the trajectory of aggregate labor productivity as well as of the different creative destruction components is analyzed during the productivity shocks in the scope of the study. An additional element, the possible correlation between exports and labor productivity in certain sectors as well as a second way of classification are introduced. The study ends with a summarizing Section including several final remarks on the findings and some predictions on the development of creative destruction in the near future.

2 CENTRAL CONCEPTS

2.1 Labor productivity and creative destruction

There are several different productivity measures, all of which have the same underlying idea: the productivity of any factor of production is the output produced by this factor of production divided by the input used to produce it. In this study, the focus is on labor productivity, which is simply defined as value added divided by the labor input (hours worked, for instance). Labor productivity can be thought of as the capacity of a firm to harness the full potential of its human resources. Firms tend to have an incentive to increase their labor productivity, since it is an very inexpensive way for earning more profits.

Creative destruction is a mechanism that can be measured through productivity growth, which can be decomposed in several different ways which then enable studying the factors that influence productivity growth in more detail. It is necessary to define what type of productivity is subject to the research. Theoretically, total factor productivity (referred to as TFP) could be used as a productivity measure instead of labor productivity. Total factor productivity is the part of productivity that does not come directly from any of the factors of production in use (such as physical capital and labor) and it includes intangible assets such as human capital and technology.

Since several measurement issues arise using total factor productivity, labor productivity has been chosen to be in the focus of the study. Labor productivity has been shown to correlate strongly with total factor productivity in previous research, and therefore labor productivity can be considered a fairly accurate indicator of productivity growth in terms of creative destruction. For measuring labor productivity, some simple measure of labor input such as total number of hours worked $L_{k,t}$ can be used on the input side. Real value added based labor productivity can be defined, for instance, as real value added $RVA_{k,t}$ divided by $L_{k,t}$, where real value equals the nominal value added $VA_{k,t}$ deflated by an industry specific price index. If the study has been directed to total factor productivity instead, this would get more complicated: on the input side, a nominal capital and labor cost per industry and per time period would be needed and choosing one or several suitable deflators would become a lot more complex. (Balk (2016), 16–17.)

Aggregate labor productivity is defined as a weighted mean of the real value added based labor productivity $RVA_{k,t}$ of all sectors, each of them are weighted with some factor $\omega_{k,t}$ demonstrating the relative importance of that sector in question. The development of that mean is then studied over time. An additional advantage in using labor productivity in the study instead of TFP is related to these weights. The weights are a lot more complex in the TFP case, because the use of nominal or real cost shares has to be considered first in order to be able to measure the importance of different industries. (Balk 2016.) Hence, the evidence found seems to support the idea of maintaining oneself with labor productivity when proceeding to this kind of analysis. The definitions introduced in this chapter are also referred to later in the study.

Having reviewed labor productivity, the study next examines the mechanism of creative destruction. The term was originally launched by Joseph A. Schumpeter in *Capitalism, Socialism and Democracy*, first published in the United States in 1942. Schumpeter can be considered an economist who was forgotten in mainstream economics because the ideas he presented have been particularly difficult to express in mathematical or statistical form. However, thanks to advances in economic methodology and the availability of production unit specific data, modeling Schumpeter's ideas has become feasible. (Böckerman 2001, 74).

Inspired by endogenous growth theory (reviewed in Chapter 3), many Schumpeterian new growth models have been created since the introduction of new growth theory in the 1980s. These models emphasize that adopting the newest technology available requires previous technology to first disappear or no longer be in use. By adopting the newest technology firms then enhance their productivity and this enables growth to be sustained on the economy level. According to this orientation, recessions have the ability to change the structure of an economy through structural change, which is exceptionally strong during economic downturns. This is caused by the fact that under recessions the value of the loss of production, which can be considered as the opportunity cost caused by reallocating production resources between production units and between industries, is smaller than when the economy grows strongly. (Böckerman 2001, 74–75.) The underlying idea of this thesis is to find out whether there is actual empirical evidence of the structural change augmenting during economic downturns.

Schumpeter describes creative destruction as an evolutionary process that is the essence of economic change (Schumpeter 2006, 82). Thanks to constant changes and continuous progress in different industries, the economic structure of a sector or an entire economy is completely transformed from within: new markets appear while existing organizations develop (Schumpeter 2006, 83). The underlying force, that makes less productive firms exit the industry and gives productive firms a strong incentive to stay, is market selection (Criscuolo, Gal & Menon 2014, 9). Presuming that previous firms and ideas give way to new production units and innovations, the appearance of new companies and new markets can be associated with creative destruction. According to Böckerman (2001, 78), Schumpeter (1987) describes the innate renewal of capitalism as creative destruction, in which the essence is exactly in how old structures are destroyed and give way for new, better structures. For Schumpeter, innovations include everything from organizational restructuring, the opening of new markets resulting from entrepreneurs' actions to the development of the financial system in addition to mere changes in production technology which is traditionally thought of as innovation (Böckerman 2001, 76).

In Schumpeter's analysis, creative destruction symbolizes capitalism. First and foremost, creative destruction is supposed to maintain the endurance and continuity of capitalism, which Schumpeter considers unable to achieve an equilibrium state, because the structure of economy is under constant change. It is important to note that the concept has been separated from its original context in its current use and that Schumpeter never distinguished creative destruction from capitalism nor gave any detailed definition of the concept. For Schumpeter, creative destruction is the cleansing of the production structures so that companies with new technologies and production methods replace previous ones. However, he does not clarify whether he means this from the standpoint of productivity. It could be that creative destruction has actually only been associated with productivity later on. This idea is supported by the fact that when Schumpeter talked about creative destruction, he discussed about it in the context of the lucrativeness of firms instead of productivity. However, Schumpeter's analysis is so versatile that interpreting creative destruction in a simpler, more defined way is more than necessary. (Schumpeter 1987, as according to Böckerman 2001, 76–81). This study is solely based on the notion of creative destruction in its current use and is therefore at least partly unrelated to the underlying ideas Schumpeter had on capitalism.

Creative destruction can be defined as productivity-enhancing structural change in companies (Maliranta 2014a, 21). Thanks to the creative destruction mechanism, the productivity of an economy or a sector grows, creating and destroying jobs accordingly (Maliranta & Määttänen 2011, 237). From the standpoint of an economy, creative destruction is a central factor driving economic growth regarding both productivity, which is augmented thanks to creative destruction, and employment, which is also affected by creative destruction on the aggregate level. Creative destruction is clearly one of the principal mechanisms forming productivity growth (Maliranta & Määttänen 2011, 234). Not surprisingly, creative destruction is a time-demanding process and many of its components take time to reveal their final effects (Schumpeter 2006, 83). Empirical studies on creative destruction have shown that it takes years for the creative destruction to materialize in the data: for instance, the positive effects of market entry are typically realized only later in the share transfer component (between component) (Maliranta & Määttänen 2011, 239–240). Already Schumpeter (2006, 83) pointed out that research should concentrate on the long-run performance of creative destruction: it is necessary to look at the process as a whole, and to look at it in time and at the effects the process may have in the future. Studying individual elements of the process exclusively might also lead to misleading results due to the interaction of the different components.

According to Schumpeter (2006, 83), firms' business strategies depend on their context and future implications and should, therefore, be seen in the role of enhancing creative destruction in order to create progress (Schumpeter 2006, 83). The problem lies right here: older companies and established industries, specifically firms in the end of their life cycle, tend to live in the perennial gale, as Schumpeter calls it, until sudden situations or general crisis arise and force the industry to make increasing productivity a priority (Schumpeter 2006, 90). This is practically true on an economy level as well: in the introductory sector, it was noted that an extremely high level of national competitiveness leads into ineffectiveness in the economy. Arising from the perennial gale as well as an increase in productivity after it has declined results in unemployment as well as other losses, but according to Schumpeter (2006, 90), there is no need to try to maintain non-viable industries in life.

Recapitulating, Maliranta & Määttänen (2011, 237) define the term as the mechanism in which former products, production processes and production units that have become inefficient or inadequate to market requirements are replaced by improved, new products and more productive production units and production processes. Nevertheless, Maliranta & Määttänen (2011, 237) consider that in terms of terminology, the term creative destruction is slightly misleading and should be reversed into 'destructive creation', because it is destruction that causes creation rather than vice versa.

2.2 The components of creative destruction

Creative destruction was previously defined as the change in microstructures, arising when new production units enter the market, older less productive units exit the market and when the production units that have already established themselves in the market grow at different speeds (Maliranta & Määttänen 2011, 234). Creative destruction can be decomposed dynamically at the production unit level as well as statically comparing the productivity levels within a sector. According to the dynamic decomposition, the decomposition method used in this study likewise, creative destruction can be interpreted as the difference between productivity growth of an industry and the productivity growth of the production units in that industry. It is essential to note that the productivity of an industry can decrease even though all production units in that industry increase their productivity. This is caused by positive net job creation that takes place primarily in production units of low productivity. This situation is a sort of reverse creative destruction, as a result of which industry productivity decreases. (Maliranta & Määttänen 2011, 238–240.)

In this dynamic decomposition, creative destruction consists of four different elements: the entry component, exit component, productivity growth within the production units and the share transfer between the surviving production units (Maliranta & Määttänen 2011, 239). The entry component is positive if the productivity of the firms entering the market in a certain time is higher than the productivity of the firms which were in the market already in the last period (Maliranta & Määttänen 2011, 239). However, the entry component is typically negative (Maliranta & Määttänen 2011, 239). This does not necessarily mean it has a negative effect on productivity: some of the entering firms are extremely productive and affect productivity positively through the between (share transfer) component (Maliranta & Määttänen 2011, 239). The effect of entering firms can also be realized indirectly through the former firms that remain in the market, since they are forced to ameliorate their performance in order to be able to stay in the market (Maliranta & Määttänen 2011, 239).

The exit component is positive if the general productivity level increases after the exiting firms have left the market (Maliranta & Määttänen 2011). Since the least productive firms in the market tend to be the ones that are obliged to exit the market, the exit component should generally have a positive sign. The size of the entry as well as the exit component depends on the proportional amount of entering or exiting firms as compared to the total amount of firms in the market (Maliranta & Määttänen 2011). Measuring the entry and exit components (and all components, in general) can be challenging since the measures are extremely sensitive to the quality of the data (Maliranta & Määttänen 2011, 245). To avoid this problem, Maliranta & Määttänen (2011, 240–246) compute the components for different sectors using several alternative data sources and the results obtained for the entry, exit and share transfer components in different sectors are very similar to each other despite the fact that the results have been conducted from different data.

Disregarding the entry and exit components that generally tend to even out each other, the productivity growth of an economy or a sector can be generated by two distinct mechanisms. First of all, the so-called within component can be measured by calculating how quickly production units are able to enhance their productivity under a specific time period. This is what is traditionally thought of as productivity growth. However, Maliranta & Määttänen (2011, 234–235) consider this method more vulnerable to measurement errors such as errors related to measuring product quality and to variations in the utilization rate of factors of production. They consider that measuring creative destruction and especially the between component, the second mechanism and measures microstructural change, gives more results in productivity growth analysis.

Because it measures microstructural change, the between component is also known as the structural change component, and the size of it depends on the productivity of new jobs created as compared to the productivity of the older jobs destroyed (Maliranta & Määttänen 2011, 234).

The structural change component (which may also be called the share transfer component, reallocation component, and the between component) is created between the firms that survive the creative destruction or, in other words, stay in the market after other firms have entered and others exited (Maliranta & Määttänen 2011, 239). The share transfer refers to the changes in labor input shares that happen between companies in the industry due to the creative destruction process. This can be also thought of as the reallocation of resources between firms that have passed from the initial experimentation and market selection phase to the phase where they establish themselves in the market (Hyytinen & Maliranta 2013, 1082). The between component stems from the changes in microstructures between production units, of which some grow constantly while others keep constantly decreasing (Maliranta & Määttänen 2011, 239). The growing firms tend to be firms in the beginning of their life cycle and with high levels of productivity (Maliranta & Määttänen 2011, 239). More productive firms grow at the expense of less productive ones, and this enables the industry productivity to grow faster than if resources had not been reallocated to the more productive production units (Hyytinen & Maliranta 2013, 1082).

Hyytinen & Maliranta (2013, 1082) research firm life cycles, age groups and labor productivity. They find evidence showing that the productivity-enhancing reallocation of resources between continuing production units (the positive effect of the between component) is mainly concentrated on firms that are middle-aged, ranging from 6 to 15 years old (Hyytinen & Maliranta 2013, 1082). They also conclude that rapidly growing, young manufacturing firms contribute negatively to productivity first through the entry effect as they enter the market and have a lower productivity than other companies already established in the market. Middle-aged firms grow relatively fast as well, but have already accomplished a higher level of productivity and therefore contribute positively to productivity through the between component. (Hyytinen & Maliranta 2013, 1086.) Therefore, the more significant the between component, the more there are growing, most likely middle-aged firms in the industry. In industries with lots of expanding, young firms, the between component is naturally smaller. (Hyytinen & Maliranta 2013, 1093.)

As mentioned in the introduction, the between component has received a lot less attention in economic literature than the entry and the exit components of creative destruction have. Recent studies show that the entry phase and the final phase in a company's life cycle last for years on average. Since the entry and exit effect may take years to materialize in the data, it is likely that an important part of their productivity-enhancing effect is captured by the between component. Maliranta & Määttänen (2011, 239) also consider the between component as the most reliable component to study since most new entering firms do not have a direct effect on productivity (their effect on productivity is indirect through both the entry and the exit components) and because the entry and exit components seem more sensible to definitional issues and to how well the data is able to cover small production units. (Maliranta & Määttänen 2011, 239.)

Summarizing, the between component seems to be the most relevant and reliable measure of the microstructural change. It is a relevant component to study, because it consists of interesting temporal phases and because most of the entry and exit effects actually show up in the between component. The between component seems to explain some significant differences in productivity growth in Finland between certain time periods, between different sectors, between different regions and between different countries (Maliranta & Määttänen 2011, 234). It is also reliable in the sense that it is a lot less sensitive to measurement errors than the entry and exit components and seems more robust than within productivity growth for which analyzing trends has been found relatively difficult (Maliranta & Määttänen 2011, 234–235). Therefore, the empirical section of the study concentrates especially on the between component.

2.3 Prerequisites of creative destruction

Several prerequisites have to be met in order for the creative destruction mechanism to be able to function in an industry. First of all, innovations and ideas have to be non-rival and excludable, as considered in the economics of ideas (Jones & Vollrath 2013, 82). Non-rivalry means that technology, for instance, can be used by several people without having to fear about running out of it, while physical goods might run out relatively likely if used in large amounts. Excludability refers to the fact that technologies have to be able to be patented, while patents, in turn, make it possible for the innovator to charge some compensation from others wishing to access the technology in question. For an entreprise to be able to innovate and then sell this innovation in the form of a product or service to customers, a functional patent system, an entreprise grant or other innovation funding system as well as many other characteristics of a welfare state, are required. Kerr, Nanda & Rhodes-Kropf (2014), who focus on the entering and exiting units in creative destruction, see creative destruction as an experimentation process. They identify certain frictions that slow down innovating and experimenting with new innovations and business ideas, and list as such the costs of experiments, organizational frictions, financing risks and decisions of individual investors (Kerr et al. 2014, 35–40).

Since the dot-com boom in the late 1990s, technological change has lowered the costs of experimenting in both software and information technology, as well as in very capital-intensive industries thanks to the introduction of new technologies such as supercomputers that can simulate the operation of a nuclear plant or cloud computing. Since the costs related to initial testing have been reduced significantly, projects that would previously have been impossible to invest in have become interesting investments. Thus, technological advances can be considered as a factor that has likely accelerated the creative destruction mechanism.

Organizational frictions, on the other hand, refer to problems such as the lack of ability to dismiss unsuccessful projects. This difficulty tends to be common for both executives and project managers in large companies and for politicians, while external investors such as venture capitalists are more flexible and understand that when innovating, some experiments also need to fail. In large organizations, this may even lead to innovating less as project managers try to avoid taking over projects that might fail. (Kerr et al. 2014, 35–38 and 43.) Therefore, for creative destruction to take place on the organizational level, testing the project in the first place needs to be sufficiently inexpensive for the project to be financed and then for innovative projects to be executed, willingness to take risks and also admit losses when they occur are required.

For innovations to be made, external financing is also often required. The financing risk is also a funding-related risk caused by financing in stages. Start-ups funded in stages have to return to the financial markets regularly for a new funding round, and there is always a risk that projects worth investing do not actually receive capital on the next round. If they choose to take larger funds at a time, the abandonment options become less valuable in the eyes of the investor. Projects that need to go back to the capital markets on several occasions suffer from the largest financing risk and are often also the ones that have the highest potential value in case conditional on succeeding. On the other hand, the advantage of the carrying out the experimentation process in stages is that entrepreneurs and investors can invest in risky ventures in rounds, making it possible not to invest the full amount at once. (Kerr et al. 2014, 28 and 38–39.) From the point of view of the 'creation side' in creative destruction, a market with sufficient funds to finance new innovations is also required for advances to be made and new ideas to be created.

The last friction mentioned is related to the decision makers, that themselves also affect investment decisions greatly. Individual investors choose to finance certain innovations, basing their decisions on incomplete information and significant uncertainty. The actual creative destruction type experimentation happens only was a project has been chosen to be funded, and individual investors are also the ones to interpret the results in the subsequent financing rounds. This is one of the reasons why government institutions should support innovation when profit-seeking and risk-minimizing investors do not have incentives to invest in research and development. (Kerr et al. 2014, 28 and 38–40.) Therefore, for innovation and R&D to be sustained at a minimum level and for some excellent start-up ideas with positive externalities in the society to become executed, some government intervention is needed to correct market frictions.

Finally, national laws and institutions, meaning both national laws and institutions and those of the European Union in the case of Finland, have been found to be of significant importance in driving productivity growth by creating incentives as well as in imposing or reducing costs on the ability of private agents to innovate (Kerr et al. 2014, 40). In addition, Bartelsman, Gautier & de Wind (2010, 4) claim that high firing costs and more generally stringent employment protection legislation could harm both productivity and innovation, because it decreases the size of innovative sectors. Therefore, the easier it is for a company to both hire and fire personnel, the more there will be innovation in such economy. For experimentation to happen efficiently, both entering the market as well as exiting the market has to be facilitated through institutions and government action, and therefore laws and regulations concerning themes such as bankruptcy (and limiting the personal liabilities of an entrepreneur in case of failure without trying to minimize business failure as this may lead to conserving unhealthy projects that should fail and hindering the creating destruction process) and employment protection play a crucial role. Kerr et al. suggest removing regulations that complicate entering the market and remind that governments are more likely to succeed in promoting innovation by reducing overall experimentation costs instead of investing in individual firms and ideas (Kerr et al. 2014, 42–43). In other words, the prerequisites for creative destruction are practically the same as for innovation on a more general context.

3 THEORETICAL BACKGROUND

3.1 Life cycle theory and growth theory

Life cycles are studied in several different fields: products, organizations, firms and industries are considered to have life cycles including a starting phase, continuation phase and final phase. In this thesis, the focus is on firm life cycles, also sometimes nominated industry life cycles. The existence of firm life cycles is the underlying idea behind the concept of creative destruction: firms have to be born, after which they either grow and establish themselves in the market or exit the market at this point. The firms that establish themselves and continue their activities also gradually pass onto a final phase in which they decline. In other words, firm life cycles and industry life cycle theory simply study firm age and size dynamics.

Peltoniemi (2011) reviews the literature related to the industry life cycle theory in detail. In industry life cycle theory, several distinct phases can be defined: industry emergence, transition to industry maturity and industry maturity. Industry emergence can be associated with new innovations and technologies, frequent entries and exits to and from the market, population-level collective learning that encourages innovation and R&D as well as organizational support. In the transition to industry maturity, firms experience a shift from short-term product R&D to longer term process R&D, and some dominant design, which is a sort of production standard allowing learning-by-doing along the production process, appears. The dominant design then leads to increasing production capacity and market shares being reallocated to the most productive firms or firms with technological innovations leading to greater product and process standardization causing a wave of exiting firms called a 'shake-out'. Another related area of study, though less researched, is the inter-industry effects. It is known of inter-industry effects that knowledge and entrepreneurs, among many other attributes, are spilled over from mature, established industries to new, emerging industries. Mature industries may also themselves create new, related industries. (Peltoniemi 2011, 350–54.)

It is necessary to note that industry life cycle theory is not the only field of study assessing firm dynamics: as areas with research on the same theme, Hyytinen & Maliranta (2013, 1080) cite also endogenous growth theory, Schumpeterian growth theory and study of economic development and industry evolution as well as models of technology- and innovation-based firm entry and growth. As key components making up productivity growth, Hyytinen & Maliranta (2013, 1081–1082) mention experimentation, selection, reallocation of resources and firm-level productivity growth. In firm life cycle theory, firms enter the market through the experimentation phase, which was considered from the perspective of prerequisites for creative destruction in the previous section. This phase is also consistent with firm entry as part of creative destruction.

According to Kerr et al. (2014), experimentation can be studied in two different frames of reference. The first one is experimentation at the economy level, taking place in market-based economies in which new enterprises compete with the products and technologies already on the market, and in which the fittest ones survive. The winners are selected by consumers through competition, and the experimentation process is driven by a promise of large rewards in case of success. New ideas, products and technologies are continually tested and either succeed or fail in the market. For this type of experimentation to become creative destruction, the production units losing market share need to be let to fail. The second frame of reference is experimentation at the micro level before the above mentioned ideas are able to compete in the market: in the venture capital market, for instance, few investors choose whether to invest in a new technology. This experimentation does not function through the market mechanism, since the investment decisions have to be made by investors with different incentive, agency and coordination problems before the experimentation takes place in the market, and therefore choices made by individuals become excessively important in the selection process. (Kerr et al. 2014, 26–27 and 44.) Even though this study is related closer to the typical market-based approach and entry barriers are left out of consideration for the moment, it is necessary to note that the existence of entry barriers might hinder the creative destruction process very likely.

The second phase of a firm's life cycle is market selection, which may consist of an industry 'shake-out' (a wave of exiting production units, as explained earlier), of technological competition as is generally considered in the Schumpeterian approach or of natural selection in its Darwinian sense (Hyytinen & Maliranta 2013, 1081–1082). Market selection is the force that makes less productive firms exit the industry and gives productive firms a strong incentive to stay (Criscuolo et al. 2014, 9). After market selection, certain firms continue in the market and others have exited the market. In the next phase, resources are reallocated among the continuing units. The reallocation of resources may happen in different ways: either through industry evolution, which is associated with the fittest firms getting to use the majority of the resources in the industry, the emergence of dominant designs (as described earlier) or the simple maturing of the industry. (Hyytinen & Maliranta 2013, 1082.) When the fittest firms, that are the most productive ones, gain resources from less productive companies, it is structural change that increases productivity in the industry. While resources can be reallocated to enhance productivity through structural change, firms can also grow from within. An increase in the average productivity growth of a firm can be due to internal restructuring, increases in or new kinds of R&D efforts, introducing new, more efficient routines, implementation of new technologies, catching-up with current technology and imitating firms with higher initial productivity among numerous other ways (Hyytinen & Maliranta 2013, 1082).

In practice, life cycles are often studied by separating firms into age groups. For example, Hyytinen & Maliranta (2013, 1084) separate firms into five age groups: entrants less than 1 years old, continuing units ranging from 1 to 5 years old, continuing units ranging from 6 to 10 years old, continuing units ranging from 11 to 15 years old and then exiting units 16 years or more. Hyytinen & Maliranta (2013, 1093) find out that entering firms have a negative effect on labor productivity. This effect is alleviated by the labor input share of entering or experimenting firms, which also remains small. Exiting units, on the other hand, have a prolonged positive effect on labor productivity which declines over the life cycle. A possible explanation for this is that the productivity gap between exiting and continuing units has narrowed down over the years. The contribution of the between component, the structural change the study focuses particularly on, also seems to vary with age as younger growing firms having a negative and middle-aged established firms a positive effect on the industry labor productivity.

The within industry growth, which can also be considered as average productivity growth, is the component that most clearly explains productivity growth (Hyytinen & Maliranta 2013, 1093), as mentioned in the introduction. Yet, its relative importance is somewhat questionable, because the relatively old production units also hold the largest share of industry resources and therefore even if they renew themselves extremely slowly, this enhances overall industry productivity more than the other components do (Hyytinen & Maliranta 2013, 1093). This bias in measuring the different components also explains why the within component has been studied much more as compared to the between component, and also sheds light onto why studying the between component is necessary in order to gain a broader understanding of the creative destruction mechanism.

