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Technological Change and R&D Activities as a Factor of Economic Growth

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ABSTRACT:

The aim of this thesis is to concurrently evaluate the significance of technological change as an ultimate driver of productivity performance and economic growth, while also examining the role of research and development (R&D) investments in economic growth. The most important question in my thesis is: what creates growth? Factors for this creation could be various, but special attention is paid to firm performance and its changes over the firm size distribution. Measuring productivity growth and R&D performance is important as accurate estimation of R&D investment would help a firm to optimize its R&D spending and avoid unproductive expenditures. Moreover, R&D investment depends on a firm's technological opportunities and expected profitability. In the empirical part, I examine firm growth rates in Finland. The results show the significant positive impact of R&D on growth. I found that the growth impact varies with firm size, showing a positive relationship for small and medium-sized firms but a negative relationship for large firms. Additionally, I observe positive autocorrelation for all types of firms.

KEYWORDS: Research and Development, R&D, R&D investments, Productivity growth, Autocorrelation, Firm growth

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

ABRREVIATIONS

GDP gross domestic products

GNP gross national product

R&D research and development

SME small and medium-sized enterprise

TFP total factor productivity

VAR vector autoregression

NIPA national income and product accounts

1 INTRODUCTION

Economic growth takes a central focus in my thesis because it is one of the most important indicators of a country's prosperity and can help various macroeconomic objectives such as price stability, reduction in unemployment and debts. Many factors can spur economic growth, sometimes is difficult to explain the reasons for it. While a variety of definitions of the term economic growth have been suggested, this paper will use the definition suggested by George Korres (2008) who saw it as a process of constantly increasing production of goods and services which is subject to scarcity of resources such as physical and human capital. In this case, production expansion cannot be possible in the long run if it is based only on the use of resources. That is why my thesis highlights productivity as a key to micro- and macroeconomic stability and furthermore the importance of sustainable growth. Sustained growth refers to an increase in output over a long period of time, while periods of growth related to rise in aggregate demand and lack of persistence might affect merely changes in the level of price. Therefore, understanding long-term growth is very important.

Economists examined three sources of economic growth in order to explain sustained economic growth. These sources are capital accumulation, population growth and technological change. Capital accumulation is considered the basic dynamic of economic growth. On one hand, it cannot explain permanent and sustained growth, on the other hand, it is characterized by the feature of diminishing returns. According to Takatoshi (2014), the accumulation of capital is the engine of growth in the short run.

The second source is population growth. The growth of the population increases the supply of labour, which in turn will induce more consumption and accumulate additional wealth. Population growth explains economic growth but is devoid of any measure of standard of living. A cause for this is that growth in workforce increases production while the production would be divided among an increasing number of people.

The third source is a technological change which is the focus of my thesis. Technological change plays a key role in economic growth – knowledge accumulates, workforce becomes highly skilled, techniques improve, and all these make machinery and processes more productive and efficient. Recent studies found that the accumulation of human capital may not be affected by diminishing returns when invested in education, training, and research. This means that skills and abilities have an impact on long term growth (Takoshi, 2014).

R&D investment is an interesting topic for me as Finland is among the countries that spend the highest percentage of gross domestic product (GDP) on research and development. Although Finland is still one of the top spenders on R&D among EU counties, its share has dropped in recent years from 3.71% in 2010 to 2.71 in 2019 (Statistic Finland). In conjunction with this, I examine the relation between R&D investments and growth. An object of this paper is also the autocorrelation dynamics of firm growth between different growth periods and the influence of firms' size and industry on growth.

The rest of the paper is organized as follows: chapter 2 attempts to introduce the theoretical studies in economic growth and explain topics such as technological change, productivity, and R&D performance. Chapter 3 presents Schumpeterian theory of economic growth and examines the connection between competition and growth. Chapter 4 examines firm dynamics in relation to innovation, productivity, and growth. Finally, chapter 5 shows the impact of R&D activities to growth.

2 Economic growth, technological change, and R&D investments

This chapter first presents a brief overview of theoretical studies in economic growth. Second, it attempts to explain the main concepts such as technological change and R&D investments. Technological change is seen as an essential driver of productivity growth affecting economic performance. R&D is seen as determinant of productivity growth and competitive advantage over firm's rivals. Measuring of productivity growth and R&D performance is important as effective estimation of R&D investment would help a firm to optimize its R&D spending and avoid unproductive expenditure. R&D spending depends on firm's technological opportunities and expected profitability. Thus, technological opportunities are important factor in R&D decisions and difficult to qualify.

2.1 Review of theoretical studies in economic growth

Classical economists represented by Adam Smith, Thomas R. Malthus, David Ricardo, and later by Frank Ramsey, Allyn Young and Joseph