Literature on economic growth, on the other hand, tends to start by describing growth as the explanation for cross-country income differences (see Romer 2012, 6–8 and Jones & Vollrath 2013, 1–2). The fundamental question that drives economists to study growth is why are some countries and regions wealthier than others: for instance, why are western countries wealthier than developing countries (Jones & Vollrath 2013, 1). The same question was already discussed by classical economists including Adam Smith in the 18th century (Blaug 1985, 35). The treatise for which Smith became famous focuses on the wealth of nations (Jones & Vollrath 2013, 1). Another renowned economist in the time was David Ricardo, who studied economic growth in the context of agriculture and Corn Laws. Together with many other economists, Ricardo brought up the concept of diminishing returns in the context of agricultural activity. He considered these returns were actually diminishing despite technological improvements. (Blaug 1985, 77). In addition, Ricardo concluded that only rapid technical advance could ensure continuous economic growth, and that there should be no state intervention to discourage technological progress (Blaug 1985, 133). It is important to note as well that Ricardo's model did not actually concern long-run but rather short-run growth, and with his model he aimed to demonstrate that the Corn Laws did not serve their purpose (Blaug 1985, 107).

Huge advances have been achieved in economic growth theory since the era of economists such as Smith and Ricardo. As Jones & Vollrath (2013, 2) put it, "the modern examination of this question by macroeconomists dates to the 1950s and the publication of two famous papers by Robert Solow". Solow explicitly modeled how capital accumulation affected growth and totally revolutionized the field by bringing forth technology as the one single factor explaining sustained, continuous growth (2013, 2). Solow's models were developed further on later in the 1960s and in the beginning of the 1970s, as numerous well-known economists from Arrow to Kuznets contributed to growth theory. Finally, in the 1980s, Paul Romer and Robert Lucas brought focus back onto economic growth by highlighting new factors affecting growth, namely human capital and the so-called economics of ideas. Romer also utilized advances in other areas such as those concerning the theory of imperfect competition to emphasize the importance of technology as an important input affecting growth. (Jones & Vollrath 2013, 2.) Recapitulating, modern economic growth theory can be divided into two distinct phases: the period of exogenous growth models, created in the 1950s, and the period of endogenous growth models, created since the late 1980s. Schumpeterian growth theory consists of models developed from the first endogenous growth models and serve as the theoretical framework most related to the concept of creative destruction. Therefore, the study starts examining neoclassical models, then proceeds onto studying endogenous models and lastly reviews Schumpeterian models briefly.

3.2 Neoclassical growth theory

Probably the largest issue that classical models preceding neoclassical models had was that they were unable to explain sustained economic growth. Growth had been explained merely by two factors of production, capital K and labor L, but economists soon realized that just concentrating these two factors was not enough to explain continuous growth perceived in empirical data. The previous growth models were perfected by adding a new factor describing technological or knowledge-based (R&D) growth, often denoted with letter A. Technology was first considered as exogenous, and this is why they are also often referred to as exogenous growth models (as opposed to the endogenous growth models they were followed by). Exogenous growth models are sometimes simply referred to as the Solow model or the Solow-Swan model, probably the most renowned single growth model in economic theory. An updated version of the Solow model based on the presentations of Jones & Vollrath (2013) and Romer (2012) is presented in this chapter.

The Solow model evolves around two key equations: the production function equation and the capital accumulation equation (Jones & Vollrath 2013, 22). In the Solow model case, the production function is often expressed in the Cobb-Douglas form:

$$Y = F(K, AL) = K^{\alpha}(AL)^{1-\alpha}, \tag{1}$$

where α is a scalar with between 0 and 1 and constant returns to scale are also assumed. The production function describes how inputs such as capital and labor produce output. In this specification, the output produced in an economy (Y) is measured as a function of capital (K) and effective labor (AL). It is convenient to think of output Y as a country's gross domestic product (Jones & Vollrath 2013, 21). In addition, it is assumed that the economy only produces a single, homogeneous good which can be thought of as the GDP and that there is no international trade (Jones & Vollrath 2013, 21). Effective labor consists of labor (L) and the technological or knowledge factor (A), which is useful to have in a multiplicative form as term AL in the model, because the capital-output ratio seems relatively constant in practice. (Romer 2012, 10.) Jones & Vollrath (2013, 37) calls A a labor-augmenting term, meaning that technological progress makes labor more productive.

Note the general property of any function exhibiting constant returns to scale: the factor payments of the input factors, here labor and capital, use up the entire output produced (Jones & Vollrath 2013, 23). There are no additional economic profits to be earned by specialization, meaning that the economy is assumed to be large enough for new inputs to affect the output only in the same degree than older inputs did. Secondly, it has to be assumed that other inputs than capital K, labor L and technology A are of relatively minor importance and can be left out of the model without distorting the results. (Romer 2012, 11.) Unlike in certain other models, time t enters into the function indirectly through variables $Y(t)$, $K(t)$, $L(t)$ and $A(t)$, instead of entering the function directly. As a consequence, for output to grow in time when holding capital and labor constant, there has to be technological advancement. (Romer 2012, 10.) For reasons of simplicity, it is denoted $Y(t)$ by Y, $K(t)$ by K, $A(t)$ by A and $L(t)$ by letter L henceforth where possible.

The Cobb-Douglas production function (here referred to as the CD-function) was originally created by Charles Cobb and Paul Douglas already in 1928 (Jones & Vollrath 2013, 22). The production function assumes constant returns to scale, and firms are maximizing their profits by maximizing the equation

$$\max_{K,AL} F(K,AL) - rK - wL. \tag{2}$$

(Jones & Vollrath 2013, 23.) The production function (1) can be placed into the maximization equation and derive the first order conditions, setting them to zero followingly:

$$\frac{\partial F(K,AL)}{\partial K} = \alpha \frac{Y}{K} - r = 0 \tag{3}$$

and

$$\frac{\partial F(K,AL)}{\partial L} = (1-\alpha)\frac{Y}{L} - w = 0. \tag{4}$$

The first order conditions yield $r = \alpha \frac{Y}{K}$ and $w = (1-\alpha)\frac{Y}{L}$, which can be interpreted in such way that firms rent capital until the price of the capital equals the marginal product of capital r and, respectively, employ more and more people until wage w reaches the marginal product of labor. Manipulating the same equations yields $\frac{rK}{Y} = \alpha$ and $\frac{wL}{Y} = 1-\alpha$, the share of output paid to capital and labor correspondingly. These output shares are also assumed to be constant over time. (Jones & Vollrath 2013, 23.)

We are often interested in expressing the functions derived above in the form of output per worker and per capita output. Therefore, y can be defined as equivalent to $\frac{Y}{AL}$ and k as equivalent to $\frac{K}{AL}$. Romer (2012, 11) calls this the intensive form. Utilizing the aforementioned CD production function, this yields the first key equation of the Solow model:

$$y = f(k) = k^{\alpha}. \tag{5}$$

This is the equation later referred to as the production function equation. The first derivative of the equation is $f'(k) = \alpha k^{\alpha-1}$, which is positive, approaches infinity as k approaches 0 and approaches 0 as k approaches infinity, and the second derivative $f''(k) = -(1-\alpha)\alpha k^{\alpha-2}$, which is negative (Romer 2012, 13).

The Solow model is a continuous time model: nevertheless, primarily the same implications apply for discrete time as well (Romer 2012, 13). The initial levels of capital, labor and knowledge are assumed as given and it is also assumed that they get positive values (Romer 2012, 13). Capital, consumption and population all grow at constant rates, which induces the so-called balanced growth path (Jones & Vollrath 2013, 38). The population growth leads to the fact that labor also grows at a constant rate, as does knowledge (population at rate n and knowledge at rate g). As related to capital, investments grow and capital depreciates at constant rates as follows (see both Jones & Vollrath 2013 and Romer 2012). The second central equation of the Solow model is the capital accumulation equation. It can be derived by assuming the following form for the differential of K with respect to t:

$$\frac{dK}{dt} = \dot{K} = sY - \delta K \tag{6}$$

(Jones & Vollrath 2013, 24), where $\frac{dK}{dt}$ denotes the change in the capital stock, sY the gross investment (investment rate multiplied by output) as well as δK the depreciation occurring the production process (depreciation rate multiplied by capital). Individuals are assumed to save a constant fraction of their income, sY, and that savings equal investment (Jones & Vollrath 2013, 25). Regardless of production, the capital stock depreciates every period with a constant rate δ, which is also assumed constant. The equation above can also be manipulated into the form $\frac{\dot{K}}{K} = s\frac{Y}{K} - \delta$ indicating that the growth rate of K is constant only if $\frac{Y}{K}$ is also constant (Jones & Vollrath 2013, 37). Taking logarithms of $k = \frac{K}{AL}$ yields

$$logk = logK - logA - logL \tag{7}$$

and differentiating

$$\frac{dlogk}{dt} = \frac{dlogK}{dt} - \frac{dlogA}{dt} - \frac{dlogL}{dt} \tag{8}$$

Noticing that $\frac{dK}{dt}/K = \frac{dlogK}{dt}$, this can be written in the form

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{A}}{A} - \frac{\dot{L}}{L}. \tag{9}$$

(Jones & Vollrath 2013, 39.) The last term $\frac{\dot{L}}{L}$ is the growth of labor force which can be denoted by population growth n so that there are nL new workers each period, that is

$$L = L_0 e^{nt}. \tag{10}$$

Taking logarithms and differentiating yields then

$$\frac{\dot{L}}{L} = n. \tag{11}$$

(Jones & Vollrath 2013, 26.) In the same way, the technology factor A is considered to grow at a constant rate g:

$$A = A_0 e^{gt} \tag{12}$$

which results accordingly in

$$\frac{\dot{A}}{A} = g \tag{13}$$

when taking logarithms and differentiating (Jones & Vollrath 2013, 37). In the equations presented above, the parameters n, g (as well as the parameter s in the capital accumulation equation) are considered exogenous. The sum of n, g and δ, the rate of depreciation of capital, is assumed to be positive (Romer 2012, 13). Since the growth rate of a variable equals the rate of change of its natural logarithm and can therefore be exponentiated, it is assumed that n and g grow exponentially, as presented above. (Romer 2012, 13–14.)

Expressing (6) in terms of capital per effective labor, the second key equation of the Solow model becomes:

$$\dot{k} = sy - (n + g + \delta)k. \tag{14}$$

(Jones & Vollrath 2013, 39.) This is the equation is later referred to as the capital accumulation equation. Having defined the two key equations of the model, the production function (5) and the capital accumulation equation (14), the implications of the model can be studied. The capital accumulation equation states that the change in capital per effective labor is determined as the difference of two terms, the first being investment per effective labor and the second term $(n+g+\delta)k$ describing population growth, technological growth and capital depreciation per effective labor. Romer (2012, 16) calls $(n+g+\delta)k$ the break-even investment, which refers to the minimum level of investment required in order to keep up the current level of k constant (remembering that $k = \frac{K}{AL} = \frac{k}{A}$). Some minimal investment is required because of capital depreciation (δk) and because the effective labor grows at rate $n+g$, meaning that capital has to grow accordingly, $(n+g)k$, to maintain the current level and not to fall (Romer 2012, 16). Now considering that the growth rate of both capital and effective labor is $n+g$ and one of the first assumptions that was made introducing the model was constant returns to scale, it can be deduced that output Y also grows at rate $n+g$ and moreover, capital per worker $\frac{K}{L}$ and output per worker $\frac{Y}{L}$ grow at rate g (Romer 2012, 17). According to the Solow model, the economy tends to an equilibrium situation, a balanced growth path leading to the steady state, where capital, labor and knowledge grow at a constant rate (Romer 2012, 18).

If the amount of investment per worker in the economy exceeds the necessary amount to keep the k constant, there will be a so-called capital deepening until a certain point k^* where $sy = (n+g+\delta)k$ so that the change in k, $\dot{k} = 0$. Accordingly, if the capital stock is larger than required to keep k constant, the amount of capital per effective labor declines until it falls to point k^*. The point where $\dot{k} = 0$ is called the steady state. (Jones & Vollrath 2013, 28–29.)

If there is no change in capital per effective labor but capital is growing, this is referred to as capital widening (Jones & Vollrath 2013, 28). The effects of capital widening and capital deepening can bee seen in Figure 1.

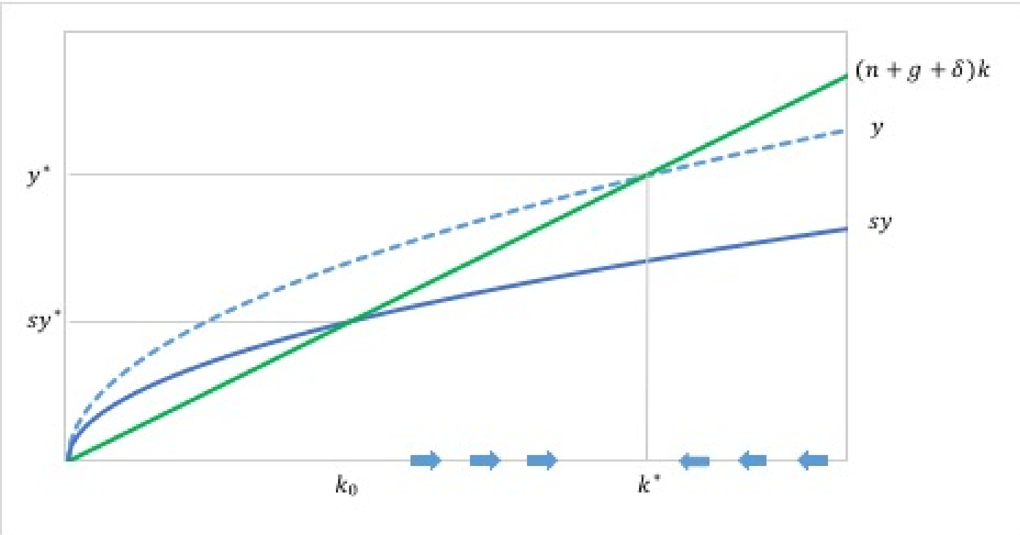

Figure 1: The Solow diagram

The figure, commonly known as the Solow diagram, determines the steady state value of output per effective labor, y^*, as a function of capital per effective labor, k^* (Jones & Vollrath 2013, 29). The steady state consumption is also shown in the figure as the difference between sy^*, the steady state investment per effective labor, and y^*, the steady state output per worker (Jones & Vollrath 2013, 29). The curve that reaches the point y^* is the production function, $y = k^{\alpha}$.

The Figure 2 demonstrates how shocks affect the steady state of the economy. If there is a shock such as an increase in the investment rate in the economy, the steady state value of y raises to another point y^{**} as the sy curve also shifts up to a new level $s'y$. Capital deepening leads to a higher level of steady state capital per effective labor k^{**} associated with y^{**}, a higher level of output per capita. According to the Solow model, an increase in the investment rate makes an economy richer than before. If, instead, the population growth rate increases due to immigration, for instance, the $(n+g+\delta)k$-curve shifts left to $(n'+g+\delta)k$ associated with a lower level of output per effective labor y° and a lower level of capital per effective labor k°. The economy ends up with less capital per effective labor and has therefore become poorer than before (Jones & Vollrath 2013, 30–32).

Countries that have higher investment rates (remembering that investments equal savings) accumulate more capital per effective labor and therefore will have more output per effective labor, ending up being wealthier than countries with high population growth rates, that spend all additional savings to keep their capital per effective labor ratio constant (Jones & Vollrath 2013, 33).

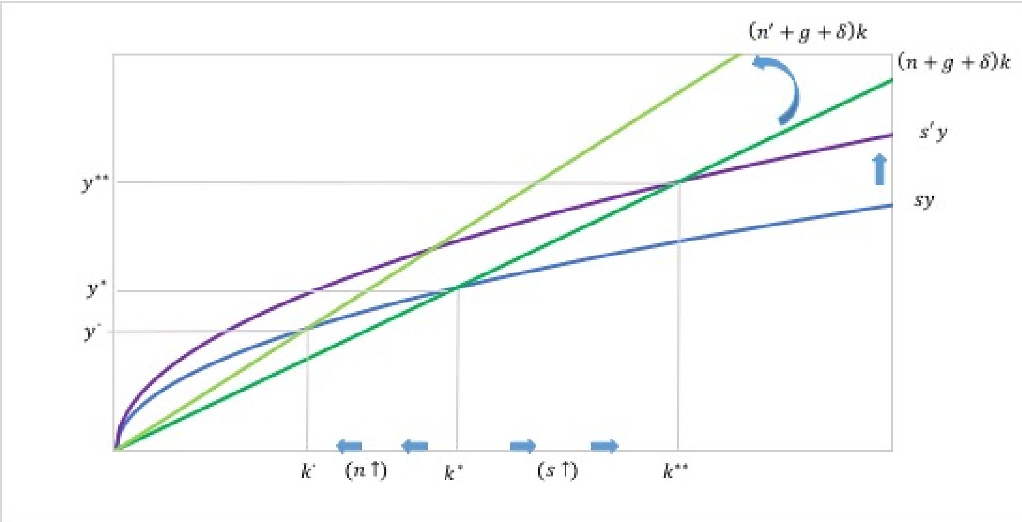

Figure 2: The Solow diagram with population growth and savings growth

The steady state equation for the optimal k^* can be calculated by placing the production function equation (5) into the capital accumulation equation (14) (Jones & Vollrath 2013, 28 & 32) , which yields

$$\dot{k} = sk^{\alpha} - (n+g+\delta)k \tag{15}$$

Setting the function to zero, it can solved for the steady state that:

$$k* = \left(\frac{s}{n+g+\delta}\right)^{\frac{1}{1-\alpha}} \tag{16}$$

and, substituting this into $y = k^{\alpha}$,

$$y* = \left(\frac{s}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha}}. \tag{17}$$

(Jones & Vollrath 2013, 39–40.)

An important feature to note is that changes either in the investment rate or in the population growth rate have an effect on the long-run level of output per worker, but do not influence the long-run growth rate of output per worker (Jones & Vollrath 2013, 40–41). For example, a policy change that leads to an increase in the investment (or savings) rate first causes an increase in the growth rate, but only temporarily before growth returns, moving along the balanced growth path, to its initial constant long-run rate g. However, the occurring change is a level change, meaning that the policy change can permanently increase or decrease the level of per capita output (Jones & Vollrath 2013, 43). When k (measured as $\frac{K}{L}$) is constant, y (measured as $\frac{Y}{L}$) grows at the constant rate g, the growth rate of technology (measured by factor A) (Romer 2012, 16). As Romer (2012, 16) defines it, if the savings (which can also be considered as investments) increase permanently, this generates a temporary increase the in g, the growth of output per worker. It is temporary, because k increases for some time but this increase cannot last as at a certain point all further savings go into preserving the higher level of k that has been achieved. For a more detailed description of the transition dynamics in the Solow model, see Romer (2012, 15–23).

There are numerous empirical applications of the Solow model. In his second article published in 1957, Solow (1957) introduced growth accounting which enables breaking growth down into different components: growth in capital, growth in labor as well as growth in technological change (Jones & Vollrath 2013, 45). The principal outcome of the Solow model is that the amount of capital accumulated does not seem to have a significant influence on economic growth (Romer 2012, 27). Differences in investment rates and population growth rates seem to rather explain differences in per capita income, and countries with a higher investment rate and/or lower population growth rate tend to allow more capital per worker to be accumulated and thus increase labor productivity (Jones & Vollrath 2013, 43–44). In other words, cross-country income differences seem to be easier to explain through differences in labor productivity than in capital per worker.

According to the Solow model, the only way for economies to grow is along the balanced growth path leading to the steady state, and growth slows down as the economy approaches its steady state and stops altogether as the steady state is met (Jones & Vollrath 2013, 34). In the model, technological progress is the only factor that is able to "offset the tendency for marginal product of capital to fall". In the long run, countries are expected to grow at the rate of technological change. (Jones & Vollrath 2013, 44.) Although technology is a central factor in the Solow model and all neoclassical models, the defect of these models is that technology is also left unmodeled and considered exogenous and constant (Jones & Vollrath 2013, 79). The concept of some steady state to which the economy converges to does not seem to be supported by empirical evidence either.

3.3 Endogenous growth theory

Endogenous growth theory was created at the end of the 1980s. One of the pioneers in the field was economist Paul Romer, who wrote a series of articles on endogenous growth theory, including a paper on technological change that was now considered endogenous, published in 1990 (Jones & Vollrath 2013, 98). The fundamental improvement as compared to the Solow and other neoclassical models was that long run economic growth was now determined within the model, thanks to the technology parameter that had become endogenous. Intelligent capital also known as human capital was equally incorporated into the model, which explains why the model is sometimes also referred to as the 'economics of ideas'.

Many other endogenous growth models were created at the time as well, among them the so-called AK-model, which turns around a production function as simple as $Y = AK$ and is completely linear. The AK-model is formally presented by Jones & Vollrath (2013, 216–226). While the Solow model represented knowledge and technology through the effective labor term, endogenous growth models explicitly model knowledge and the accumulation of it (Romer 2012, 101). The variable A can be interpreted as knowledge from which countries around the world can equally benefit from (Romer 2012, 110). The assumption that technology could grow at a constant rate, as was earlier presented in the case of exogenous models, is purely theoretical. In empirical data, technology does not seem to grow at a constant rate. The aim of new growth theory is therefore to avoid the incoherence between the theory and empirical observations by incorporating technology in to the model.

Just like in the Solow model case, $A(t)$, $K(t)$ and $L(t)$ are denoted by A, L, K respectively, and output $Y(t)$ by Y. It is also noted that A, K and L get positive values and their initial levels are taken as given. The endogenous state variables of the model are A and K (Romer 2012, 104) whereas Y and K were endogenous and A exogenous in the Solow model. To be able to model knowledge in such way, the economy is considered to have a specific sector (the R&D sector) where new ideas are produced (Romer 2012, 102). A combined production function incorporating labor, capital and technology such that they produce technological improvements in a deterministic manner is also assumed (Romer 2012, 102). In the endogenous growth model presented by Romer (2012, 101–134) and in several earlier R&D growth models presented in the 1990s, the output is modeled as a function of time in the following manner (Romer 2012, 103):

$$Y = [(1-\alpha_K)K]^{\alpha}[A(1-\alpha_L)L]^{1-\alpha}, \tag{18}$$

where $0 < \alpha < 1$.

The economy has two sectors, one that produces goods and the R&D sector, the fraction α_L referring to the labor force that is used in the R&D sector and the fraction $1-\alpha_L$ referring to the labor force used to produce goods (Romer 2012, 103). α_K is the fraction of capital stock used in the R&D sector and $1-\alpha_K$ the fraction of capital stock used for producing goods (Romer 2012, 103). Both α_L and α_K are exogenous and constant parameters (Romer 2012, 103). The production functions of the R&D sector and the goods producing sector have been simplified and are represented in a generalized Cobb-Douglas function form (Romer 2012, 102). The equation implies constant returns to capital and labor, but not necessarily for knowledge A (Romer 2012, 102–103). The capital accumulation equation for the model is equal to the capital accumulation equation presented in the Solow model case. The saving rate remains exogenous and constant (Romer 2012, 104). The expression for capital accumulation is

$$\dot{K} = s_K Y - \delta K. \tag{19}$$

(Jones & Vollrath 2013, 100.) In equation 19, s_K stands for the savings rate just like s did in equation 6 in the Solow model case, with the single difference that it is now explicitly emphasized that the savings rate refers to the savings rate of physical capital. However, for reasons of simplicity, the form $\dot{K} = sY - \delta K$ will be used in the equations that follow.

Population growth is also considered exogenous and constant and to be positive at all times and works exactly as presented in the Solow model case equation in (11). In endogenous models, the focus is on the state variables A and K and particularly on the dynamics of the growth of these variables ($\dot{A}$ and $\dot{K}$ respectively) (Romer 2012, 111). $A(t)$ is the stock of knowledge or ideas that have been invented at any time before time t, making the time derivative of the knowledge factor $\dot{A}$ the amount of new ideas produced (Jones & Vollrath 2013, 100). $\dot{A}$ also works as the knowledge production function, and assuming a CD-production function, it can be defined as

$$\dot{A} = B[\alpha_K K]^{\beta}[\alpha_L L]^{\gamma} A^{\theta}, \tag{20}$$

where $B > 0$ (and B is a shift parameter), $\beta \geqslant 0$, $\gamma \geqslant 0$ (Romer 2012, 103). The production function of knowledge, unlike that of capital and labor, is not assumed to have constant returns to scale: there might be diminishing or increasing returns in R&D, but it is very unlikely that $\dot{A}$ would be constant (Romer 2012, 103), meaning that the same amount of new ideas would be created each period (Jones & Vollrath 2013, 104).

As was mentioned earlier, there had been advances in the theory of imperfect competition that Romer took advantage of when creating his endogenous growth model. The variable A is known to have increasing returns to scale (see equation 12), and for there to be increasing returns on knowledge or innovations, there has to be imperfect competition in the market that compensates researchers for their research effort. For comparison, in the Solow economy, there is no remaining output to compensate people that invest their time in researching. In other words, imperfect competition is absolutely necessary for research to be done and is, thus, a crucial factor making sustained economic growth possible. (Jones & Vollrath 2013, 117–119.)

Whether capital and knowledge modeled in the production function (18) have on the net increasing, decreasing or constant returns to scale depends on their returns to scale in the knowledge production equation (20). The degree of the returns to scale of K and A in knowledge production is $\beta + \theta$. This can be seen from the abovementioned equations: if both K and A are increased by some factor Z in equation (18), this increases equation (20) by $Z^{\beta+\theta}$. Therefore, whether $\beta + \theta$ is greater, smaller or equal to one determines how the economy actually behaves. The long-run growth rate of the economy is determined in the model, and it is an increasing function of population growth n. This works also in the way that if there is no population growth, the long-run growth rate of the economy is also zero meaning that there has to be positive population growth for long-run growth to exist. (Romer 2012, 103-114.)

Long-run growth is unaffected by the fraction of labor force working in the R&D sector (as it is by the investment rate s), because α_L affects the growth rate g_A but does not affect $\dot{g_A}$, the subsequent behavior of g_A. This indicates that there is only a level effect but no growth effect. (Romer 2012, 106–107.) An interesting result, similar to the results for the Solow model case, is that even though long-run growth is unaffected by changes in the investment rate or in the amount of population working in the R&D-sector, policy changes affecting these factors do have a level effect as they affect the growth rate when growth moves along a transition path to the new steady state (Jones & Vollrath 2013, 106–107). This is the typical semi-endogenous model case, where long-run growth is endogenous and rises endogenously in the model, but depends solely on the parameters of knowledge production function and population growth and not on any other parameters. The model is called semi-endogenous as growth only seems partially endogenous in it. (Romer 2012, 114.)

If $\beta + \theta = 1$ and population growth $n = 0$ instead, the economy does not converge to a balanced growth path and stays steady no matter what the initial level of growth (Romer 2012, 109). The economy can be shown to have one single balanced growth path, and new knowledge depends on population growth and savings rate, both of which increase the long-run growth rate if they also increase. (Romer 2012, 115.) If θ alone is greater than one and capital is left aside, a marginal increase in the level of production of knowledge actually increases the growth rate of knowledge ever-increasingly and as a result, an increase in α_L (labor working in the R&D sector of the economy) has a huge impact on the in the growth of knowledge A (Romer 2012, 108). In the case that $\beta + \theta =$ 1, the intuition considering the effects of population growth is essentially the same. The economy's growth rate depends on various parameters and deriving it is complicated. Because long-run growth is dependent on so many different parameters, this type of models are called fully endogenous growth models (Romer 2012, 115–116.)

The parameter θ itself is the parameter describing how existing knowledge affects the technological process and the success of R&D in the future (Romer 2012, 103). θ can either get positive or negative values depending on whether previous findings and inventions facilitate or complicate making new ones (Romer 2012, 104). If θ is greater than zero, research becomes more productive thanks to past discoveries. If θ is smaller than zero, past discoveries make it increasingly difficult to be able to make new inventions. Finally, if θ equals zero, the most obvious ideas are so easy to find that this offsets the positive effect that previous inventions might have by helping researchers discover new ideas. (Jones & Vollrath 2013, 101.) Romer (2012, 107–109) describes different cases for different values of parameters θ and β more in detail. In the Solow model case, $g_y = g_k = g$ holds along the balanced growth path (Jones & Vollrath, 38). In the Romer model, output per capita, capital per labor and technology must all grow at the same rate along the balanced growth path meaning that $g_y = g_k = g_A$ (Jones & Vollrath 2013, 103).

To understand the rate of technological progress along the balanced growth path, it is necessary to first find out what is $\frac{\dot{A}}{A}$ (Jones & Vollrath 2013, 103). Proceeding just as in the Solow model case, first substituting the production function (18) into the capital accumulation function (19), yields

$$\dot{K} = s(1-\alpha_K)^{\alpha}(1-\alpha_L)^{1-\alpha}K^{\alpha}A^{1-\alpha}L^{1-\alpha} - \delta K, \tag{21}$$

see Romer (2012, 111). Diving this equation by K yields the growth rate of capital:

$$g_K = \frac{\dot{K}}{K} = s(1-\alpha_K)^{\alpha}(1-\alpha_L)^{1-\alpha}\left(\frac{AL}{K}\right)^{1-\alpha} - \delta \tag{22}$$

(Romer 2012, 111). Assuming that $\delta = 0$ and taking logarithms and differentiating with respect to time (remembering that K denotes $K(t)$, A denotes $A(t)$ and L denotes $L(t)$) shows the subsequent behavior of the growth of capital:

$$\frac{\dot{g_K}}{g_K} = (1-\alpha)[g_A + n - g_K] \tag{23}$$

(Romer 2012, 111), where $g_K(t)$ is denoted by g_K and $g_A(t)$ is denoted by g_A. Whether the right-hand side of the equation $g_A + n - g_K$ is greater, smaller or equal to zero determines whether g_K is rising, falling or constant correspondingly (Romer 2012, 111).

Now similarly for the growth rate of knowledge A, dividing both sides of equation (20) by A gives:

$$g_A = \frac{\dot{A}}{A} = B{\alpha_K}^{\beta}{\alpha_L}^{\gamma}K^{\beta}L^{\gamma}A^{\theta-1} \tag{24}$$

(Romer 2012, 111). Taking logarithms and differentiating with respect to time produces the subsequent behavior of the growth of knowledge:

$$\frac{\dot{g_A}}{g_A} = \beta g_K + \gamma n + (\theta - 1)g_A \tag{25}$$

(Romer 2012, 112). Similarly to g_K, whether the right-hand side of the equation $\beta g_K + \gamma n + (\theta - 1)g_A$ is greater, smaller or equal to zero determines whether g_A is rising, falling or constant correspondingly (Romer 2012, 112).

While in neoclassical models population growth n reduced the level of income along a balanced growth path, because more population meant that capital should also grow accordingly in order to keep the capital-labor ratio constant, the situation is different for fully endogenous models. Population growth is actually the key input creating new advances and knowledge growth, and having more population translates into having more new, non-rival ideas and can, therefore, be benefited of by everyone in the population. (Jones & Vollrath 2013, 104–105.)

Romer (2012, 143) notes that all knowledge accumulation models aim to explain growth on a global scale as well as cross-country income differences and also provide many possible explanations of what determines growth levels and incomes in different countries. What knowledge accumulation models fail to explain, however, is the non-rivalry of knowledge: even though someone uses certain knowledge, this does not prevent others from using it simultaneously. Some explanations have been sought for in reasons such as poor countries fearing for their intellectual property rights, not having access to past inventions and technology, as well as the lack of knowledge to use the available technology. It seems, though, that the main source of cross-country income differences is not caused by differences in the level of knowledge or technology in use, but rather differences in the factors that allow to exploit the technology. (Romer 2012, 143–144.)

Nevertheless, Romer (2012, 145) considers knowledge growth or accumulation of technology the main reason explaining economic growth when comparing previous centuries to the present, and that it would be necessary to be able to identify what types of knowledge are most important for growth and how much as well as how knowledge accumulates. Romer proposes to enhance the presented endogenous model by introducing human capital and social infrastructure and measuring not only physical but also human capital (see Romer 2012, 151–183). This is in line with Schumpeterian models that integrate innovations in to them, as shown in the following section. Schumpeterian growth theory is an alternative way to assess endogenous growth.

3.4 Schumpeterian growth theory

Where Romer treated new, technologically incremented versions of previous intermediate products as new varieties of goods, there is also an alternative specification where new products are considered the same goods with improved quality (Jones & Vollrath 2013, 98). In other words, alternative innovations completely replace existing intermediate goods (Jones & Vollrath 2013, 119). This specification was originally developed by Aghion and Howitt as well as Grossmann and Helpman in the early 1990s. They were preceded by Joseph Schumpeter who presented the underlying ideas already in the late 1930s and early 1940s by introducing the notion of creative destruction on which the model is based on. Therefore, this orientation in endogenous growth theory is known as Schumpeterian growth theory (Jones & Vollrath 2013, 98).

Schumpeterian growth theory has both a macroeconomic as well as a microeconomic aspect to it: in addition to merely studying the general macroeconomic structure of growth, it enables understanding microeconomic issues related to growth and for instance, who benefits and who suffers from innovations and human capital and what net rents do innovations have. Schumpeterian features in growth are that growth is generated through innovations, previous technologies are replaced by new innovations and innovations stem from private investments which are themselves motivated by gains from monopoly rents. Schumpeterian growth theory evolves around two equations, the labor market clearing equation and the research-arbitrage equation. (Aghion, Akcigit & Howitt 2014, 2–4.) Similarly to the Romer model presented above, the economy works in both R&D and goods production. Namely, there are three different sectors: the final-goods sector, the intermediate-goods and the R&D sector (Jones & Vollrath 2013, 124).

Innovation occurs in steps rather than in a continuous manner, and therefore Schumpeterian growth deals rather with expected than the actual values. For instance, trend growth of output per capita is dependent on the growth rate of technology in both Romer and Schumpeterian models, but in the Schumpeterian case, the trend growth of y actually depends on the expected growth rate of technology, that is to say that $g_y = g_k = g_A = E(\frac{\dot{A}}{A})$ (Jones & Vollrath 2013, 120–122). The aggregate production function is similar to the equation (18) in the previous model:

$$Y = K^{\alpha}(A_i L_y)^{1-\alpha}, \tag{26}$$

(Jones & Vollrath 2013, 120), where the index i stands for a certain idea, a version of some capital good, with a corresponding level of productivity. Everyone doing research is working on some version $i+1$ of the capital good i. Aggregate productivity is A_i (note the subscript i) and depends exactly on the version of capital good i that is used: for instance, A_1 can refer to the one of the first mechanical calculating devices produced, A_2 to the first computer and A_3 to a modern PC. In terms of productivity, there is a great difference in producing the same amount of goods with the productivity A_i or with the productivity A_{1+i}, and using a capital good x_i firms implicitly choose to use the productivity level A_i (Jones & Vollrath 2013, 120–128).

Since innovations happen randomly, a simple knowledge production function, such as equation (20) in the Romer model case, can not be written down. The knowledge production function has to be divided into the size of innovations (once there is innovation) and into the probability according to which innovations happen. Let γ denote the "step size", as innovations occur in steps and $\overline{\mu}$ denote the probability any individual doing research has to discover a new innovation. Note also that γ can equally be interpreted as the growth rate of A from one innovation to another, but not the growth of A in time, which depends on the probabilty according to which innovations occur. Consider that $L = L_Y + L_A$ where L_Y denotes all labor working in the final-goods sector and L_A all workers in the R&D-sector. (Jones & Vollrath 2013, 120–121.) Aghion et al. (2014, 3) call the equation $L = L_Y + L_A$ the labor-market clearing equation, because its states that the entire labor force is allocated either into production activities or to the R&D-sector. Now the probability for innovating for the entire economy is:

$$P(innovation) = \overline{\mu} L_A, \tag{27}$$

(Jones & Vollrath 2013, 120–121). A is expected to grow over time in the following manner:

$$E(\frac{\dot{A}}{A}) = \gamma\overline{\mu}L_A, \tag{28}$$

where γ denotes the size of innovation and the remaining term the probability of innovating as presented above. (Jones & Vollrath 2013, 122). The labor force growth and the capital accumulation equations are the same as in both the Solow and the Romer model cases presented, see equations (11) and (19). As innovations are random instead of happening at a constant pace, there is no exact balanced growth path that could be specified like was done in the previous cases. However, it is possible to talk about a balanced growth path with the average growth rate of output per capita (g_y) and of the capital-labor ratio (g_k), those being constant and equal to average growth rate of technological change (g_A) as shown in the beginning of the section. In the Schumpeterian case, it is more common to refer to technological change as productivity, making g_A the average productivity growth. (Jones & Vollrath 2013, 122). The average growth rate of productivity

$$g_A = \frac{\delta n}{(1-\phi)} \tag{29}$$

can be decomposed into population growth n, the duplication of research effort δ and spillovers ϕ. Note that γ does not enter the equation, because even though a larger γ boosts technology more each time innovations happen, the absolute size of A also grows meaning that each occurring innovation it take longer for the next innovation to occur, offsetting the positive effect (Jones & Vollrath 2013, 123.)

According to the Schumpeterian model, final goods firms hire labor until their marginal product equals the wage and purchase capital goods until their price is equal to what the intermediate goods market charges for them, similarly to the neoclassical model equations (3) and (4) with the slight modification of replacing L by L_Y and noting that capital K is now denoted by the capital good x_i and its first order condition yields the rental price of the capital good p_i. The intermediate goods market produces only one type of final good, that has a certain level of productivity. Therefore, innovations have a positive effect on output only if final goods firms actually purchase the latest version of the good. It actually turns out that the only version of the good produced is the latest version, since the intermediate goods market charges the same price for all versions of the good produced. All final goods firms choose to buy the latest version of the good associated with the highest level of productivity. The intermediate goods market is monopolistic, meaning that there is only one firm producing a certain good at a time. The situation is due to imperfect competition, a requirement for both the Romer and the Schumpeterian model: in the Schumpeterian case, imperfect competition shows in the market in such way that there is only a single intermediate good produced at once (which goes into the use of the final goods firms) and this good is produced in a monopolistic intermediate goods firm. This intermediate goods firm holds a patent for the latest design and has purchased it from the R&D sector. The monopoly also ends up receiving all the capital market funds to produce the latest version of the intermediate good. (Jones & Vollrath 2013, 126–128.)

In the research sector, on the other hand, all researchers aim to come up with the same innovation $i+1$, an improved version of the current capital good in the market, i. In case a researcher manages to come up with a new innovation, he patent sit and sell it onwards to a new intermediate-goods firm that replaces the previous one. Any firm producing intermediate goods is constantly under the risk of being replaced, and if replaced, will loose the value of the entire patent as final-goods firms only purchase the latest version of the good by definition. This is the essence of creative destruction: previous firms get replaced by new firms thanks to new innovations. In the Schumpeterian case, a patent for a certain design will eventually loose its value completely. (Jones & Vollrath 2013, 124–129.)

The price of a patent can be defined for both the Romer model as for the Schumpeterian model. In both models, the price of a patent depends on the discount rate that applies to the profits of innovating. The higher this discount rate is, the lower the share of labor working in the R&D sector, s_R, no matter which one of the two models is examined. However, in the Schumpeterian model, the price of a patent depends on additional factors (the mathematical form for the price of a patent of both models can be found in Jones & Vollrath 2013, 117 and 129). In the Schumpeterian mode, the price of a patent depends also on μ, the probability of coming up with a new innovation, and γ, the size of innovations. It making a new innovation becomes more likely than before and μ increases, At first, if the probability of innovating rises, the share of labor working in R&D, s_R, increases. If the value of a patent decreases due to an increase in μ increase, however, innovating becomes less attractive due to the higher risk of being subsequently replaced by another innovation and s_R falls. Remember, though, that the price of a patent also depends on the size of innovation. If the value (and the price) of the patent increases, the size of innovations increases accordingly. (Jones & Vollrath 2013, 129–131.)

To finally solve the model, it is necessary to first form what Aghion et al. (2014, 3–4) call the research-arbitrage equation, the second central equation in the model among the labor-market clearing equation. The research-arbitrage equation practically defines the wage of the skilled labor working in the final goods sector, w_Y, as equal to the expected wage of the skilled labor working in R&D in search for new innovations, w_R. Individuals are indifferent between working in the final-goods or in the R&D-sector, meaning that

$$w_Y = (1-\alpha)\frac{Y}{L_Y} \tag{30}$$

is equal to

$$E(w_R) = \overline{\mu} P_A, \tag{31}$$

where P_A refers to the price of a patent along a balanced growth path (Jones & Vollrath 2013, 130). The fact that the equations equal eachother means in practice that the wage earned from the final-goods sector must be the same as the expected wage in the R&D-sector. However, one must note that this is the expected and not the actual wage for the R&D-sector, and that in reality researchers earn either zero or the value of the patent P_A, depending on whether they innovate or not. (Jones & Vollrath 2013, 130.)

Both endogenous models, the Romer and the Schumpeterian model, have the same result according to which population growth n is essential for long-run growth and that policy changes can only have level and no growth effects (Jones & Vollrath 2013, 132). Empirical studies have shown that the positive externalities of R&D tend to outweigh the negative ones, and that generally the amount of research and development provided by the market alone is insufficient. For what goes to imperfect competition, classical theory considers monopolies as toxic for the economy and claims that firms should be prevented to be able to price at a price point surpassing the marginal cost, while the economics of ideas (endogenous growth theory) concludes that firms should actually be allowed to price higher than at the marginal cost since the profits created are an incentive for firms to fund innovation. R&D activities are also fully dependent on property rights, which enable the innovators to be compensated for their work by holding a patent. Social returns of R&D also seem greater than private returns, meaning that it is still worth investing in creating new mechanisms fostering more and more research. (Jones & Vollrath 2013, 134–136.) The results provided by the model are in line with the prerequisites for creative destruction listed in Section 2.3.

Both Aghion et al. (2014, 1) and Jones & Vollrath (2013, 132) see the Schumpeterian approach to growth theory as advantageous as compared to previous models because it is able to combine growth to firm dynamics as well as growth to industrial organization. The Schumpeterian model differs from the Romer model in the specification of the share of labor s_R working in R&D (note that this is denoted by α_L in the previous section). The difference lies actually in the level of income per capita which is created through a difference in s_R. The Schumpeterian model will provide a higher or lower share of labor engaged in R&D activities depending on the rate by which profits are discounted. Put otherwise, it is the way how individuals value the possible gains of innovation as opposed to the risk of not being able to come up with an innovation from which they can profit from. This can be interpreted as the sensitivity of individuals to either the 'creation side' or the 'destruction side' of the creative destruction process. Regardless of which of the two models is selected, the general results that policy changes have merely level and no growth effects and that long-run growth depends on population growth n hold. (Jones & Vollrath 2013, 132.)

In addition, endogenous growth models account for imperfect competition like mentioned previously. Competition tends to correlate positively with growth, and R&D-intensive industries tend to be associated with higher rates of job creation and job destruction (Aghion et al. 2014, 1), which also serves as a theoretic starting point for this study as the aim is to find out whether R&D-intensive industries have experienced more structural change that other industries in the past years, like the theory seems to predict. Schumpeterian growth theory focuses on long-term technological waves and might even explain the occurring productivity slowdown by providing an explanation for why these waves seem to increase the flow of firm entry and exit (Aghion et al. 2014, 1). Another important aspect is the concept of step-by-step innovation, which seems to fit empirical data a lot better than constant innovation (such as in the Romer model) would. Aghion et al. (2014, 6) consider that in sectors with initially little competition, more competition leads to innovations and productivity growth, whereas it has less positive or sometimes even negative effects in sectors with tough competition. The Schumpeterian model also grasps the idea of knowledge spillovers, meaning that technological advances and information spread in a way that makes it possible for current innovators to exploit the findings of previous innovators. Current innovators are expected to have a positive spillover effect on subsequent innovators but they are also expected to drive out older technologies, and this is a phenomenon called the escape competition effect (Aghion et al. 2014, 7). Competition has a central influence also on sectors with less intense competition, as in these sectors competition can even discourage innovating in stagnated companies that merely seek for short-term results since they do not have the need to become market leaders. This, in turn, is called the Schumpeterian effect. (Aghion et al. 2014, 7.)

Lastly, Schumpeterian growth theory also addresses the so-called catching-up effect meaning that economies with low levels of innovation and located far from the global technology frontier tend to grow faster than economies with a high level of innovation. In the long run, the economies with little innovation tend to fall behind the frontier, but nevertheless grow at the rate of the frontier thanks to knowledge spillovers. However, the sources of growth in economies with little innovation are necessarily not at all the same as the sources for particular sectors or countries experiencing a lot of creative destruction, and also institutions that enhance growth seem more efficient in the frontier economies. (Aghion et al. 2014, 20–21.) In this study, our main focus is studying creative destruction from the point of view of a single, small industrialized country, which can be assumed to be located rather close to the global technology frontier.

4 METHODOLOGY AND DESCRIPTION OF THE EMPIRICAL STUDY

4.1 The Diewert-Fox decomposition

There are numerous different decomposition formulas that can be used, and the choice of formula seems to affect labor productivity growth to such extent that different sectors may seem to drive growth under a certain period using different decompositions. They can be classified into arithmetic, geometric and harmonic decompositions. Balk (2016) reviews a large scale of different methods. He compares five arithmetic decomposition methods, the first four of them which are asymmetric and the fifth being symmetric. The comparison is done by the help of an arbitrary scalar a, and as different methods have a different reasonable choice for the value of a depending on the decomposition, and the value then affects the net entry and exit effect. Some of the decompositions have been widely used in literature while others are not known to have any empirical applications. (Balk 2016, 28–39.)

All of the arithmetic decompositions presented by Balk (2016) are based on the following equation:

$$PROD_t - PROD_{t-1} = \sum_{k \in \kappa_t} \omega_{k,t} PROD_{k,t} - \sum_{k \in \kappa_{t-1}} \omega_{k,t-1} PROD_{k,t-1}. \tag{32}$$

(Balk 2016, 29.) κ denotes the set of production units operating at the period in question, k a single productivity unit (expressly a firm), superscripts $t-1$ and t refer to time periods $t-1$ and t accordingly. $PROD_{k,t}$ is the index corresponding the productivity of a production unit at period t and $PROD_t$ the aggregate productivity level at period t. ω is a weight given to each production unit k and measuring the relative size or importance of the unit, and the weights add up to 1 on all periods. Production units in period $t-1$ cover both continuing units ($C_{t,t-1}$) and exiting units (X_{t-1}) so that $\kappa_{t-1} = C_{t,t-1} \cup X_{t-1}$, and production units in period t cover continuing units as well as entering units (N_t) so that $\kappa_t = C_{t,t-1} \cup N_t$. (Balk 2016, 20–21 and 28–29 and Hyytinen & Maliranta 2013, 1096.)

Since the approach that has been chosen is rather the geometric than the arithmetic approach, the aggregate productivity level needs to be defined as a geometric (instead of an arithmetic) average of the unit specific productivities:

$$PROD_t = \prod_{k \in \kappa_t} (PROD_{k,t})^{\omega_{k,t}}. \tag{33}$$

This is equivalent to

$$\ln PROD_t = \sum_{k \in \kappa_t} \omega_{k,t} \ln PROD_{k,t}. \tag{34}$$

(Balk 2016, 39.) The advantage of using this form is that changes can now be interpreted as percentage changes, since logarithmic changes equal percentage changes approximately, considering that the change is relatively small (Balk 2016, 39–40). The equation (32) can be decomposed into four parts:

$$\begin{aligned}
&\ln PROD_t - \ln PROD_{t-1} \\
&= \sum_{k \in N_t} \omega_{k,t} \ln PROD_{k,t} \\
&+ \sum_{k \in C_{t,t-1}} \omega_{k,t} \ln PROD_{k,t} - \sum_{k \in C_{t,t-1}} \omega_{k,t-1} \ln PROD_{k,t-1} \\
&- \sum_{k \in X_{t-1}} \omega_{k,t-1} \ln PROD_{k,t-1}.
\end{aligned} \tag{35}$$

(Balk 2016, 29). The first term is the contribution of production units entering the market where $\sum_{k \in N_t} \omega_{k,t}$ is the labor input share of entering units (defined as in Hyytinen & Maliranta 2013, 1096), the second and third terms show the contribution of continuing production units (units that have already established themselves in the market and operate on both periods $t-1$ and t) and the final term is the contribution of exiting production units. The two terms in the middle denoting the contribution of continuing units consist of both the productivity change happening within the production units, $PROD_{k,t} - PROD_{k,t-1}$, also referred to as the within component, and the relative size change happening between production units, $\omega_{k,t} - \omega_{k,t-1}$, also referred to as the between component. (Balk 2016, 29.) The significance of this relative size change which has been studied a lot less than the within component is also of interest.

The five arithmetic methods mentioned (as presented in Balk 2016, 28–38) consist of decomposing the equation (35) in different ways. Four of the five methods are decomposed in what Balk (2016, 28–35) calls Laspeyres- and Paasche-type measures, the names originating from index number theory. The fifth and the only symmetric method (as opposed to asymmetric methods) is the Bennet-type method that corresponds the Diewert-Fox method utilized in this study. The methods differ from eachother in how the terms are weighted: with a Laspeyres-type measure, Balk (2016, 28–35) refers to weighting a component using base period weights, and with the Paasche-type measure, to weighting a component using productivity levels of the comparison period. It is not necessary to choose between the different combinations of Laspeyres- and Paasche-type measures as what Balk (2016, 28–35) calls either the Laspeyres-approach or the Paasche-approach can also be chosen. In other words, either type of measure can be used for both the within and the between component. The problem that arises, though, is that a new covariance-type has to be added to the equation, and this covariance-type term does not have any empirical equivalent as it is an artificial term created due of the use of a certain method. (Balk 2016, 31–35.)

A related concept is the so-called Fox paradox or monotonicity problem, which refers to a situation where a productivity increase does not necessarily contribute positively to aggregate productivity change do to the decomposition in use. It is actually the between term, the measure of inter-unit relative size change, that might exert a negative effect on the productivity increase. However, the formula suggested as the solution to this issue requires setting the entering units and their corresponding productivity to zero at period $t-1$ (when these units have not yet entered the market) as well as setting exiting units and their corresponding productivity to zero at period t (when the exiting units have already exited the market). Because the logarithm of zero tends to $-\infty$, there is no geometric equivalent to the equation proposed, and the study therefore does not address the matter any further. (Balk 2016, 41–42.)

The data used in the empirical part of this study has been decomposed according to the geometric Diewert-Fox Diewert & Fox (2010) decomposition method, sometimes also thought of as a compound method and called the Vainiomäki-Diewert-Fox decomposition after Vainiomäki (1999), who created a similar decomposition in another context several years before Diewert and Fox (Balk 2016, 38). The decomposition method Vainiomäki first presented in 1999 is an augmented decomposition of another method based on the Berman, Bound and Grilliches-method already presented in 1994 (Berman, Bound & Griliches 1994), but which had only accounted for the between and within components. Vainiomäki augmented the BBG-presentation with the entry and exit components, because he noticed that the entry and exit components could change the balance of the between and within effects at the industry level as compared to the plant level conditional on whether entry and exit occurred within or between industries. Vainiomäki discusses a theme closely related to the concept of labor input shares as he talks about the share of skilled labor in his article. (Vainiomäki 1999.) Independently from Vainiomäki, Diewert & Fox 2010 came up with a similar decomposition in their article published in 2010. A related discussion paper was published already in 2005 (Balk 2016, 38). Diewert and Fox focus on accounting for the contributions that entering and exiting firms have on the industry productivity and on the other hand concentrate less on the between and within effects (which they call the productivity growth of continuing firms and continuing firm reallocation contribution), the components that have been seen as more dominant in studies in the past. (Diewert & Fox 2010.)

In the decomposition method proposed by Diewert and Fox, time is treated in a symmetric way so that “the industry productivity difference in levels between two periods reverses sign when the periods are interchanged, as do the various contribution terms". Several other studies have also proposed such symmetric decompositions in the late 1990's and in the beginning of the millennial. (Diewert & Fox 2010, 2.) The Diewert and Fox study tackles the idea, an assumption often made in Economics for reasons of simplicity, according to which there are multiple outputs and inputs each firm produces and uses instead of just one homogeneous output and one homogeneous input. Therefore normal index number theory cannot be used to construct output and input aggregates for each firm continuing in the market, considering that the firm is present in two time periods, t and $t-1$. Diewert and Fox propose using the multilateral index number theory in order to account for firms entering and exiting the market, since they are difficult to compare with any base observation. Using multilateral index number theory, the data of each firm's data in a certain period of time is treated as if it belonged to a country. Among the multilateral methods that had previously been in use, Diewert and Fox proposed a new alternative. (Diewert & Fox 2010.)

The Diewert-Fox decomposition can be presented equally in an arithmetic, geometric or harmonic form. Our decomposition is a combination of the method as presented by balk Balk (2016, 37–38) and Hyytinen & Maliranta (2013, 1096) and is:

$$\ln PROD_t - \ln PROD_{t-1} = \triangle \ln PROD_{t,t-1} = EN_t + EX_t + WH_t + BW_t. \tag{36}$$

The aggregate productivity change between two periods can be decomposed into the entry component EN_t, the exit component EX_t, the within component WH_t and the between component BW_t. The components are formed in the following way, starting from the entry component:

$$\begin{aligned} EN_t &= \left(\sum_{k\in N_t} \omega_{k,t}\right)\left(\ln PROD_{N,t} - \ln PROD_{C,t}\right) \\ &= \left(\sum_{k\in N_t} \omega_{k,t}^{N}\right)\left(\sum_{k\in N_t} \omega_{k,t}^{N} \ln PROD_{k,t} - \sum_{k\in C_{t,t-1}} \omega_{k,t,t-1}^{C} \ln PROD_{k,t,t-1}\right), \end{aligned} \tag{37}$$

where the relative size change (weight) of a production unit is given by its labor share:

$$\omega_{k,t} = \frac{L_{k,t}}{\sum_{k\in C_{t,t-1}} L_{k,t}}, k \in C \tag{38}$$

(Balk 2016, 33). The size of the entry component depends on the labor input share of entering units at period t as well as the productivity gap between the entering and the continuing units (Balk 2016, 38).

The exit component is:

$$
\begin{aligned}
EX_t &= \left(\sum_{k\in X_{t-1}} \omega_{k,t-1}\right)\left(lnPROD_{C,t-1} - lnPROD_{X,t-1}\right) \\
&= \left(\sum_{k\in X_{t-1}} \omega_{k,t-1}\right)\left(\sum_{k\in C} \omega^C_{k,t-1} \ln PROD_{k,t-1} - \sum_{k\in X} \omega^X_{k,t-1}) \ln PROD_{k,t-1}\right).
\end{aligned} \tag{39}
$$

The size of the exit component is dependent on the labor input share of exiting units at period $t-1$ as well as the productivity gap between the exiting and the continuing units (Balk 2016, 38).

The within component is:

$$
WH_t = \sum_{k\in C} \frac{1}{2}\left(\omega^C_{k,t} - \omega^C_{k,t-1}\right)\left(\ln PROD_{k,t} - \ln PROD_{k,t,t-1}\right). \tag{40}
$$

The within component have a positive effect on the productivity change if the productivity levels (indexes) of the production units increase on average (Balk 2016, 38).

Finally, the between component is:

$$
\begin{aligned}
BW_t = \sum_{k\in C} \left(\omega^C_{k,t} - \omega^C_{k,t-1}\right)\Bigg(&\frac{1}{2}(lnPROD_{k,t-1} + lnPROD_{k,t}) \\
&- \frac{1}{2}(\sum_{k\in C} \omega^C_{k,t}) \ln PROD_{k,t} + (\sum_{k\in C} \omega^C_{k,t-1}) \ln PROD_{k,t-1}))
\end{aligned} \tag{41}
$$

Continuing units also have another channel through which they can exert a positive effect on the productivity change: it units that have a mean productivity level above the mean relative size (or as Balk defines it, above scalar a) increase in their relative size or significance (Balk 2016, 38).

We have now defined the four elements contributing to the aggregate productivity change. Equations (36)-(41) are the equations according to which the data used in the empirical study that follows has been decomposed.

4.2 Alternative decomposition methods

As already mentioned, there are numerous other decomposition methods according to which productivity change (labor productivity, in our case) can be decomposed into smaller components. One of the most well-known methods is the so-called OP-method that was presented by Olley & Pakes (1996). The OP-method is a static method that has been a popular choice in productivity literature in the past years, and it evolves around a covariance component called the reallocation component (Maliranta & Määttänen 2011, 246). The main idea behind the OP-method is to use the so-called within-industry covariance for measuring the impact of misallocation of resources (see Bartelsman, Haltiwanger & Scarpetta 2013, 9). Maliranta & Määttänen (2011, 240) refer to the within-industry covariance as the allocation component, which is can be calculated when creative destruction is assessed through a static analysis instead of a dynamic one.

The purpose of such decomposition is to enable studying themes such as whether firm age and/or firm size correlate with productivity in such way that larger firms become more productive than small ones, or whether firms become more productive once they reach a certain point in their life cycle or not (Balk 2016, 42–43). According to Balk (2016, 42–43), the OP-method mainly consists of rearranging a general relation already created by Bortkiewicz in the 1920s into a new form, creating a covariance-term typically interpreted as reallocation. However, reallocation seems to be actually the mere difference between a weighted and an unweighted mean and is therefore an artificial term as well. Although Balk (2016) admits the OP-method can be used for decomposing aggregate productivity, it fails to distinguish between entering, exiting and continuing firms. (Balk 2016, 42–43.) Maliranta & Määttänen (2011, 246–249) propose using an augmented method that divides the components into two effects, the direct and the indirect effect. However, they also conclude that even using the augmented version the results provided remain problematic to interpret.

It is important to emphasize that the Olley-Pakes method as well as the Diewert-Fox method are two individual methods among many other options. The Diewert-Fox method has been chosen to be used both due to practical reasons as well as for the possible misconceptions the popular OP-method is claimed to suffer from. We disregard of numerous other methods that could equally be used as the base of such study.

4.3 Description of the empirical study

The following empirical analysis is conducted based on industry-specific decomposed panel data. The data has been provided by Mika Maliranta and consists of partially unpublished sector-specific calculations that were made as part of a research conducted by Maliranta & Määttänen (2014). The sectoral data in use has been formed by aggregating production unit specific productivities starting at the micro level. This is the so-called bottom-up approach as presented by Balk (2016). In this approach, aggregate productivity is a weighted mean of production unit specific productivities (Balk 2016, 17). In the study, a sectoral shift-share analysis is carried out focusing on the different components of labor productivity as according to the geometric Diewert-Fox method presented in chapter 4.1. The decompositions have been made by taking the logarithms of firm-level values that have then been aggregated by their corresponding labor input shares as explained in our Diewert-Fox decomposition section. The values have been multiplied by a hundred, which means that they can be interpreted as logarithmic percents (log-%). The values are annual differences, describing the change from the previous year to the year in question. First, the data has been indexed in order to be able to study the cumulative effect using 1974 as the reference year.

Since the data is from manufacturing statistics, only the industrial sectors are applicable in our study. Studying the manufacturing industry is reasonable because creative destruction is more significant as compared to other sectors such as services (Maliranta 2014a, 29). In addition, it is a natural subject of study, because production unit specific data is available for a longer period of time in manufacturing than for other sectors and since creative destruction appears to be closely related to national competitiveness while changes in competitiveness tend to be transmitted into manufacturing more rapidly than to other sectors (Maliranta 2014b, 36–37). It is worth noting, though, that the service sector has lately become more significant and could, therefore, be an interesting sector to study, but that the service sector has to be left out as there is currently no production unit data specific enough available for such study (Maliranta 2014b, 37–38).

The aforementioned Balk (2016) paper as well as many other productivity related articles focus on labor productivity based on real value added. Our data consists of nominal data, and a deflator would be needed in order to study the within component and investigate how real labor productivity growth within the sectors. A suitable deflator, for instance, would be a sectoral value added price index. Since the study concentrates on other components, namely the between component, it is sufficient to leave the data in nominal form.

As was shown in the chapter 4.1 that discussed the Diewert-Fox decomposition, the decomposition can be based on either the arithmetic, geometric or harmonic average, each of which have their own advantages. Among the options, the most relevant options, that are also used in current literature, are the geometric and harmonic averages. Since the geometric average is simpler in use and less sensitive to outliers in data, the geometric average has been chosen to be used here. It is also acknowledged that the non-logarithmic harmonic average might at least theoretically be a more optimal option as it attaches better to the aggregate variables in the statistics. However, overall results are typically similar and the non-logarithmic decompositions include the cross effect term of the within component, which might be relatively large and volatile and also difficult to describe and analyze.

We also acknowledge that using the Hodrick-Prescott filter is a common way to study the trend component and separate the trend from the cyclical component in current literature. However, using the Hodrick-Prescott filter would mean that several values in both ends of the series should be left out of the range of our investigation, which is problematic when handling annual data. Using the Hodrick-Prescott filter also requires choosing a certain smoothness parameter λ, the value of which remains quite controversial. Ravn & Uhlig (2002) propose a value of 6,25 where as professor Lanne (2007) suggests using the lambda value 10 in the Statistics Finland article (published in the Productivity Review 2007). Since the HP-filter remains a very disputed indicator in other respects as well and study aims to proceed in a prudent manner, the empirical study will be performed directly using indexed, but not detrended data.

Because the values of the different components of creative destruction for the public sector tend to be not comparable in time and comparing incompatible productivity values with each other might cause a misleading general picture and because the influential factors behind productivity growth can differ significantly between the private and the public sector (Maliranta & Määttänen 2011, 235), the focus is on studying private sector data on Finnish firms. More specifically, the data is industrial statistics. This is also a typical data source in the field.

In the sectoral shift-share analysis conducted in this study, ten representative industries are studied on the sectoral level. The focus is especially on the between, entry and exit components for each sector, which have been composed by aggregating individual production units. A sector can be defined a group of production units that have activities in the same or similar fields with each other. In the case of productivity analysis, researchers are often limited to those sectors with a quantifiable input and output (Balk 2016, 16). Different sectors are of different importance, and the importance of each sector is measured by a weight $\omega^{k,t}$, getting values between 0 and 1 (Balk 2016, 16). In the literature, there is a lot of discussion on whether these weights should reflect the nominal value added share, the real value added share or the labor input share of each sector (Balk 2016, 16). Our data is composed using the labor input share of each sector.

A typical outcome of shift-share analysis is a table that shows relatively precise decomposition results compared both between sectors and in time. This way of measuring the components enables studying sectors with certain particularities, such as studying strictly regulated or ICT-intensive sectors. (Balk 2016, 16). According to current research, the creative destruction process is firmest in industries in which employment decreases rapidly, in industries with a lot of research and development (R&D) activities, and in industries with a lot of experts and executives, that is to say firms with a lot of intellectual capital (Maliranta 2014a, 32–36). Intellectual capital affects the output only after a certain delay. This also supports the idea that firms can enhance their future productivity by investing in innovation, research and highly educated professionals.

The data is annual panel data conform to the European statistical classification NACE (originating from the French term Nomenclature Statistique des Activités Économiques dans la Communauté Européenne, the statistical classification of economic activities in the European community), revision 2. The data concerns the Finnish the manufacturing industry, and ten representative combined sectors have been chosen to be examined more in detail in this study. In the beginning, there were 60 different manufacturing sectors and combinations of sectors ranging all the way from the food industry to the furniture, other manufacturing; repair and installation of machinery and equipment industry, classified according to the NACE 2-classification (manufacturing sectors from 10 to 33). Of those sectors, ten representative combined sectors were then chosen to account for all manufacturing sectors (10–33).

The sectors chosen include the following: food products and beverages (NACE sectors 10–11), textiles, wearing apparel, leather and related products (NACE sectors 13–15), wood and paper products, and printing (NACE sectors 16–18), chemical and pharmaceutical products (NACE sectors 20–21), rubber and plastics products, and other non-metallic mineral products (NACE sectors 22–23), computer, electronic and optical products (NACE sector 26), machinery and equipment (NACE sectors 26–28), transport equipment (NACE sectors 29–30), furniture; other manufacturing; repair and installation of machinery and equipment (NACE sectors 31–33) as well as all sectors in manufacturing combined (all NACE sectors from 10 to 33). The data used covers all establishments in the manufacturing industries employing five or more people.

We also aim to concentrate on the nature of different sectors, classifying them as presented in Tables 1 and 2. In Table 1, the chemical and pharmaceutical products, machinery and equipment, transport equipment and computer, electronic and optical products industries are all innovative, and therefore R&D-intensive sectors, that require plenty of capital in order to function. Therefore, they are classified as capital and R&D-intensive sectors. The reason why both computer, electronic and optical products (NACE sector 26) and machinery and equipment (NACE sectors 26–28) have both been chosen to be representative sectors lies in the particularity of computer, electronic and optical products: the computer, electronic and optical products industry differs from all other manufacturing industries and could also be classified as an ICT-intensive sector. It has thus been separated from the machinery and equipment industry in order to be able to distinguish the differences between the computer products industry and other industries within machinery and equipment.

The food products and beverages industry is a typical capital-intensive sector that is

Table 1: Sector classification 1

Capital and R&D-intensive sectors	• Chemical and pharmaceutical products (NACE 20–21) • Computer, electronic and optical products (NACE 26) • Machinery and equipment (NACE 26–28) • Transport equipment (NACE 29–30)
Capital but not R&D-intensive sectors	• Food products and beverages (NACE 10–11) • Wood and paper products, and printing (NACE 16–18) • Rubber and plastics products, and other non-metallic mineral products (NACE 22–23)
labor-intensive sectors	• Textiles, wearing apparel, leather and related products (NACE 13–15) • Furniture, other manufacturing; repair and installation of machinery and equipment (NACE 31–33)

rather concentrated in capital than in labor and which has a relatively low rate of innovation. Wood and paper products, and printing, as well as rubber and plastics products and other non-metallic mineral products, are also typical examples of sectors requiring an important amount of capital. The sectors of textiles, wearing apparel, leather and related products are typical labor-intensive industries with a declining employment rate and that should therefore experience more creative destruction than other sectors in general (Maliranta 2014a, 32). Equally labor-intensive are furniture, other manufacturing; repair and installation of machinery and equipment as well as repair and installation of machinery and equipment which are all grouped into NACE sectors 31–33. The last representative sector covers all manufacturing (sectors 10–33), and naturally can not be classified into any one of these groups mentioned due to the wide range of different types of industries it consists of. It has been chosen as a representative sector mainly for comparative reasons, as it is considered a good idea to reflect changes and possible interpretations to the overall progress in manufacturing to the sector, years and component(s) in question.

It is worth noting that the classification presented is a purely arbitrary one and de-

Table 2: Sector classification 2

Industries dependent on domestic demand	• Food products and beverages (NACE 10–11) • Textiles, wearing apparel, leather and related products (NACE 13–15) • Furniture, other manufacturing; repair and installation of machinery and equipment (NACE 31–33)
Industries dependent on export demand	• Wood and paper products, and printing (NACE 16–18) • Chemical and pharmaceutical products (NACE 20–21) • Rubber and plastics products, and other non-metallic mineral products (NACE 22–23) • Machinery and equipment (NACE 26–28) • Computer, electronic and optical products (NACE 26) • Transport equipment (NACE 29–30)

pendent on the prior assumptions made in the study. The industries in question could be classified in several different ways, which necessarily also affects the results to be presented. Therefore, an alternative classification, yet less common in creative destruction related literature, is proposed as according to Table 2. Now the sectors are classified relative to the markets they are dependent on in terms of productivity, grouping them into sectors dependent on domestic demand and sectors dependent on export demand. This dependence does not necessarily mean, though, that the production units would be operating principally on a national scale in the case of sectors dependent on domestic demand nor that the sectors dependent on export demand would necessarily be sectors operating principally exporting products abroad. Note also that the division of the representative sectors into sectors dependent on domestic and on export demand is not definitive, and the final division of the sectors will later be presented in Section 5.3. The section also shows which sectors are classified as export-dependent and which as dependent on domestic consumption. The chosen final classification is justified according to the results obtained in Section 5.5.

Other possible classifications have also been presented in the literature. For instance, Bartelsman et al. (2010) classify industries in terms of ICT-intensity as well as strictness of employment protection legislation (EPL), claiming that in countries with strict EPL the high-risk innovative sectors which can be associated with intensive ICT use are relatively small (Bartelsman et al. 2010, 1). As a measure for ICT-intensity Bartelsman et al. (2010, 8) use broadband use and calculate the gross job flows (defined as job creation subtracted by job destruction and then both divided by employment) and employment-weighted gross firm turnover, also interpreted as entry-exit job flows (defined as fired employees at firm exit and hires at firm entry divided by employment).

Bartelsman et al. (2010, 8) compare two periods, 1986–1994 and 1995–2004. When measuring by gross job flows, they were on the same level regardless of the level of ICT in the firm for the first period 1986–1994, but on the second period 1995–2004, gross job flows increased to around five times more in the high ICT industries than they had in the low ICT industries. Looking then at entry-exit job flows, entry-exit job flows stayed constant for both periods in low ICT industries. In high ICT industries, entry-exit job flows had increased by 50 % when comparing the first period 1986–1994 to the second 1995–2004. (Bartelsman et al. 2010, 8.) It seems rather clear that the ICT-intensity of the sector had a great effect on whether new jobs were created and older ones destroyed, that is, whether there was creative destruction. With the aim of obtaining similar results in the context of R&D-intensity and dependence on export demand, for instance, the study benchmarks the idea of examining the data in specific time periods.

4.4 Preliminary comments on the industries studied

In manufacturing, the creative destruction process seems to be reawakening in Finland since a turning point in 2002. This has been found to be especially visible in the metal and electrotechnical industry. Another field of interest is the dispersion of productivity, which has grown significantly in the manufacturing of machinery and equipment. (Maliranta 2014a, 22–23.) Because the effect of creative destruction is known to have started to strengthen in the start of the millennial (around the time of the dot-com bubble), this makes the early 2000s an especially interesting time period to study, and also serves as a good argument for analyzing the electrotechnical and ICT-industry as much in detail as possible.

Piekkola & Åkerholm (2013) studied the effects of intangible investments on productivity. They found out that the effect of structural change has transformed drastically in the last years, in around 2008, as structural change went from being a factor slowing down growth to a factor actually supporting growth in all sectors (from negative to positive). This seems true especially for capital-intensive industries and industries that have a lot of expertise and know-how (empirical results for this are found in their cluster analysis, which has been left unpublished). They also claim that even though intangible capital does not necessarily change results from other previous studies in which it has not been taken into account, intangible capital may be able to explain the nature of the structural change. Investments in intangible capital show particularly as improvements in production processes inside of firms, which is captured by the within component. The effect may also partly show in the between component after the financial crisis broke out in 2008, as technology firm Nokia started to lose its market leading position and a large number of ICT-engineers were employed into other similar companies and industries. (Piekkola & Åkerholm 2013, 438.)

Similarly, Maliranta (2014a, 22) defines the amount of experts and executives in a company as the indicator of the company's level of innovation. According to Maliranta (2014a, 22), the same definition is used in intangible capital studies and it seems a relatively accurate indicator. Bearing in mind the aforementioned way of defining innovation, it looks like a major part of aggregate productivity growth in innovative firms happens through creative destruction. This can be interpreted as labor input being redirected among the firms with variation in productivity in a way that, in turn, enhances productivity. However, the average productivity growth rate of innovative firms does not greatly differ from that of less innovative firms. (Maliranta 2014a, 22.) Piekkola & Åkerholm (2013, 438) also note that since the financial crisis, the Finnish economy seems to become more and more divided into labor-intensive sectors that invest little or not at all in intangible capital and therefore grow less (notably services) and into manufacturing industries representing the top of the value chain. It can be deduced that also looking at all manufacturing industries, the industries that are able to produce high-quality products as opposed to raw materials and simple products are likely to innovate more and invest in intangible capital, which then generates more innovation and increases industry productivity repeatedly.

Criscuolo et al. (2014) made a cross-country study on the dynamics of employment growth, and found out that the age profile of firms became especially important when studying small firms as net job creators. Entering firms appear to contribute the most to job creation, and were followed by growing firms less than three years old. Nevertheless, there was a clear drop in the contribution of both new entrants and young firms during the Great Recession. (Criscuolo et al. 2014, 6.) During the latest recession, young firms were also hit relatively harder by the downturn than larger firms. Regardless the fact that young firms faced less creation and more destruction than before, they still contributed positively to employment growth even during the crisis. (Criscuolo et al. (2014), 11.) Even though firm age nor size is not directly in the focus of this study, these findings might shed light on the nature of the industries that have suffered from economic downturns. For instance, industries with lots of young, entering firms can be expected to have been hit hardest by both the 1990s depression as well as by the Great Recession.

As was seen in Section 2.3, there are several factors that affect the creative destruction process on an institutional level. Criscuolo et al. (2014, 12) mention high entry barriers, subsidies to continuing units and policies complicating the exit of the least productive firms as factors that slow down resource reallocation and thus reduce competition. This results in the productivity of new entrants being unnecessarily high while the exiting units tend to exit laggardly with even lower productivity than with which they should already exit the market. (Criscuolo et al. 2014, 12.) Criscuolo et al. (2014, 13) also point out that even though former theory and models may suggest that recessions are followed by the creative destruction process that increases overall productivity and therefore have a positive outcome, stringent financial market conditions may slow down or even prevent structural change to such extent that productivity is also slowed down on the long term. This might be a considerable issue especially in the case of young, entering units that have found obtaining additional financing become a lot more challenging than it was before the Great Recession as banks have tightened their credit standards all around the globe.

5 EMPIRICAL ANALYSIS

5.1 Changes in aggregate labor productivity

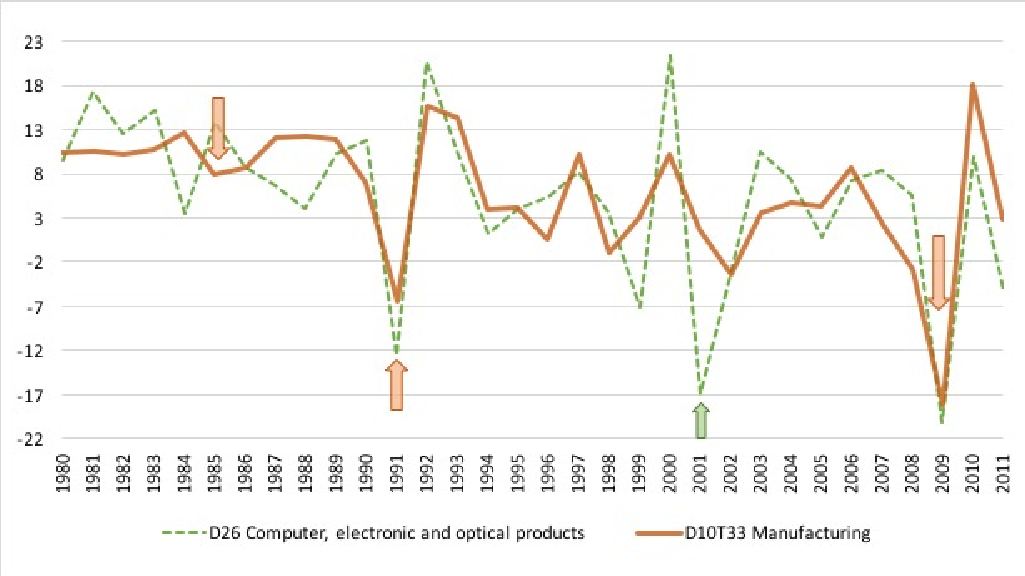

Figure 3: Aggregate labor productivity, manufacturing and the computer, electronic and optical products industry

We have first modeled aggregate labor productivity growth for the entire manufacturing industry as well as for the electronic products industry (NACE 26) which is an especially interesting industry in terms of its nature. In aggregate labor productivity, changes in productivity in all periods of interest can be seen clearly. There are two major periods where productivity falls significantly: in both 1989–1991 (starting in 1989 and steepening in 1990), corresponding the Finnish depression in the early 1990s, and in 2006–2009 (starting in 2006 and steepening in 2008), corresponding the latest recession that is marked by the financial crisis that broke out on a global scale in 2008.

In addition, there is one significant fall in the electronic products industry in 2000–2001, a fall that was already preceded by a first, smaller productivity decrease in 1997–1999. This period corresponds to the so-called dot-com bubble, which blew out in the start of the millennial when the markets realized that the huge growth of the IT companies that had been born at an amazing phase all around the world where overestimated in value. Lastly, it can also be noticed that there is a small productivity slowdown around years 1984 and 1985, which corresponds most likely to the changes in the banking and capital market legislation. It is necessary to note that this slowdown is relatively small as compared to the previous ones mentioned and that there are actually several other slowdowns in productivity which were relatively of the same size and have not been noted here. However, the productivity slowdown in the mid-1980s is significant, because it was clearly a precedent slowdown to the depression that occurred in the early 1990s, which then became a major productivity shock in Finland. It is also worth pointing out that the latest shocks corresponding the dot-com bubble and the recent financial crisis have had an even more severe effect on the country's productivity than the productivity shock caused by the 1990s depression.

Except for the electronic products industry and the wood, paper and printing industry (NACE 16–18), which suffers also from extremely volatile productivity, most other manufacturing sectors have developed relatively similarly to the entire manufacturing industry.

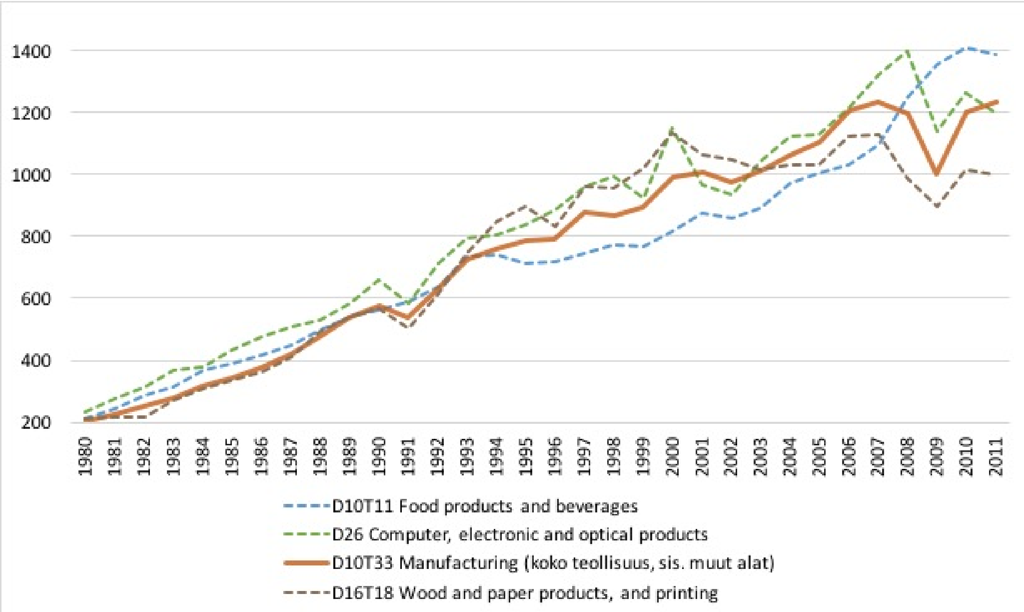

Figure 4: Cumulative aggregate labor productivity, manufacturing and the computer, electronic and optical products industry
(1974 = 100)

Another useful tool is to look at cumulative aggregate labor productivity, as shown in Figure 4. All years in the data have been modeled starting from the year 1980, in which significant changes in productivity started to occur. The index value 100 corresponds to year 1974. The figure shows that since 2008, the food products and beverages sector (NACE 10–11) has actually been more productive in terms of aggregate labor productivity than the manufacturing industry overall. This change, however, is unlikely to be caused by creative destruction as the industry is not particularly R&D-intensive nor does it experience lots of structural change as will be shown as follows, and it can therefore be deducted that the productivity growth in the food products and beverages industry is likely to be caused by growth within firms (as measured by the within component) rather than by microstructural change (the between component). Aggregate labor productivity of the electronic products industry (NACE 26) has also grown faster than the manufacturing industry in general since the 1980s, except for the years 2000–2002 corresponding the dot-com bubble. The electronic products industry is a typical sector with lots of R&D and in which creative destruction is expected to be an important source of productivity growth. It can also be seen from the figure that productivity in the wood, paper and printing industry (NACE 16–18) grew faster than the manufacturing industry overall in 1993-2003, but its growth smoothed out in 2003 and has has been at a lower level than the rest of the manufacturing industry since, though growing according to the same pattern.

The textiles, wearing apparel, leather and related products industry (NACE 13–15) follows the manufacturing labor productivity as does the machinery and equipment industry (NACE 26–28) and the furniture, other manufacturing; repair and installation of machinery and equipment industry (NACE 31–33), which does though have a slightly smaller growth rate during the period 1991–2009. The transport and equipment industry (NACE 29–30) productivity growth also has the same form as the manufacturing industry in general, but it has grown at a significantly lower level since 1988. For the rubber and plastics products industry (NACE 22–23) the situation is the same, but only since 1989 and for the chemical and pharmaceutical products industry (NACE 20–21) since 1991. For reasons of simplicity, all of the sectors with a growth path similar to the general manufacturing industry have been left out of the figure and the sectors remaining are the food products and beverages sector (NACE 10–11), the wood, paper and printing industry (NACE 16–18), the electronic products industry (NACE 26) and the entire manufacturing industry (NACE 10–33).

5.2 Structural change, market entry and exit and time interval analysis

The between, entry and exit components for all representative sectors have been plotted in Figures 5-14. The dotted red line shows the between component for the entire manufacturing industry (including the industries in question), which works as a reference when willing to compare the development of the between component to the development of the overall between component in manufacturing. Figure 5 shows all sectors (10–33 according to the NACE classification).

In terms of the creative destruction process, or microstructural change, in the entire manufacturing industry (see the between component in Figure 5), the creative destruction process seems to be augmenting since 1980. The overall augmentation from 1980 to 2011 has been approximately 29%. However, there are several years during which the growth of the creative destruction process has slowed down: in 1993–1995, in 1997–1998, in 2001–2002, and again in 2004 since which it stayed stable until the year 2008. Since 2008, the creative destruction process is again on the rise.

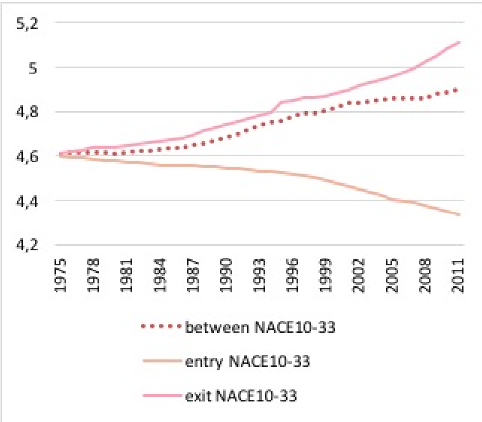

Figure 5: Manufacturing

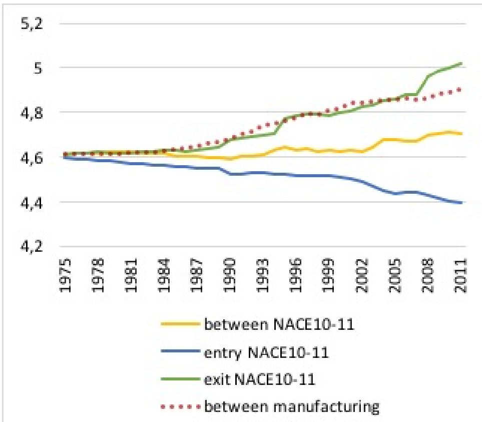

Figure 6: Food products and beverages

In the food products and beverages industry (NACE 10–11, Figure 6), microstructural change as measured by the between component has been a lot less significant than in other sectors of the manufacturing industry since 1984. However, the food products and beverages industry has experienced a few clear periods in which its microstructural change has grown: first in 1992–1995 (experiencing approximately a 5% growth), after which the growth was smoothed out, and now again in both 2002–2004 (approximately 6 % growth) and 2007–2011 (approximately 4 % growth). The recent growth since 2002 in the food products and beverages industry is consistent with the idea of the reawakening of creative destruction as presented by Maliranta (2014a, 22–23).

The textiles, wearing apparel, leather and related products industry (NACE 13–15, Figure 7) is a typical labor-intensive industry with declining employment, which can be expected to experience lots of creative destruction (Maliranta 2014a, 32). In the textiles, wearing apparel, leather and related products industry, creative destruction has also been found to concentrate in companies with a low level of productivity (Maliranta 2014a, 32). The between component of the industry is almost identical to the between component of manufacturing in general, with the distinction that the growth started

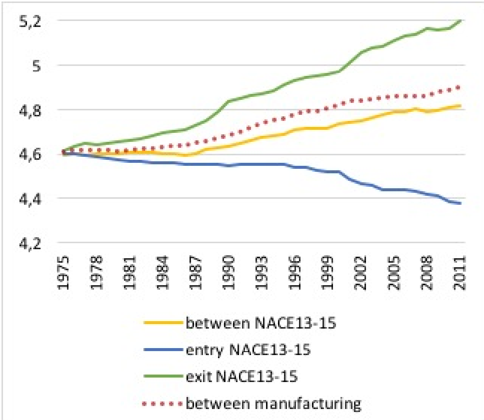

Figure 7: Textiles, wearing apparel, leather and related products

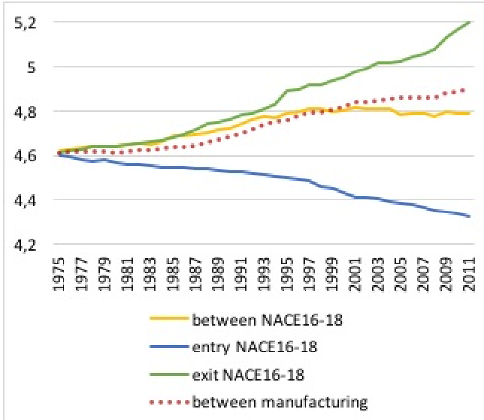

Figure 8: Wood and paper products, and printing

slightly later (in the entire manufacturing industry, in the 1980s, and in the textile industry around 1987) and that the industry has therefore been growing at a lower level of labor productivity. The difference between the textile industry between growth and the manufacturing between growth has also been growing, ranging from 5% in 1987 to 9% in 2011. In 2007, the textile industry experienced a steeper decline in structural change than all sectors together (where between growth was merely smoothed out), though the drop was only about 1% indicating that the sector might have recovered quickly or that the shock was almost of the same extent as in other manufacturing sectors.

The wood and paper products, and printing industry (NACE 16–18, Figure 8) grew in terms of microstructural change at a phase faster than that of manufacturing in general until 1998. From 1979 to 1998, the sector experienced a 19% growth in the between component. However, in 1999, the amount of microstructural change in the industry fell below the general level of manufacturing and has been at a lower, fairly stable level since. The year 1999 could be interpreted as the beginning of the dot-com bubble, during which there was actually a decline in productivity also in other industries apart from the dot-coms as can be seen in Figure 3. Between 1998 and 2011, the growth of microstructural change has also fallen down slightly in the wood, paper and printing industry (by about 2 %).

In the chemical and pharmaceutical products industry (NACE 20–21, Figure 9), the between component has grown in the industry far less than in manufacturing in general and even less than it has in the wood, paper and printing industry. While the between component rose in manufacturing overall by around 29% in 1980–2011, the equivalent rise in the chemicals and pharmaceutical products was of 8%. It seems like the chemical and pharmaceutical products industry has not experienced much creative destruction

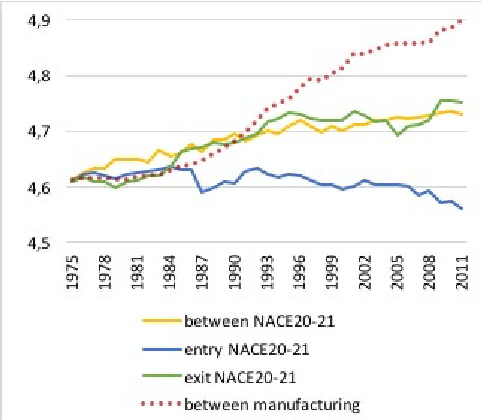

Figure 9: Chemical and pharmaceutical products

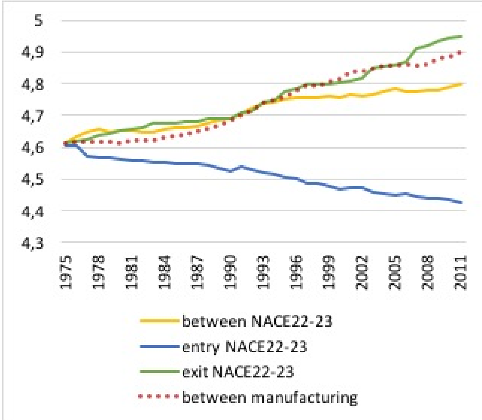

Figure 10: Rubber and plastics products, and other non-metallic mineral products

under the entire time period studied, and this supposition seems to be confirmed in Section 5.2. As shown by the following Figure 10, the evolution of the between component in the rubber and plastics products, and other non-metallic mineral products (NACE 22–23) is similar to that of the manufacturing industries in general, but however with a milder slope. Until the year 1990, it grew slightly faster than the between component in manufacturing did in general. For around three years, it continued growing at the same phase as the structural change for manufacturing in general, until the growth in structural change started somewhat smoothing out around 1993.

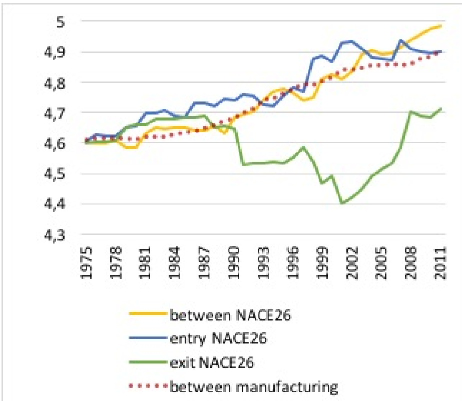

Figure 11: Computer, electronic and optical products

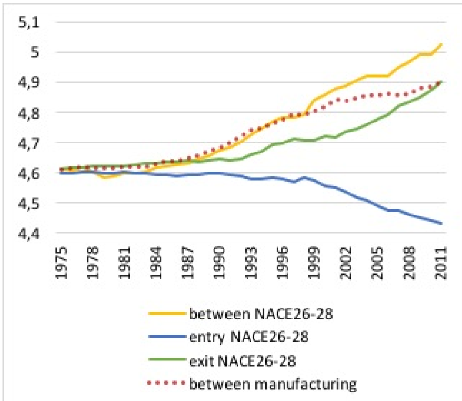

Figure 12: Machinery and equipment

As might be expected, the evolution of structural change in both the computer, electronic and optical products industry (NACE 26, Figure 11) as well as in machinery and equipment (NACE 26–28, including the electronic products industry, Figure 12) is similar to each other. In the electronic products industry, the creative destruction process seems a lot more volatile than in machinery and equipment and than in any other industry, which is in line with the fact that the aggregate labor productivity of the electronic products industry has also been a lot more volatile than that of the industry in general, as can be seen in Figure 3. In the electronic products industry, the creative destruction process appears to be growing at a faster phase than in the rest of the manufacturing sectors since year 2002. In machinery and equipment, the same process actually started earlier, growing faster than the rest of the manufacturing industries already since 1998.

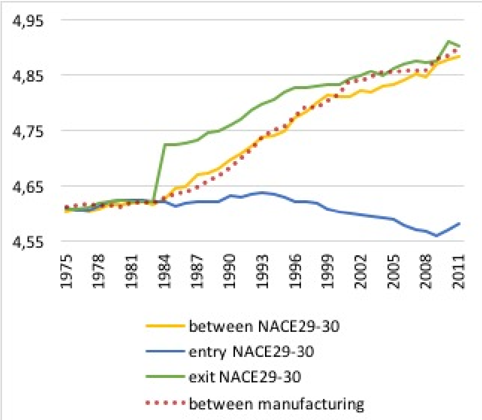

Figure 13: Transport equipment

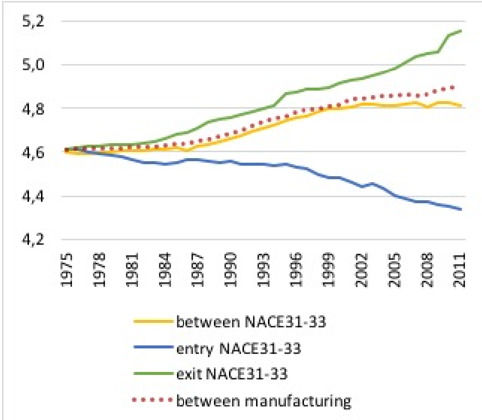

Figure 14: Furniture, other manufacturing, and repair and installation of machinery and equipment

In both the transport equipment (NACE 29–30, Figure 13) and the furniture, other manufacturing and repair and installation of machinery and equipment industry (NACE 31–33, Figure 14), the creative destruction process has been most similar to the one in manufacturing in general. As what goes to the transport equipment industry, it could even be said that the industry has grown in terms of structural change almost exactly as manufacturing in general, except for years 2000–2008, during which it has experienced somewhat less creative destruction than the other manufacturing industries. Since 2008, the structural change is clearly on the rise in the transport equipment industry as it seems to be growing again at the same phase as manufacturing in general.

In the furniture, other manufacturing; repair and installation of machinery and equipment industry, the microstructural change slowed down in year 2002 (again corresponding with the mentioned turning point but now with a totally different result) and has been staying on its same stable level from 2002 till 2011 except for a fall in 2007 corresponding the recent financial crisis and the changes it lead to in all of the components of labor productivity. While the transport equipment industry seemed to be experiencing creative destruction very recently, the furniture, other manufacturing; repair and installation of machinery and equipment industry appears to follow the same progression as do the wood and paper products, and printing and the rubber and plastics products, and other non-metallic mineral products industries with little creative destruction.

To complete the analysis, the entry and exit components and their evolution in time for the chosen representative sectors can also be examined bearing in mind that these components are more sensitive to measurement errors and harder to distinguish as was explained earlier in the study. As was stated in Section 2.2, the entry component tends to be typically negative as new firms enter the market with a lower initial level of productivity and once their productivity grows they are already middle-aged companies and their effect is captured into the between component. Likewise, the exit component tends to be typically positive since the firms leaving the market are often the least productive ones, therefore augmenting the industry productivity by shutting down. The end of the firm life cycle is also a longer process than what is captured into the exit component, and for this reason, the exit component also exerts a positive effect on industry productivity through the between component as the less productive firms first start by losing market share to the more productive ones. First considering the entire manufacturing industry as shown in Figure 5, the entry is a steadily descending slope, with its descent accelerating visibly around the year 1999, then smoothing out a little in years 2005–2007 and turning back to its accelerated descent since 2007.

In terms of sectors, the one single sector that does not follow the general pattern at all is the electronic products industry (NACE26, Figure 11), that has an ascending entry slope, unlike all other manufacturing industries. It can also be noted that the ascent of the entry component steepens radically around 1997, and since the entry component is constantly on the rise, it can be deduced that a lot of young, productive firms enter the market, especially in the years preceding the dot-com bubble as well as in the recent years.

Examining the entry component, several other industries can also be noted as not exactly following the general evolution of the entry component in manufacturing. These are the chemical and pharmaceutical products industry (NACE 20–21) and the transport equipment (NACE 29–30). In chemical and pharmaceutical products, the entry component is slightly upward sloping from 1979 to 1986, until it falls in 1987 and then again ascends in 1987–1992, being descending like the other sectors since 1992. The transport equipment industry also has an ascending entry component throughout 1977–1994 (except for 1984 and 1990, during which it falls), after which it is descending until year 2009, from which it then seems to be ascending again.

Looking again at the manufacturing industry in general in Figure 5, the exit component is a steadily ascending slope, its ascent accelerating slightly around year 1986, then increasing and decreasing back to its prior level in years 1994–1999 and finally increasing again since 2008. The form of the entry and exit components correspond each other, and they seem to even out each other approximately like they are expected to. As in the entry component case, the electronic products industry is the single industry clearly deviating from the evolution of the exit component in the manufacturing in general from 1987 to 2002. In 2002 though, the turning point again, the exit component turns positive and starts ascending and ascends until 2011 (except for the year 2008).

The chemical and pharmaceutical products industry is equally interesting considering the exit component, as its exit component grew more or less following the manufacturing industry until 1995, and from then on has been fairly stable except for a short period 2005–2009 when it ascended again. Regarding the exit component, the textiles, wearing apparel, leather and related products industry (NACE 13–15) is also interesting as its exit component grew significantly between 1986–1990, therefore allowing the industry to ascend at a higher level than the rest of the manufacturing industry did, except for 2008. The transport equipment industry (NACE 29–30) is equally interesting as its exit component experienced a significant increase in 1983, which shows in Figure 13 as a sharp rise in that particular year. This increase was smoothed out afterward and has then made the industry ascend somewhat slower than the industry overall.

Tables 3-12 show the aggregate labor productivity change for capital and sectors (chemical and pharmaceutical products, computer, electronic and optical products, machinery and equipment and transport equipment), for capital but not R&D-intensive sectors (food products and beverages, wood and paper products, and printing and rubber and plastics products, and other non-metallic mineral products) as well as labor-intensive sectors (textiles, wearing apparel, leather and related products and furniture; other manufacturing; repair and installation of machinery and equipment) and the overall manufacturing industry (NACE 10–33). The tables show all components of labor productivity at specific intervals, and are in the form of annual percentage (%) growth (remembering that the underlying values are actually logarithmic percents that approximately equal percents and can, therefore, be interpreted as such).

The results have been computed for six different time periods, four of them which correspond a productivity shock and two of them serving as reference periods for time periods not known to have been affected by economic downturns. The first period 1980–1988 corresponds the period during which the capital markets were liberalized in Finland and the country opened up to economic trade, followed by the Finnish depression in the early 1990s (period 1989–1992), then by the dot-com bubble around the turn of the millennial (1997–2002) and finally the recent great depression (2008–2011). The reference periods are 1993-1996 and 2002–2007.

Looking at the entire manufacturing industry (displayed in Table 3), it seems rather

Table 3: Manufacturing industry

	aggregate	within	between	entry	exit	net entry
1980–1988	10.58	9.61	0.49	−0.33	0.82	0.49
1989–1992	7.03	4.47	1.45	−0.29	1.39	1.10
1993–1996	5.70	2.61	1.49	−0.52	2.12	1.60
1997–2002	**3.44**	2.46	1.05	−1.13	1.06	−0.07
2002–2007	**3.37**	2.56	0.29	−1.23	1.75	0.52
2008–2011	**0.00**	−2.54	1.07	−1.28	2.75	**1.47**
average	5.02	3.19	0.97	−0.80	1.65	0.85

clear that the aggregate productivity has slowed down gradually since 1980. In literature, this is called the productivity slowdown and it affects Finland just like it affects numerous other Western countries. In the 1980s it grew by an annual rate around 10 % while in the period 2008–2011 the annual aggregate productivity growth had dropped down to 0% per year due to the productivity shock triggered by the financial crisis that turned productivity growth negative, as can be seen from Figure 3. In the period 2008–2011, the change turned out to be strongly negative in the within component, while it stayed positive for both the net entry effect (the positive exit effect being larger in size than the negative entry effect, net entry being measured as the entry component plus the exit component) and the between component.

Table 4: Chemical and pharmaceutical products

	aggregate	within	between	entry	exit	net entry
1980–1988	10.19	9.05	0.40	−0.15	0.90	0.75
1989–1992	6.35	4.93	**0.15**	**0.84**	0.43	1.27
1993–1996	2.60	1.44	0.67	−0.36	0.85	0.49
1997–2002	3.00	3.23	−0.10	−0.09	−0.04	−0.13
2002–2007	3.22	3.65	0.21	−0.24	−0.41	−0.65
2008–2011	**2.97**	**2.44**	0.12	−0.61	**1.02**	0.41
average	4.72	4.12	**0.24**	−0.10	0.46	0.36

The Table 4 shows the detailed decomposition results for the chemical and pharmaceutical products industry. Conforming to results in the previous sections, the chemical and pharmaceutical products industry has been experiencing lower aggregate labor productivity than manufacturing in all periods, except in 2008–2011, also according to the time interval analysis. The between component is a lot less significant for the chemical and pharmaceutical products industry than it is for manufacturing overall. In the case of period 2008–2011, in which the industry seems to be quite surprisingly growing more on the aggregate than manufacturing in general, the difference is accounted for by the within component, while both the between component and the net entry effect seem insignificant. Coming to period 2008–2011, the relative importance of the exit grows, still leaving the net entry effect of minor importance in all the periods studied.

Table 5: Computer, electronic and optical products

	aggregate	within	between	entry	exit	net entry
1980–1988	10.17	8.62	**0.76**	**0.82**	**−0.03**	**0.79**
1989–1992	7.54	8.44	1.22	**0.82**	**−2.94**	−2.12
1993–1996	5.30	2.76	1.46	**0.65**	0.42	1.07
1997–2002	**0.94**	−0.63	**1.23**	**2.49**	**−2.15**	**0.35**
2002–2007	**5.17**	0.31	**1.66**	**0.15**	3.04	**3.19**
2008–2011	**−2.46**	−6.42	**1.80**	−0.99	3.15	**2.16**
average	4.44	2.18	1.36	**0.65**	0.25	0.91

As noted in Section 5.1, the electronic, computer and optical products industry (NACE 26) has been growing faster than the manufacturing industry in general in terms of cumulative growth already since 1980, except for the years 2002–2003, and in terms of actual aggregate labor productivity growth since the year 2002. It can also be seen from Figure 3 that the aggregate productivity growth dropped first moderately in 1997–1999 and then even more in 2000–2001, and thus these are the years that are also expected to come up in the time interval decomposition results. It was also noted previously that the between component has been a lot more volatile for the electronic products industry than it is for the machinery and equipment sector, for instance. Now studying Table 5, it can be seen that in the electronic products industry, the entry component is positive for all time periods except in 2008–2011. The net entry effect has been larger in the electronic products industry than in manufacturing in general over the years 1980–1988 and 1997–2011. The volatility of the industry is also reflected in its aggregate labor productivity: the aggregate labor productivity has been clearly smaller in periods 1997–2002 and 2008–2011, and, on the other hand, clearly larger than for manufacturing in general between 2002 and 2007, which is also generally considered a period of higher growth between economic shocks. The structural change appears also to contribute more into the electronic products industry than it does into manufacturing in general, especially in the three periods covering the years 1997–2011.

As was also noted previously in Section 5.1, the between component has been grow-

Table 6: Machinery and equipment

	aggregate	within	between	entry	exit	net entry
1980–1988	9.62	8.80	**0.66**	−**0.04**	0.20	0.16
1989–1992	7.31	5.85	1.36	−**0.08**	0.19	0.10
1993–1996	7.82	4.62	**2.11**	−**0.24**	1.33	1.09
1997–2002	2.63	1.00	**1.71**	−**0.72**	0.63	−0.09
2002–2007	**4.25**	2.69	**1.17**	−**1.30**	1.69	0.39
2008–2011	**0.77**	−2.18	**1.94**	−**1.07**	2.09	1.01
average	5.40	3.46	1.49	−**0.58**	1.02	0.44

ing faster than in the manufacturing industries in general since the year 1998 also in machinery and equipment, and similarly to the electronic products industry. Comparing next machinery and equipment (NACE 26–28) as presented in Table 6 to manufacturing in general (Table 3), aggregate labor productivity growth seems a lot more similar to manufacturing and less volatile than the electronic products industry. In both 2002–2007 (as for the electronic products industry) and in 2008–2011 the aggregate labor productivity growth per year was larger than that of manufacturing in general. In machinery and equipment, all of the entry components are negative instead of positive as for the electronic products industry, which suggests that the entry component could potentially be even more negative without the bias created by adding such a particular industry as the electronic products industry in. Net entry seems to have a little less significant effect than for manufacturing in general and the between component seems to have a similar effect as for the electronic products industry, as structural change contributes more to machinery and equipment than it does to manufacturing in general from 1993–2011. All evidence seems to indicate that similar changes in the electronic products industry show also in the machinery and equipment industry, often occurring a few years prior to the electronic products industry. It is also important to note that on the aggregate, the machinery and equipment sector was significantly less affected by the Great Recession in period 2008–2011 than the electronic products industry.

Considering the transportation equipment industry (NACE 29–30), it was commented in Section 5.2 that the sector seems to exhibit less creative destruction than other industries during 2000–2008, and otherwise similar effects to manufacturing overall. Transport equipment was also noticed to have a lower level of aggregate labor productivity since 1988. In 1980–1988 and 2002–2007, the between component was more significant than in manufacturing, but during the other years studied it was fairly similar to that of the entire manufacturing industry. From 1980 to 1996 the aggregate labor productivity growth was smaller than in manufacturing in general, and on the contrary

Table 7: Transport equipment

	aggregate	within	between	entry	exit	net entry
1980–1988	9.69	7.64	**0.64**	0.01	1.40	**1.41**
1989–1992	3.69	1.12	1.24	0.34	0.99	**1.33**
1993–1996	3.38	1.46	1.27	−0.36	1.02	0.65
1997–2002	**4.04**	3.27	0.79	−0.38	0.36	**−0.02**
2002–2007	**3.52**	2.84	**0.64**	−0.50	0.54	0.04
2008–2011	**2.21**	**0.37**	**0.86**	0.28	0.70	**0.97**
average	4.42	2.78	0.91	−0.10	0.83	0.73

from 1997 to 2011 the aggregate labor productivity has been greater than in manufacturing in general. Until 2007 the growth seems almost merely accountable to within industry growth, but in the last period 2008–2011, this seems to have changed as both the net entry effect as well as the between component account for the most part of productivity growth while the within component only contributes about a half of what the aforementioned components do.

Table 8: Food products and beverages

	aggregate	within	between	entry	exit	net entry
1980–1988	10.07	10.46	**−0.30**	−0.34	0.24	−0.10
1989–1992	6.23	5.25	0.13	−0.46	1.32	0.86
1993–1996	2.96	0.27	0.78	−0.39	2.30	1.91
1997–2002	3.00	2.83	**−0.13**	−0.43	0.73	0.30
2002–2007	3.77	2.89	0.66	−1.01	1.22	0.21
2008–2011	**5.79**	**2.79**	0.84	−1.23	3.39	**2.16**
average	5.30	4.08	0.33	−0.64	1.53	0.89

The food products and beverages sector (NACE 10–11) was noted in the previous chapter to have been more productive than manufacturing in general (NACE 10–33) on the aggregate since year 2008. This can be seen by comparing Table 8 to Table 3: the aggregate annual productivity growth for both periods 2002–2007 and 2008–2011 is larger for the food products industry than for manufacturing, and the difference is notable especially for the latter period during which manufacturing in general did not experience any productivity growth and food products grew by 5.79 percent (%). As was suspected, the difference lies in the within component that turned negative for manufacturing but remained positive for the food products industry, whereas the between component has been less significant in the food products industry than in manufacturing in general. The between component has even been negative for the food products industry in 1980–1988 and in 1997–2002. In addition, in 2008–2011 the net entry effect was larger in the food products and beverages than in the overall manufacturing industry. Section 5.3 showed that the food products and beverages industry is particular in its dependence on consumption rather than export demand, and should, therefore, be rather classified as an industry dependent on domestic demand and than as a capital-intensive industry.

Table 9: Wood and paper products, and printing

	aggregate	within	between	entry	exit	net entry
1980–1988	**10.93**	9.62	**0.63**	−0.44	1.12	0.69
1989–1992	5.57	3.18	**1.62**	−0.55	1.31	0.76
1993–1996	**7.59**	4.61	0.88	−0.60	2.70	2.10
1997–2002	**3.84**	3.53	0.20	−1.40	1.51	0.11
2002-2007	1.03	0.96	−**0.46**	−0.82	1.36	0.53
2008–2011	−**3.01**	−5.65	0.05	−0.99	3.58	**2.59**
average	4.32	2.71	0.49	−0.80	1.93	1.13

It was also noticed that the wood and paper products, and printing industry (NACE 16–18) had grown faster than the overall manufacturing industry until the year 1998 in terms of actual growth (see Section 5.2), and from 1993–2003 in terms of cumulative growth (see Section 5.1). Looking at Table 9, it can be seen that on the aggregate, the wood and paper industry actually grew faster in three periods: 1980–1988, 1993–1996 and in 1997–2002. It was also noted that since 2003, the productivity growth had been at a clearly lower level. This is definitely true for the period 2002–2007 (compare Tables 9 and 3) and even more than clear from the following period 2008–2011, in which the aggregate labor productivity growth had turned clearly negative (-3,01% for the wood and paper industry) while it only became neutral (0%) in manufacturing in general. This negative change in aggregate labor productivity in 2008–2011 was principally due to an extremely negative within component which was somewhat relieved by the positive exit (net entry) effect, while the between component had almost no contribution at all. The between component was actually less significant for the wood and paper industry than in manufacturing in general in all periods except for years 1980–1992 (being particularly negative in 2002–2007), which seems to reflect the fact that the industry was exposed to the structural change already before the mid-1980s as mentioned previously.

In the rubber and plastics products sector (NACE 22–23), the aggregate productivity

Table 10: Rubber and plastics products, and other non-metallic mineral products

	aggregate	within	between	entry	exit	net entry
1980–1988	10.21	9.63	0.30	−0.25	0.52	0.27
1989–1992	3.32	1.81	1.20	−0.31	0.62	0.31
1993–1996	**7.26**	**5.39**	0.76	−0.69	1.80	1.11
1997–2002	2.56	2.41	0.11	−0.48	0.52	0.04
2002–2007	**5.41**	**4.00**	0.16	−0.46	1.70	**1.25**
2008–2011	**0.19**	**−1.04**	0.66	−0.46	1.02	0.57
average	4.82	3.70	0.53	−0.44	1.03	0.59

growth seemed to follow the same pattern as that of the overall manufacturing industry with the exception that it had grown at a clearly lower level since 1989 (as noted in Section 5.1). In Section 5.2, it was also noted that until the 1990s, the industry productivity grew faster than manufacturing in general, and that the aggregate labor productivity fell simultaneously while the growth in the between component was smoothed out around the year 1993. The fall in 1993 is suspected to might have been a consequence of the early 1990s depression. Interestingly enough, when looking at the time periods given (see Table 10), the rubber and plastics products, and other non–metallic mineral products industry seems to have experienced more aggregate labor productivity growth in both 1993–1996 and 2002–2007, and even slightly more in 2008–2011 as compared to manufacturing overall (Table 3). This seems to be simply caused by differences in the size of the within component (which was more positive in 1993–1996 and 2002–2007 as well as less negative in 2008–2011) as well as in 2002–2007 due to a more positive exit (net entry) effect. Moreover, the between component is less significant in the rubber and plastics industry throughout the years than it is in manufacturing in general.

Table 11: Textiles, wearing apparel, leather and related products

	aggregate	within	between	entry	exit	net entry
1980–1988	8.37	7.34	0.23	−0.32	1.13	**0.80**
1989–1992	**8.86**	4.98	1.04	**0.03**	2.82	**2.84**
1993–1996	**5.98**	3.56	1.11	−0.35	1.66	1.31
1997–2002	**4.02**	2.39	0.75	−1.29	2.17	**0.88**
2002–2007	**4.56**	2.38	**0.94**	−0.95	2.18	**1.23**
2008–2011	**0.72**	0.32	0.32	−1.41	1.49	0.08
average	5.42	3.49	0.73	−0.72	1.91	1.19

Finally, looking at the sectors first classified as labor-intensive, one can start by reviewing Figure 11 corresponding the textiles, wearing apparel, leather and related products industry (NACE 13–15). In Section 5.1, it was noted that the textile industry follows a relatively similar pattern as manufacturing does overall, and in Section 5.2 it was noted that the between component was also similar to that of the manufacturing industry except that structural change started to grow slightly later in 1987 and has grown at a lower level since. Now proceeding to Table 11, it can bee seen that since 1989, the textile industry seems to experience faster productivity growth on the aggregate that manufacturing does in general. This is accounted for mainly by the within component, while the between component has a similar effect than it in manufacturing does in general except for 2002–2007 during which it has a greater impact on the productivity growth as in other industries. The net entry effect seems to contribute more than it typically does in years 1980–1992 and 1997–2007 (as compared to Table 3), but however is less significant in 2008–2011. The similarities in the evolution of the textile industry and the food products and beverages industry seem self-explanatory and therefore it is also preferred to classify the textile industry rather as dependent on consumption demand than labor-intensive.

Table 12: Furniture; other manufacturing; repair and installation of machinery and equipment

	aggregate	within	between	entry	exit	net entry
1980–1988	10.17	8.93	0.36	−0.26	1.14	**0.88**
1989–1992	5.27	2.92	**1.55**	−0.44	1.24	0.80
1993–1996	**6.79**	3.41	1.43	−0.24	2.19	**1.96**
1997–2002	2.84	2.30	1.03	−1.52	1.03	−0.49
2002–2007	**4.46**	3.77	0.25	−1.41	1.85	0.44
2008–2011	**2.17**	0.53	**−0.25**	−0.88	2.75	**1.88**
average	5.28	3.64	0.73	−0.79	1.70	0.91

It was previously noted in Section 5.1 that the furniture, other manufacturing; repair and installation of machinery and equipment industry (NACE 31–33, Figure 12) seemed to grow less rapidly than manufacturing in general from 1991 to 2009 in terms of cumulative aggregate labor productivity. In addition, in Section 5.2, it was found out that in 2002 the structural growth slowed down instead of having accelerated, then fell in 2007 and has otherwise followed a fairly stable level in 2002–2007. Looking at Table 12, it actually seems like the aggregate annual growth has been growing faster in the furniture, other manufacturing; repair and installation of machinery and equipment and other manufacturing industry than in manufacturing during years 1993–1996 and 2002–2011. In the furniture, other manufacturing; repair and installation of machinery and equipment industry, the between component seems to contribute approximately as much as in manufacturing in general, except for 2008–2011 during which between actually turns negative and during which the changes are mainly accounted for by the positive net entry and especially the positive exit component as well as partially by the positive within growth respective to manufacturing in general.

Both the textiles, wearing apparel, leather and related productsindustry as well as the furniture, other manufacturing; repair and installation of machinery and equipment industry seem to imitate the aggregate labor productivity growth of manufacturing (Table 3). However, the furniture, other manufacturing; repair and installation of machinery and equipment industry was found more dependent on exports than on domestic demand, and has also some temporal particularities which means it should be rather classified as an export-dependent industry. Even though somewhat similar to the textile industry, the classification into consumption and export demand is preferred instead of considering the aforementioned industries labor-intensive.

5.3 Export demand and consumption demand

In the study, it was also considered a possibility that export demand could explain productivity in the some of the representative sectors studied whereas consumption (domestic demand) would explain the productivity of others. Export demand measured as total exports of goods for Finland (scale on the right) is shown together with the cumulative aggregate labor productivity of five sectors known to depend heavily on exports (scale on left) in Figure 15. The data is from the statistics of the Organization for Economic Co-operation and Development (OECD 2016a) and has been retrieved from the Federal Reserve Bank of St. Louis site under the title Total Exports of Goods for Finland. As can be seen from the the figure, many industrial sectors are clearly dependent on the evolution of exports. When exports abroad grow (decline), productivity in export-dependent sectors is likely to grow (decline) respectively. To investigate which industries were dependent on exports, a linear regression was constructed for each representative sector at a time in order to explain both aggregate labor productivity and between component growth by growth in exports (measured in logarithmic percents like earlier). Results of the regression analysis together with corresponding figures are found in Appendix I. The analysis shows that aggregate labor productivity seems to be dependent on exports in the textiles, wood and paper, chemical and pharmaceutical products,

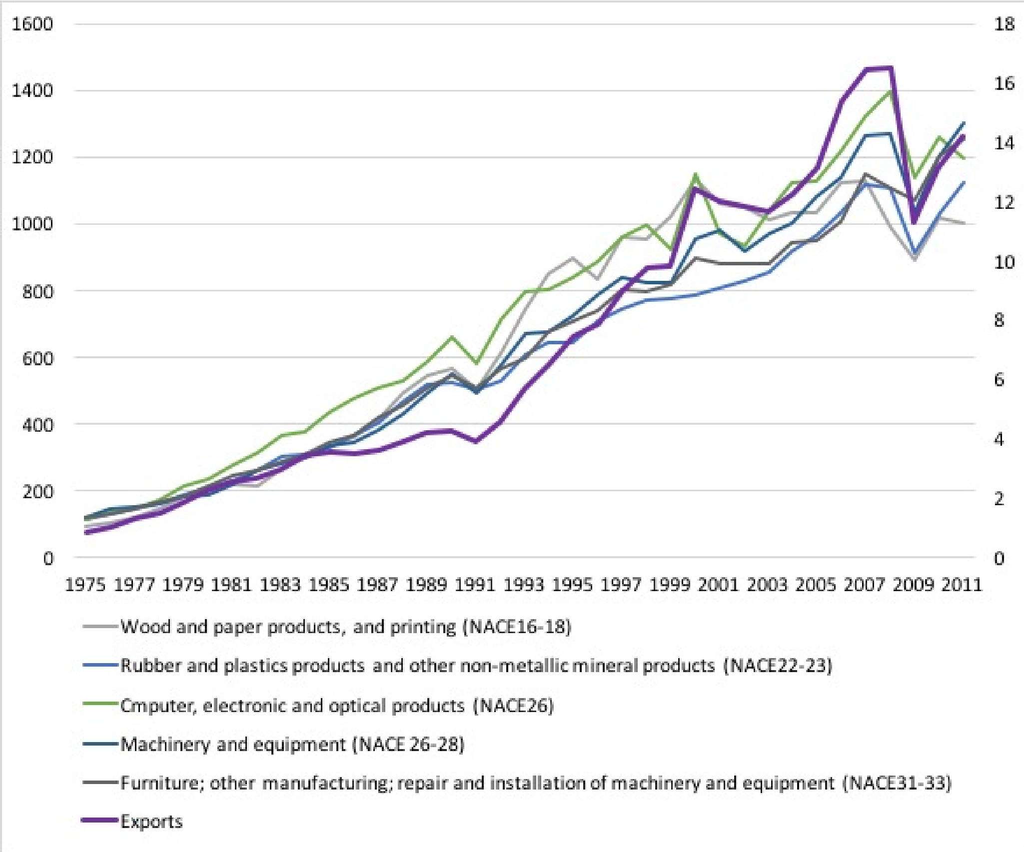

Figure 15: Cumulative aggregate labor productivity in several sectors and exports

rubber and plastics products, and other non-metallic mineral products, computer and electronic products, machinery and equipment, transport equipment, in furniture, other manufacturing; repair and installation of machinery and equipment industries and in manufacturing overall. Exports seem to be non-significant only in the food products and beverages industry, which also has a different shape cumulative aggregate productivity curve than the other industries as can be seen already in Figure 4. Therefore, explaining the aggregate labor productivity growth in the food products and beverages industry by exports did not produce reliable results enabling to make any predictions on the regression analysis.

In terms of structural change (measured by the between component), regression analysis showed that structural change could not be explained by growth in exports even though aggregate labor productivity growth was. Only the between component of transport equipment and of overall manufacturing explained by exports reached a significant confidence level $p \leqslant 0.05$ but even those regressions did not seem particularly accurate as measured by R^2 or adjusted R^2. The results suggest that structural change between production units is very unlikely to depend on exports even in the industries driven by export growth, whereas aggregate labor productivity seems to correlate most clearly with exports.

Figure 16 shows the evolution of private consumption (scale on the right) as compared to three sectors (scale on the left) of which food products and beverages seems lately to be the sector most driven by consumption demand. The data is from the statistics of the Organization for Economic Co-operation and Development (OECD 2016b) and has been retrieved from the Federal Reserve Bank of St. Louis site under the title Private Final Consumption Expenditure in Finland. The textiles, wearing apparel, leather and related products industry and machinery and equipment serve as a reference showing the general growth of cumulative aggregate labor productivity growth in other industries, all of which seem to have evolved similarly to domestic consumption throughout the years. In terms of this study, the most significant part of the figure lies in years 2009–2011, in which productivity and exports dropped but both private consumption and aggregate productivity in the food products and beverages industry are on the rise. Therefore, the food products and beverages industry can be nominated as the industry that is clearly the most dependent on private consumption in Finland and is significantly more dependent on domestic demand rather than on exports. Though not shown in the figure, it was also noticed that the chemical and pharmaceutical products industry and the transport equipment industry were the sectors that were found the least dependent on consumption demand while manufacturing overall seems to follow consumption demand until 2007 since which it has been diverging more from the consumption demand and rather following export demand. The textile industry was also found relatively dependent on domestic demand as was, quite interestingly, machinery and equipment. Nevertheless, the two industries suffer from a productivity shock at the time of the Great Recession in 2007 during which consumption demand seems to carry on unaffected. Unlike what was expected in Section 4.3, the furniture, other manufacturing; repair and installation of machinery and equipment industry showed not to be dependent on consumption demand.

5.4 Overview of the sectoral results

The food products and beverages industry was seen to experience a reawakening of creative destruction around 2002. The fact that the growth of the between component in the sector is less significant than in the manufacturing industry in general corresponds the idea that productivity in the food products and beverage industry has grown rather

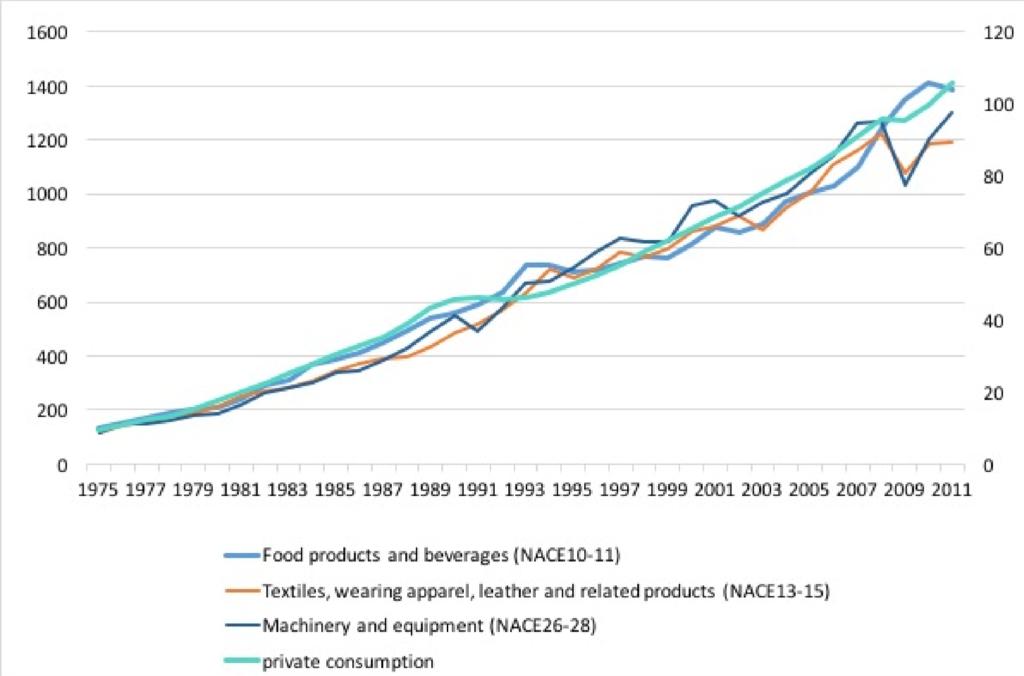

Figure 16: Cumulative aggregate labor productivity in several sectors and private consumption

thanks to growth within production units than thanks to creative destruction as was supposed in Section 5.1. However, it seems that in the periods following productivity shocks there has been some structural change though, which could indicate that the productivity shocks have obliged the food products and beverages industry also to restructure and innovate. In Section 5.2, it was noted that the food products industry had larger aggregate labor productivity growth than manufacturing in general from 2002 to 2011, especially during the Great Recession in 2008–2011 during which aggregate labor productivity grew significantly in the food product industry while it turned negative in manufacturing. The growth was largely accounted for through the within component, but looking at Table 8, the significance of the between component can also be seen to have relatively increased.

Most interestingly, the net entry effect grew remarkably in the food products industry in period 2008–2011, which could at least partially indicate creative destruction though not yet reflected by the between component. The evidence seems to support the idea that food products and beverages industry has lately experienced an increase in its productivity growth mainly due to firms optimizing their production processes and increasing productivity from within and, since the Great Recession, due to an increasingly positive exit (net entry) effect. As was suspected earlier, the evidence seems equally to support the idea that the Great Recession has obliged the food products industry to innovate, but not necessarily to restructure as much: by looking at specific years in Section 5.2, microstructural change was found to have grown in 1992–1995, 2002–2004 and in 2007–2011, but the structural change seems less significant when looking at the time interval analysis in Section 5.2. The productivity growth in the food products and beverages industry is therefore likely originating principally from other factors than the creative destruction process, except for the latest years after the Great Recession.

Next proceeding to analyze the textiles, wearing apparel, leather and related products sector, it can be deduced that the textile industry does experience creative destruction, though there is no such clear change in it around 2002 as there is for many other industries. However, when looking at specific time intervals in Section 5.2, it seems that the influence of the between component grew in the industry in the period 2002–2007. The creative destruction process in the textiles, wearing apparel, leather and related products industry appears to be slightly less significant than that in manufacturing in general, which could suggest that the creative destruction process is even stronger in R&D-intensive industries than it is in labor-intensive industries. Moreover, it could also suggest that the creative destruction process is stronger in export-dependent industries as compared to domestic consumption dependent industries, bearing in mind that the textiles, wearing apparel, leather and related products industry was found to be at least somewhat dependent on consumption previously. Section 5.2 also revealed that for the last 12 years studied, the textiles, wearing apparel, leather and related productsindustry has experienced faster aggregate labor productivity growth than manufacturing in general when measured as annual average growth and that the within component was found to be a significant underlying factor behind the aggregate productivity growth. Net entry also seemed more significant than typically in manufacturing in most of the years studied, but not in 2008–2011.

The finding that creative destruction was stronger in the wood, paper and printing industry until 1998 is consistent with prior research, in which the paper industry has been found to have experienced significant creative destruction already prior to 1985. This might have been due to market pressure from the Western markets already before in the mid-1980s (Maliranta 2014b, 33). In Section 5.2, it was also noted that the between component contributed more to the wood, paper and printing industry than to manufacturing in general in the two first periods 1980–1988 and 1989–1992. This is in line with the supposition that structural change was strong in the wood, paper and printing industry before than in many other industries and already in the mid-1980s, but it seems like structural change has become less significant since the early 1990s depression. One possible explanation for why the aggregate productivity growth has been much less significant at least since 2002 in the wood and paper products industry as opposed to other manufacturing industries lies in the lack of creative destruction which has endured for years.

The wood, paper and printing industry was particularly hit by the Great Recession in interval 2008–2011, which was principally caused by an extremely negative within component. Interestingly and somewhat similarly to what was noted in the case of the food products and beverages industry, the net entry effect lead by a very positive exit effect actually smoothed out the negative within effect to a certain extent as can be seen from Table 9. Maliranta (2014a, 32) considers that the wood and paper industry could even be experiencing negative creative destruction. The between component has had almost no contribution to the evolution of the industry in the last 15 years, indicating that there has been little structural change in the industry since the 1980s during which structural change boosted the sector. It is prudent to conclude that the wood and paper industry has not been experiencing sufficient reallocation of resources from less productive units to more productive ones since the 1990s, and this has likely affected its overall productivity growth as well. Technological advances and innovations have been less present in the wood and paper industry as compared to many other manufacturing sectors, which might be one explanation for why the wood and paper industry is one of the sectors that has least profited from creative destruction.

If one should distinguish a single industry with least creative destruction as measured by the between component, this would definitely be the chemical and pharmaceutical products industry. It was noted that the structural change in manufacturing, in general, was around 3,5 times stronger than in the chemical and pharmaceutical products industry (29% vs. 8%). Considering overall productivity growth, this can be interpreted very little or almost no development in the between component in around 30 years time, which would lead to think that there has been very little creative destruction in the industry. This is quite surprising, as one could suppose that the chemical and pharmaceutical products sector invests a lot in R&D and is constantly innovating. The difference could be partly accounted to the fact that the entry, exit and between components in the industry seem much more volatile than those of other industries. Nevertheless, it seems that microstructural change has remained at a fairly stable level in the chemical and pharmaceutical industry between 1990 and 2011, while the microstructural change has augmented rapidly in manufacturing overall.

The chemical and pharmaceutical products industry was also found interesting in terms of the entry and exit components: it was noted in Section 5.2 that the entry component of the chemical and pharmaceutical products industry was slightly ascending from 1979 to 1992, since which it has been descending like for other manufacturing industries. The ascent could tell about many young, productive firms entering the market in a similar way as for the electronic products industry, but however, this development only continued until the end of the depression in 1992. In the case of entering units in the chemical and pharmaceutical products industry, this might have meant that after the depression, the entering production units were less productive than the established units in the market in general as had been true in other industries already prior to the depression. The exit component in the chemical and pharmaceutical products industry reflects a slightly different evolution as mentioned in Section 5.2, as it diverges from the norm in the manufacturing industries starting in the year 1995, from which it stayed relatively stable for around ten years: this could reflect a long, stagnant phase preceding the financial crisis that broke out around 2008 in which the chemical and pharmaceutical industry did relatively well and the least productive units were actually not necessarily obliged to exit the market as they were able to make profits regardless of being less productive and thanks to the favorable market environment. In Schumpeterian growth theory, this is the so-called Schumpeterian effect presented in Section 3.4, in which competition works as a discouraging factor to stagnated companies that do not seek to become market leaders and only reach for short-term results.

In Section 5.1, it was noted that in terms of cumulative aggregate labor productivity, the chemical and pharmaceutical industry has grown following the same pattern than manufacturing in general with the exception that the growth has been at a significantly lower level since 1991. This was even lower than the corresponding level of wood, paper products and printing industry. This combined with the change in the entry component around the same time leads to consider that the early 1990s depression affected the chemical and pharmaceutical products industry most clearly. Since the entry, exit and between components were found very volatile, it was expected that analyzing annual averages would help correct the possible errors caused by volatility. Measured by an annual growth rate, the chemical and pharmaceutical products industry experienced lower aggregate labor productivity than manufacturing in all periods except for 2008–2011 as seen in Section 5.2. This divergence is due to differences in the within component (not in the between or the net entry component) and therefore also unrelated to creative destruction. It could also lead suggest that the Great Recession affected the chemical and pharmaceutical products industry less than the early 1990s depression. In addition, it was noted that relative to the industry level in general, the significance of the exit component has grown towards years 2008–2011.

In the rubber and plastics product industry, the slowdown in structural change since 1993 noted in Section 5.2, regardless of more important structural change than in manufacturing in general before 1990, could be reflecting a more general slowdown in all components of productivity with a couple years lag after the depression in Finland, as aggregate labor productivity in the sector dropped down after 1993 as well. It seems also relatively clear that the rubber and plastics products, and other non-metallic mineral products industry is a capital but not R&D-intensive industry much like the wood and paper products industry and also similarly dependent on export, and might therefore have evolved in a similar manner, experiencing only minor creative destruction in the last decade(s). However, as was noted in Section 5.2, in 1993–1996 and in 2002–2011 the aggregate labor productivity of the rubber and plastics industry was actually higher than that of manufacturing overall, though only slightly for the period corresponding the Great Recession 2008–2011. The differences were mainly accounted for by the within component, and for the period 2002–2007 by a more positive net entry, in particular exit, effect. The between component was also noted to be less significant in the industry than in manufacturing in general. The increase in net entry could tell about the reawakening of creative destruction to some extent, and even more so about the speeding up of the 'destruction side' effect after the productivity shock that occurred in the turn of the millennial. During the early 2000s productivity shock, especially the exit component appears to have grown more rapidly than other components and thus has an increasingly positive effect.

Proceeding to the machinery and equipment and electronic products industries, the finding that creative destruction started growing faster in machinery and equipment already in 1998 and later on in 2002 in the electronic products industry corresponds the idea that the dot-com bubble happened simultaneously with a more general productivity shock and that changes in the companies in the ICT-sector (such as those working in the electronic products industry) were actually preceded by the acceleration of creative destruction in other significant industries, such as in machinery and equipment. This is consistent with prior research that claims that the 'wave of creative destruction' in the early 2000s was actually not lead by the ICT-cluster, and that the process was actually similar in many manufacturing sectors (Maliranta 2014b, 32). Machinery (NACE 28) has also been studied as a separate sector and it seems to be one of the most significant sectors in manufacturing with creative destruction very similar to that of the entire manufacturing industry, and independent from the computer, electronic and optical products industry (NACE 26) (Maliranta 2014b, 32).

Regarding the electronic products industry, it can be considered that the rise in productivity starting in 2002 was creative destruction originating from the dot-com bubble that served as a trigger to allocate resources in a new way to more productive firms. These findings are also in line with those of Maliranta (2014a, 32), who found that creative destruction was relatively strong in industries producing machinery and equipment and that sectors with lots of R&D activities, such as the high tech industries, tend to experience lots of creative destruction. Besides, it was noted in Section 5.2 that the entry and exit components of the electronic products industry differed significantly from those of any other industry. Since the entry component is generally negative due to young firms entering the market with productivity lower than in the industry on average, the electronic products industry can be considered as particular in the sense that many firms in the industry come into the market with a new innovation, and thanks to that innovation, also with a higher level of productivity than what companies in the market currently have as they do not possess the new technology. In other words, young computer, electronic and optical products firms enter the market with a particularly high level of productivity thanks to the impressive amount of intangible capital in the sector.

Investments, especially in the IT sector and software industry, are characterized by their capital efficiency for both experimentation and for subsequent scaling as well as for their ability to generate large returns relatively fast (Kerr et al. 2014, 33). This means that it is easier for venture capital firms and investors to run lots of initial experiments at a controlled cost and then find out the 'fittest' in order to fund them on a second round (Kerr et al. 2014, 33). This is another likely reason for the computer, electronic and optical products industry to exhibit such a positive entry effect: since new firms receive funding with relative ease, there are many new technologies and ideas that compete for funding in the industry, of which the most productive ones are the ones that receive funds and then enter the market. Regardless of numerous factors that have created a positive entry effect in the past years, the time interval analysis conducted in Section 5.2 showed that the entry component turned out to be positive in all time intervals except during years 2008–2011, reflecting the gravity of the Great Recession in the electronic products industry.

Moreover, the evolution of the exit component in the electronic components industry could tell about the overheating in the dot-com market: only since 2002, the less productive firms have also been obliged to leave the market and are then replaced by new, more productive production units. Before the millennial, there might have been so much demand for the inventions of the dot-com companies that even the less productive ones could actually stay in the market, therefore causing a negative exit effect. This definitely supports the idea of the reawakening of creative destruction in 2002 and that the dot-com bubble was followed by positive productivity effects through the exit component. The exit component in the electronic products industry fell in 2008, corresponding the effects of the Great Recession that may likely have been preceded by a stagnant period and thus accelerated the exit of ineffective production units only since 2009. In Section 5.2, it was also observed that the aggregate labor productivity of the electronic products industry was clearly smaller than in manufacturing in general over periods 1997–2002 and 2008–2011, reflecting the fact that the industry is extremely sensitive to economic shocks and that, on the other hand, the industry seems to recover relatively rapidly. In 2002–2007, for instance, labor productivity grew faster in electronic products than in other manufacturing industries on the aggregate. This might be thanks to the significant contribution of creative destruction, which was clearly larger for the electronic products industry than for the overall manufacturing industry in 1997–2011.

In Section 5.2, it was also mentioned that the Great Recession affected productivity to a lot larger extent in the electronic products industry than it did in machinery and equipment, and this is also supported by the finding that machinery and equipment had higher aggregate productivity in both 2002–2007 as well as 2008–2011 than other manufacturing industries did in general. In addition, it was also noted that the structural change contributed to labor productivity in machinery and equipment from 1993 to 2011 on a larger scale than it did for manufacturing in general.

Like for manufacturing in general, it is seems that both the transport equipment and the furniture, other manufacturing; repair and installation of machinery and equipment industry that the industries are affected by structural change and that it is a relatively important factor behind their labor productivity growth. In Section 5.2, it was noted that from 2000 to 2008, the transport equipment was less affected by creative destruction and has gone back to the normal evolution of manufacturing in general since 2008. During the same period, the entry component descended and the exit component ascended similarly to the manufacturing industry in general. This 8-year period in transport equipment could reflect a period of higher economic growth during which productivity growth happened rather within production units as no significant changes in the entry, exit nor between components are found.

As noted in Section 5.2, the entry component in the transport equipment industry behaved in a particular way in 1977–1983, 1985–1989 and 1991–1994, years during which it was ascending instead of descending. The exit component did not follow the same pattern, as it experienced only a significant increase in 1983 and has since been growing rather similarly to manufacturing in general. The first two periods, in which the entry component increased, correspond the mid-1980s changes in the market and banking environment and the latter corresponds to the early 1990s depression, meaning that during economic shocks the initial productivity of entering units tends to go up in the transport equipment industry. Similar results are found in the period corresponding the Great Recession as the entry component seems to be also ascending in the transport equipment industry since 2009. The sudden increase in exits in 1983, on the other hand, could tell about a single event that hit the industry so that the least productive production units were forced to leave the market during a brief period. It is hard to distinguish what this event might exactly have been, but likely that it was related to the changes in the market and banking environment as was likely the ascent of the entry component. In Section 5.2, it was also noted that the annual aggregate labor productivity growth in the transport equipment industry had become larger than in manufacturing in general since 1997, and that this was accounted by the within component until the last period 2008–2011. In the period 2008–2011, aggregate labor productivity growth is rather accounted for by the between component, and net entry has also become more significant. This is an interesting finding that could suggest that the Great Recession has reawaken structural change in the transport equipment industry, even though later than in other industries, in which it occurred already around 2002.

Continuing to the furniture, other manufacturing; repair and installation of machinery and equipment industry, as was also mentioned in Section 5.2, saw its structural change growth turn negative in 2007. The timing corresponds the Great Recession and suggests that the furniture, other manufacturing; repair and installation of machinery and equipment has been one of the industries that were most harshly hit by the recession merely looking at structural change. The sector has experienced little creative destruction since structural change slowed down around 2002, which could be thought of as a adverse effect of the reawakening of creative destruction that occurred at the time in other industries. In Section 5.2, it was noted that the aggregate labor productivity growth (as measured as an annual percentage on certain time intervals) was actually higher in the furniture, other manufacturing; repair and installation of machinery and equipment industry in 1993–1996, 2002–2007 as well as in 2008–2011. The largest difference between the furniture and other manufacturing industry as compared to manufacturing in general lies in years 2008–2011, during which labor productivity growth was negative for the manufacturing industry on the aggregate but positive for the furniture and other manufacturing industry. Quite interestingly, the between component in the sector was found approximately as significant as for manufacturing in general, except for years 2008–2011, during which the between component was more significant in manufacturing in general and while the net entry effect (thanks to a very positive exit component) became clearly more significant for the furniture and other manufacturing industry. It can be concluded that the furniture and other manufacturing industry is a sector generally experiencing creative destruction, whereas after the Great Recession it experienced more of the positive ’destruction’ instead of structural change.

Lastly, the evolution of all manufacturing industries (NACE 10–33) is also analyzed. Like stated in Section 5.2, the shape of the entry component in Figure 5 exhibits an acceleration in the descent around 1999 from which the descent is somewhat less pronounced in 2005–2007 and then accelerates back to its prior growth rate since 2007. The change in 2005–2007 could be interpreted as a reflection of the stagnant period which is then followed by an increase in entry around the moment that the Great Recession started (approximately in 2008). Comparing this to the evolution of the between component as reviewed in Section 5.2, the creative destruction was noted to pass through a corresponding stagnant phase from 2004 till 2008 in which the amount of structural change stayed at its current level. The growth of the between component was also noted to have slowed down in 1997–1998, whereas the ascent of the entry component accelerated around 1999: less structural change in the period could, therefore, be explained by the growing amount of entering units that affected the market through the entry instead of the between component. While the between component and therefore creative destruction was also noted to have slowed down in 1993–1995 and 2001–2002, there were none clear changes in the entry component that would correspond this period.

In Section 5.2, it was also mentioned that the exit component was a steadily ascending slope respectively, with an acceleration in its ascent earlier than in the entry component already around 1986. This could reflect the changes that happened in the capital markets environment and the introduction of international trade as explained in Section 1.1, which might have forced the least productive units to exit the market once the competition between firms had become tougher and the markets more exigent than when exporting to the Soviet Union. It results that the changes in the mid-1980s lead into increasing market exit that then had a positive productivity effect on manufacturing in general, starting in 1985 and enhancing in 1986 as shown in Figure 3. The exit component was also perceived to accelerate and decelerate ending up at its initial level from 1994–1999 which could also be considered a sort of a stagnant phase, while around the same time the between component had also slowed down in 1997–1998. Both the exit and entry components accelerated in terms of descent and ascent respectively in 1999, which could reflect changes in the manufacturing industries market that preceded the dot-com bubble.

5.5 Creative destruction in recessions and the nature of the industries

One of the principal research topics in the study was the possible connection between creative destruction and economic downturns. The study concentrated on four economic downturns that have also been proved to have caused important shocks in productivity. The aim was to find out whether there is evidence supporting the hypothesis according to which the creative destruction process accelerates during and right after economic shocks as suggested by theory. In terms of the time intervals, chosen as mentioned in the introductory Section 1.1, the period in the mid-1980s seems to be the least significant of the four time periods studied in terms of both labor productivity and creative destruction. The period corresponds the changes that occurred in the banking and market environment. On the other hand, the Great Recession seems to have triggered even larger changes and more creative destruction than the early 1990s depression did. The dot-com bubble and the simultaneous productivity shock seem more significant for certain sectors (such as the computer, optical and electronic products industry and machinery and equipment) than for others. The aforementioned productivity shock started to affect creative destruction slightly before the dot-com bubble and both of the shocks took place in the late 1990s and early 2000s. The shocks might also have led to the reawakening of creative destruction that happened in many sectors around the year 2002, while in certain sectors creative destruction seems to have gained strength only after the Great Recession had hit the economy around 2008.

Even though a clear, moderate-size productivity shock occurred in the manufacturing industries in the mid-1980s, there seems to be little evidence supporting the idea that the changes at the time would have directly either enhanced or reduced the creative destruction process in any of the industries studied. In spite of the fact that no distinct changes were identified, the creative destruction mechanism was noticed to have been strong in the 1980s and to some extent also in the 1990s in sectors including the wood, paper and printing industry and the rubber and plastics products, and other non-metallic mineral products industry. Furthermore, it was noted that the early 1990s depression had a clear effect on the productivity of industries, such as the chemical and pharmaceutical products. However, in the case of the chemical and pharmaceutical products industry, the shock in the 1990s affected the within component for the most part and thus does not necessarily indicate creative destruction. In the rubber and plastics products, and other non-metallic mineral products industry as well as in the wood, paper and printing industry, creative destruction seems to have played a central role until the early 1990s depression, but no longer since the depression. This leads to conclude that the early 1990s depression actually might have even hindered creative destruction at least in the case of certain industries. The early 1990s depression clearly affected productivity, but might not have strengthened the creative destruction process in Finland, unlike the Great Recession later did.

Previous research has found that there has been a so-called reawakening of the creative destruction mechanism in manufacturing since 2002. The evidence found in this study also seems to support the idea that creative destruction gained strength around 2002, and clear signs of the phenomenon were found in the food products and beverages, electronic products, machinery and equipment and textiles, wearing apparel, leather and related products industries. The timing corresponds the productivity shock in the change of the millennial, corresponding the dot-com bubble and a simultaneous productivity shock that affected others than the ICT-sectors. It was also noted that the furniture, other manufacturing; repair and installation of machinery and equipment sector might have experienced an adverse effect, a slowdown in creative destruction, around year 2002. Moving on to the fourth shock in the scope of the study, Finland is experiencing a gradual productivity slowdown as shown in Section 5.2, and its labor productivity was particularly hit in 2008–2009 when the Great Recession had reached Europe (see Figure 3). As mentioned, in the interval 2008–2011, the productivity growth had gone down to 0%, the shock originating from a negative within component likely indicating that the financial crisis had caused an immediate negative effect on firms' ability to raise their productivity within production units. However, it was also noted that the net entry effect and the between component were positive and actually smoothed out the extremely negative productivity effects. The positive between effect and net entry effect indicate that in manufacturing in Finland, the Great Recession clearly reinforced the creative destruction process. The transport equipment industry was also found to experience a reawakening in its creative destruction around the time of the Great Recession in 2008.

Next investigating the effects of the two recessions on the different sectors, the chemical and pharmaceutical products industry seems to be the sector that most suffered in terms of productivity after the early 1990s depression, while the food products and beverages industry seems to have suffered from the depression relatively hard as well. The transport equipment and the rubber and plastics products, and other non-metallic mineral products industries seem to have suffered already during the depression in 1989–1992. On the contrary, the industries that most suffered from the Great Recession were the wood, paper and printing industry and the computer, electronic and optical products industry. Relative to other manufacturing industries, the food products and beverages industry has managed to grow in terms of aggregate labor productivity, regardless of the Great Recession and unlike manufacturing in general. The chemical and pharmaceutical products, as well as the transport equipment industry, have also been less affected than other industries in terms of productivity, and the furniture, other manufacturing; repair and installation of machinery and equipment industry seems to experience the same productivity slowdown as the nation does, but has not been hit very hard by the early 1990s depression nor the recent financial crisis.

A central topic in the study was to examine the common nature and features in the representative manufacturing industries. The study aims to explain the differences in how different industries conduct with respect to productivity shocks by differences in the nature of the industries in question. Looking at Table 1, it was first proposed to classify the representative sectors by dividing them into capital and R&D-intensive, capital but not R&D-intensive and into labor-intensive sectors.

According to the findings presented, the group 'capital and R&D-intensive sectors' is the most varied of the three groups and covers industries with certain particularities of their own. The within component seemed most determinative in the chemical and pharmaceutical products industry, for which the net entry effect nor the between component were less important. The chemical and pharmaceutical industry does not function like the R&D-intensive in terms of structural change, and would rather correspond the definition 'capital but not R&D-intensive'. On the contrary, the between component indicating structural change (also referred to as creative destruction in this study) is significant in all other three industries, especially in the electronic products industry and in machinery and equipment but also to the same extent as for manufacturing in general in the transport equipment industry. In the transport equipment industry, it looks like the between component as well as the net entry has become more significant coming to the last period 2008–2011, indicating that their contribution could be on the rise. The net entry is especially significant in the electronic products industry, but not as much in machinery and equipment. Looking at temporal differences among the R&D-intensive industries, all sectors seems to conduct differently at different time periods. In the chemical and pharmaceutical products industry aggregate labor productivity grew during the period following the recent financial crisis 2008–2011, whereas the electronic products industry suffered productivity losses in both 2008–2011 and 1997–2002, the latter corresponding the dot-com bubble. The machinery and equipment industry seems to have suffered a little less than the electronic products industry during 2008–2011. The transport equipment industry seems to have suffered the most from the productivity shocks in the 1980s and 1990s and has recovered since the turn of the millennial.

There are several points in common for the group 'capital but not R&D-intensive sectors' (food products and beverages, wood, paper products and printing and rubber and plastics and other non-metallic mineral products). Firstly, the between component seems relatively insignificant for all the three combined sectors and all the time periods studied. Secondly, aggregate productivity seems extremely dependent on the within component and somewhat dependent of the net entry effect. The net entry effect is positive and originates from a largely positive exit component. Looking at different time intervals, the wood, paper products and printing industry seems to have a similar evolution than the rubber and plastics products, and other non-metallic mineral products industry, both of which seem to have experienced strong creative destruction in the 1980s but not much since the early 1990s depression. However, the food products and beverages industry does not seem to share the same temporal evolution and has actually grown in productivity during the Great Recession while the two other industries have rather suffered productivity losses.

Lastly, in the two labor-intensive industries studied, both the textile, wearing apparel, leather and related products industry as well as the furniture, other manufacturing; repair and installation of machinery and equipment industry seemed to depend on structural change to the same extent than manufacturing industries do in general. In other words, the between component showed as somewhat important in both industries and to the same extent on average in both industries over time. In the textile industry, the effect of the between component was actually very significant during 2002–2007. However, in the furniture, other manufacturing; repair and installation of machinery and equipment industry creative destruction (as measured by the between component) shows even to have turned negative in 2008–2011, indicating that the financial crisis was a major productivity shock in the furniture, other manufacturing; repair and installation of machinery and equipment industry but did not trigger structural change. The net entry effect is relatively important to both industries as can be seen from the corresponding tables. Aggregate productivity growth was more significant in the textile industry from 1997 to 2011 and in the furniture, other manufacturing; repair and installation of machinery and equipment industry from 2002 to 2011 than in the manufacturing industry in general. Both labor–intensive sectors seem to have evolved relatively similarly in terms of aggregate labor productivity growth over the time period studied. Both have been affected by structural change, but not more than manufacturing in general. Since there are only two representative combined sectors in the labor-intensive sector group, the results might not tell the entire truth. In any case, the textiles, wearing apparel, leather and related products industry and the furniture, other manufacturing; repair and installation of machinery and equipment industry do have some similarities.

Disregarding the temporal differences between the industries and the particular nature of the chemical and pharmaceutical products industry, it seems like the common feature among the R&D-intensive industries is significant structural change as measured by the between component (unlike in the other two groups). In these industries, structural change plays an important role in contributing to aggregate productivity growth, and the significance of the component could be on the rise. The possible effect of entering and exiting units seems to vary among the different sectors, and no further predictions regarding the net entry effect in R&D-intensive sectors can thus be made. An alternative solution is to consider the second classification presented, which actually seemed to bring up interesting similarities between the sectors.

According to the results concerning the division of the sectors into dependent on domestic (consumption) demand and export demand, the food products and beverages industry was the single to be classified as clearly dependent on domestic demand. The rest of the industries were classified as dependent on export demand. In export-dependent industries, exports definitely seemed to explain aggregate labor productivity growth in all sectors, but evidence supporting the idea that exports would explain structural change was not found. However, many export-dependent sectors were found to experience lots of structural change (with a few exceptions including the wood and paper industry was found to have experienced more structural change previously and the rubber and plastics industry experience less structural change overall) while the single consumption-dependent industry (the food products and beverages sector) was found to experience growth in the within component, rather than in the between component.

Looking back at the merely capital-intensive sectors, which seemed the most uniform group in the first classification, capital-intensive industries do not seem to benefit much from creative destruction in their productivity growth. It is also hard to make predictions on the capital-intensive industries as such, since many of them are simultaneously extremely dependent on exports, producing a somewhat contradictory result. It could also be that there are different subgroups with particularities within the export-dependent industries, and that not all export-dependent industries experience lots of structural change while the majority of them still do. For instance, it can be supposed that among the export-dependent industries, the sectors that are also capital and not R&D-intensive are less affected by structural change than other export-dependent industries. Due to the little amount of sectors included in the labor-intensive group (only two) and the fact that they differed from each other in several aspects, this study does not seem to particularly support the presumption according to which labor-intensive industries would experience lots of creative destruction as such.

Due to the versatility of the results, it seems that neither the R&D-, capital- nor labor-intensity of the sector seems to explain the results clearly. The aforementioned optional classification was presented in sector 2, and finally only one sector was actually found as dependent on domestic demand and all others as dependent on export demand. It seems that the division into domestic and international target markets through growth in exports and growth in private consumption within Finland describe the nature of the industries at least as well or even better than the more typical division into capital-intensive, R&D and capital-intensive and labor-intensive sectors often seen in current literature. Nevertheless, in order to be able to confirm an actual dependence between the within and between components and the export- or domestic demand-dependence and thus make other further predictions, a more in-depth analysis would be required on the subject.

The fifth research question also included reviewing whether the productivity slowdown has affected some sectors driving the national growth rather than all manufacturing sectors together. The productivity slowdown seems common in most sectors, but not in all sectors as productivity actually seemed to have grown in the food products and beverages industry, for instance. The productivity slowdown in manufacturing has been definitely affected by the computer, electronic and optical products industry that suffered great losses already at the time of the dot-com bubble and subsequently in the Great Recession, as has the wood, paper and printing industry in the recent years. As both of the sectors are known to be important exporting industries and also of significant size in Finland, it is likely that certain sectors have been affected more drastically by the productivity slowdown, therefore, dragging down overall productivity correspondingly.

In some export-dependent sectors that would have otherwise experienced significant structural change in the recent years, structural change might have slowed down due to features such as high entry barriers as was considered in Section 2.3. High entry barriers together with subsidies and policy measures complicating market exit for less productive firms have been found to be probable causes reducing competition and slowing down the resource reallocation process as compared to those in an economy without such barriers. The result is that the productivity level of new entering firms tends to be artificially high and that the productivity of continuing unit is unnecessarily low as they continue without being forced to exit the market.

Instead of the amount of R&D in a sector, some differences in structural change as well as differences in the sensitivity of an industry to changes in the global market demand (export demand) might also be due to ease of funding in some sectors like, in general, in the IT sector in which venture capital firms and investors are more likely to invest in favorable economic periods. As capital-intensive investments tend to have a much longer payback period and are often also extremely dependent on exports, they might be less attractive to investors especially in times of economic difficulties such as after the recent financial crisis. This corresponds the result that most other industries exhibit a negative entry component like the theory suggests.

As was mentioned in Section 1.1, creative destruction is tightly linked to national competitiveness and the ability of a country to produce in a cost-effective manner thus raising its competitiveness in the global market. The cost-effectiveness of the country is likely to start ameliorating at some time in the future, thus increasing exports. Finland needs to augment its production in sectors producing products with high value added. The structure of exports seems to be going into this direction, but currently there are not enough of high value added products that pay well enough and that could be produced at a competitive price in Finland. The current situation has accelerated the outsourcing of production overseas, which partially explains the decrease in export shares and export income in Finland. (Maliranta 2014b, 98.) Maliranta (2014b, 17) predicts that if history repeats itself and the competitiveness of the manufacturing industry ameliorates thanks to a strong increase in productivity, the next economically preferable period should come up around 2020. These ideas confirm the link presented between exports and the structure of labor productivity.

6 SUMMARY AND CONCLUSIONS

6.1 Summary

Thanks to the economic shocks studied, the creative destruction process seems to have gained strength most clearly in the start of the 21st century and to a smaller extent in the end of the 20th century. Not all productivity shocks can be considered as enhancing structural change, though. The Great Recession was the productivity shock that seems to most have triggered creative destruction among the four shocks studied. In the 1980s, the creative destruction process was enhanced in only a couple of sectors, and this might not have been due to the productivity shock or even if it was, it only affected a small part of the manufacturing sectors. The early 1990s recession might actually have even slowed down the creative destruction mechanism, and the dot com bubble had significant effects in certain manufacturing sectors while others were left unaffected. Creative destruction has experienced a reawakening in Finland in the 2000s, and the negative effect of the within component during the Great Recession was undoubtedly alleviated by creative destruction accompanied with a positive net entry effect. Summing up, the Great Recession has definitely triggered creative destruction. There is evidence supporting the hypothesis that economic downturns at least occasionally accelerate the creative destruction mechanism in some sectors, but not all shocks in the entire manufacturing industry. While the Great Recession accelerated creative destruction in manufacturing, this can not be extended to all productivity shocks in general, as the effects of the other economic downturns on creative destruction remain unclear.

In terms of productivity, the chemical and pharmaceutical industry was the sector that suffered most in the early 1990s recession, but this was principally due to a negative within component slowing down its aggregate productivity growth. The food products and beverages industry also suffered productivity losses among with other industries slightly before and during the recession. In the Great Recession, the wood and paper products, and printing industry together with the computer, electronic and optical products industry have seen their productivity growth be slowed down drastically, both sectors that are or have been strongly affected by creative destruction. On the other hand, the food products and beverages industry has managed to grow its labor productivity during the latest crisis, and the chemical and pharmaceutical products industry has also suffered less than manufacturing sectors overall. The aforementioned sectors are one of the sectors least affected by creative destruction.

To determining the nature of the representative sectors, two alternative classifications were proposed. The first was to divide the sectors into capital and R&D-intensive,

capital but not R&D-intensive and into labor-intensive sectors, and the second to divide the sectors dependent on domestic demand and on export demand. Strong structural change was found to be the point in common among the R&D-intensive sectors, as it was found to contribute significantly to the aggregate labor productivity growth in three out of four representative sectors. For the capital but not R&D-intensive sectors, the between component seemed relatively insignificant and especially so in the last decade. In the case of the labor-intensive sectors, no clear connection between labor-intensity and creative destruction was found, but the sectors seemed to be somewhat affected by creative destruction and net entry.

Classifying the sectors into those dependent on domestic demand and on export demand instead and focusing on differences especially around the time of the Great Recession, only the food products and beverages industry was found as clearly dependent on domestic demand. This might thus explain its recent labor productivity growth regardless the recession. In the empirical analysis, export growth appeared to explain aggregate labor productivity growth in export-dependent sectors, but creative destruction was not found directly dependent export growth. Nevertheless, most of the export-dependent sectors were found to experience lots of structural change with the exception of the aforementioned capital and not R&D-intensive industries, which did not experience creative destruction like other export-dependent industries did. The sectors that have most suffered from the productivity slowdown lately are also extremely dependent on exports. A combination of the two classifications is therefore suggested as the most accurate way to determine the nature of manufacturing sectors in terms of productivity.

The productivity slowdown seems to be a common feature of most but not all sectors, driven by productivity losses in large export-dependent industries such as the wood and paper products, and printing industry and the computer, electronic and optical products industry. The dependence of the industry on either exports or on domestic demand might be a key factor explaining the differences between the representative sectors in different industries. The thesis confirms the many previous findings such as the reawakening of creative destruction in the early 2000s. Even though creative destruction was not found to be directly dependent on exports, the alternative classification sheds light on the differences among the sectors and serves as an interesting starting point for grouping the sectors in an alternative way as opposed to previous classifications proposed in the literature. Looking at the net entry, it also seems like the 'destructive' effect of creative destruction is lately on the rise, and that creative destruction continues strong in the following years.

6.2 Concluding remarks

Based on the theoretical background and empirical research, creative destruction has been growing for the last 30 years and will also likely continue strong in the following years. Among others, the increasing significance of the between component serves as an indicator of accelerated creative destruction. After the reawakening of creative destruction in 2002, the creative destruction mechanism went through a stagnant period before the Great Recession and is again clearly on the rise since 2008. The wood, paper products and printing as well as the rubber and plastics products, and other non-metallic mineral products sectors were found to be the industries that have most suffered since the Great Recession and also seem to be experiencing less creative destruction than they have in the previous decades. It can be suspected that the lack of creative destruction might be one of the causes due to which the industries have experienced less significant productivity growth lately. The findings also support the idea that creative destruction results in enhanced productivity growth of a sector, having done so especially in the Great Recession. Thus, the natural creative destruction process should be made possible by eliminating all institutional barriers that might be hindering it.

Even though aggregate labor productivity and exports seemed to go hand in hand, no evidence was found supporting the idea that structural change would depend on exports, leading to consider that it is rather aggregate labor productivity that is affected by the principal target market of the sector, and not its underlying components. Nevertheless, export dependence showed to be a useful alternative way to classify the nature of sectors experiencing different kind of productivity growth and creative destruction. Looking back at the first classification presented, the chemical and pharmaceutical products industry, which should be a very R&D-intensive industry, experienced only little creative destruction. This is one of the principal findings leading to consider that structural change does not depend, at least not completely, on the R&D-intensity of a sector. Capital but not R&D-intensive industries were the most compatible group in the classification, suggesting that capital-intensity might be a functional way to classify a certain type of sectors. Several sectors, in which creative destruction previously played a central role but in which the within component has become more and more significant, were identified. While the relation between high tech industries with lots of R&D and intangible capital did not seem clear for some industries, sectors like machinery and equipment and optical, electronic and computer products seem to exhibit a strong connection as they experience lots of creative destruction, have particularly productive entrants coming in the market and thus creating a positive net entrance effect, and are extremely R&D-intensive. It is also important to also note that sectors can experience positive productivity growth without experiencing creative destruction. Cumulative productivity growth revealed that the food products and beverages sector had been best off after the Great Recession and this was merely due to within effect, as the sector was found to experience only little creative destruction.

The study provides a relatively comprehensive overview of the structural change as well as on aggregate productivity in the representative manufacturing sectors studied. Though not a central theme studied in the thesis, the net entry effect in different sectors also seems to shed light on the structure of productivity growth in manufacturing. The significance of net entry has grown in the last period studied, 2008–2011, and in some of the sectors already previously. This could also be interpreted as a possible sign of accelerated creative destruction, which first shows in statistics as a increase in the positive exit effect, an increase in the so-called 'destruction' side. The coming years show whether this grown importance of the net entry effect actually translates into creative destruction.

6.3 Propositions for future research

In the study, it was noted that some sectors, such as the furniture, other manufacturing; repair and installation of machinery and equipment sector, might have experienced some type of adverse creative destruction around the year 2002, during which the mechanism has been accentuated in many industries. The possibility of a slowdown in structural change should be investigated in greater depth in order to find out the underlying causes of such adverse creative destruction. Comparing the industries with adverse creative destruction to industries that have experienced strengthening in creative destruction could also shed light on the underlying causes of the process.

This study was limited to only four economic shocks that were known to have caused a simultaneous productivity shock. Three of the shocks were found clearly significant in terms of productivity and creative destruction, but other interesting points in time worth studying could be found by enlarging the time span. It would also be possible to consider quarterly instead of annual data and concentrate on the recent years to find the exact timing of the changes found in this study, enabling to see better whether some of the changes actually have been simultaneous or subsequent. In addition, studying the latest years 2011–2016 could also be informative for the sake of making predictions on the current situation.

Especially the relationship between exports and different manufacturing industries, that arose during the study, would also require more specific analysis in order to find out whether exports actually explain structural change, what other factors might both exports and structural change be influenced by and what kind of relationship does the principal market of the industry actually have with its likelihood to experience creative destruction. An interesting comparative study further exploring the theme would be to compare the dependence of the within component as compared to the between components on exports. The differences between the different sectors in terms of dependence on exports could also be studied more precisely by comparing exports to different areas (for instance to the European Union, to the United States and so on).

It is also possible to study the between component more in detail: the between component can be decomposed further on into the entry effect and the exit effect (separate from the entry and exit component). One example of this has been done by Maliranta (2014b, 36–37) dividing the between component into the 'creation side' and the 'destruction side'. The creation side consists of the entry component and continuing units augmenting their working hours (the entry component plus the entry part of between) while the destruction side consists of the exit component and those continuing units that are decreasing their working hours (the exit component plus the exit part of between). Working hours can be interpreted as augmenting or decreasing the labor input share. For the moment, only a few applications of such further decompositions are known. Piekkola & Åkerholm (2013, 431) provide an alternative by dividing the firms studied into two groups, firms that are more productive than other firms on the average and firms less productive than other firms on the average. They then study the changes in labor input shares (the between component) separately for those two groups.

A last theme left aside is studying whether firm age dynamics explain the sensitivity of the sectors studied to either domestic or export demand, and whether entry and exit barriers together with other institutional factors slowing down creative destruction, such as ease of accessing funding during different economic times, differ between the sectors studied. For instance, the chemical and pharmaceutical products industry could be experiencing little creative destruction due to extremely high regulation of all activities in the sector. Firm age dynamics could also be investigated by comparing the early 1990s depression and the Great Recession in terms of whether there were more young firms entering the market, often considered as most vulnerable to economic crisis, at the time in the sectors that most suffered productivity-wise.

Although creative destruction still seems a subject that has gained relatively little importance in productivity literature, there seems to be a lot more into it unlike has been thought previously and the mechanism is definitely on the rise. The sensitivity of labor productivity in different sectors to exports was investigated and brings up a new point of view into the existing research on the theme. As a last recommendation, the more precise component specific analysis of labor productivity is most certainly suggested and should also be widely applied to other productivity measures such as total factor productivity.

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APPENDIX I: SECTORS

In this appendix, we present the results of the regression analysis which was conducted as described in Section 5.3. Standard errors are reported in parentheses and ** indicates significance at the 95 % level (p ⩽ 0.05) while *** indicates significance at the 99 % level (p < 0.01).

Table 13: Aggregate labor productivity growth in different industries explained by exports growth

	intercept (std. error)	β	p-value	R^2	Adj. R^2
Textiles	0.0378	0.3390	0.0000***	**0.3992**	**0.3815**
	(0.0097)	(0.0713)			
Wood	0.0189	0.5974	0.0000***	**0.4661**	**0.4504**
	(0.0149)	(0.1097)			
Chemicals	0.0460	0.2005	0.0249**	**0.1393**	**0.1140**
	(0.0116)	(0.0855)			
Rubber	0.0308	0.4207	0.0000***	**0.5026**	**0.4880**
	(0.0098)	(0.0718)			
Electronics	0.0187	0.6001	0.0000***	**0.4685**	**0.4529**
	(0.0149)	(0.1096)			
Machinery	0.0268	0.5089	0.0000***	**0.4923**	**0.4774**
	(0.0121)	(0.0886)			
Transp.eq.	0.0265	0.4124	0.0001***	**0.3587**	**0.3398**
	(0.0129)	(0.0946)			
Furniture	0.0409	0.3163	0.0000***	**0.4069**	**0.3895**
	(0.0089)	(0.0655)			
Manufacturing	0.0271	0.5063	0.0000***	**0.6316**	**0.6208**
	(0.0090)	(0.0663)			

Number of observations in all industries: 36

** = p ⩽ 0.05, *** = p < 0.01

In Table 13, 'Textiles' refers to the textiles, wearing apparel, leather and related products industry, 'Wood' to the wood and paper products, and printing industry, 'Chemicals' to the chemical and pharmaceutical products industry, 'Rubber' to the Rubber and plastics products, and other non-metallic mineral products industry, 'Electronics' to the computer, electronic and optical products industry, 'Machinery' to the machinery and equipment industry, 'Transp. eq.' to the transport equipment industry, 'Furniture and other' to the furniture, other manufacturing; repair and installation of machinery and equipment industry and finally 'Manufacturing' to the manufacturing industry overall.

Table 14: The between component of labor productivity in the transport equipment industry and in the manufacturing industry overall explained by exports

	intercept (std. error)	β	p-value	R^2	Adj. R^2
Transp.eq.	0.0097 (0.0015)	-0.0234 (0.0109)	0.0386**	**0.1199**	**0.0940**
Manufacturing	0.0098 (0.0015)	-0.0223 (0.0110)	0.0511**	**0.1074**	**0.0811**

Number of observations in both industries: 36
** = $p \leqslant 0.05$

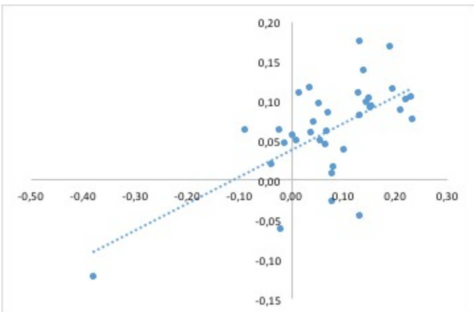

Figure 17: Exports regressed on aggregate labor productivity in textiles, wearing apparel, leather and related products

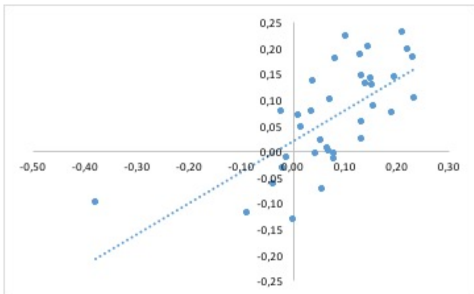

Figure 18: Exports regressed on aggregate labor productivity in wood and paper products, and printing

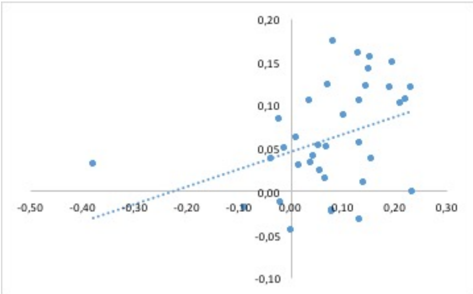

Figure 19: Exports regressed on aggregate labor productivity in chemical and pharmaceutical products

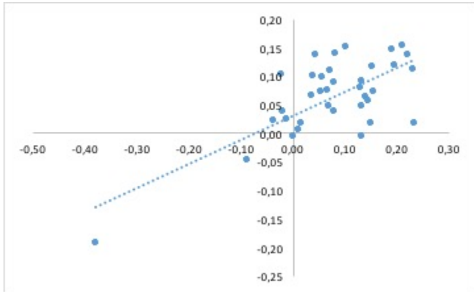

Figure 20: Exports regressed on aggregate labor productivity in rubber and plastics products, and other non-metallic mineral products

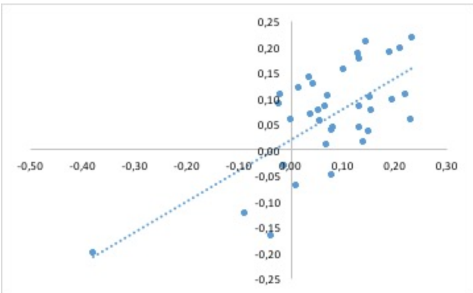

Figure 21: Exports regressed on aggregate labor productivity in computer, electronic and optical products

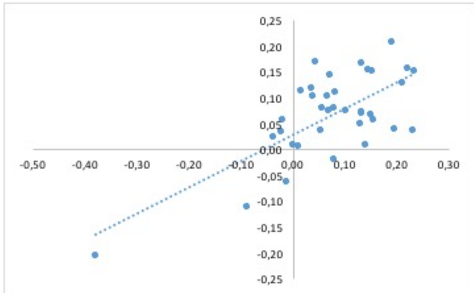

Figure 22: Exports regressed on aggregate labor productivity in machinery and equipment

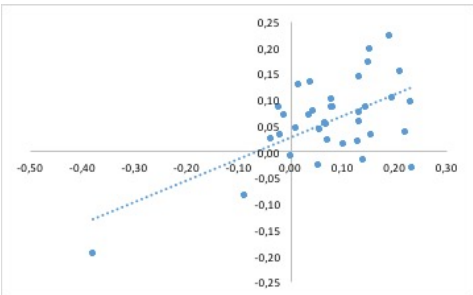

Figure 23: Exports regressed on aggregate labor productivity in transport equipment

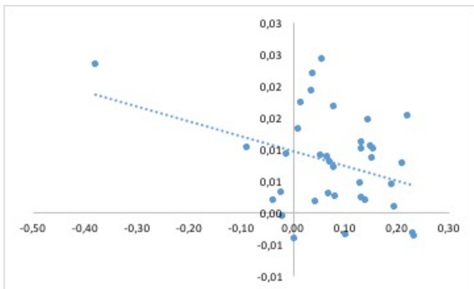

Figure 24: Exports regressed on structural change (between component) in labor productivity in transport equipment

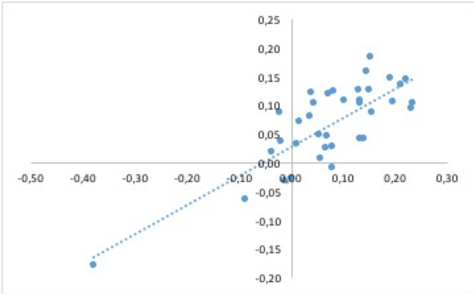

Figure 25: Exports regressed on aggregate labor productivity in all manufacturing

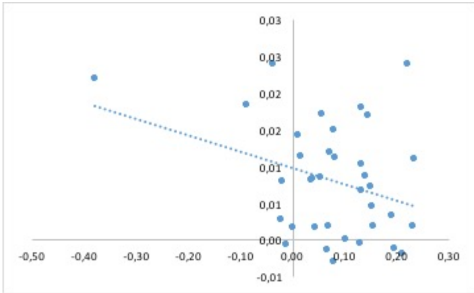

Figure 26: Exports regressed on structural change (between component) in labor productivity in all manufacturing

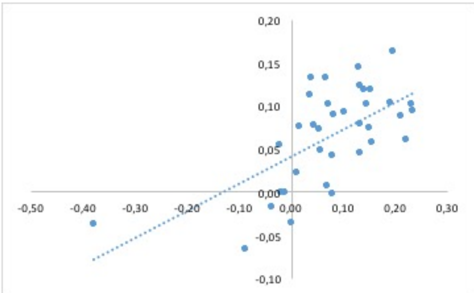

Figure 27: Exports regressed on aggregate labor productivity in furniture; other manufacturing; repair and installation of machinery and equipment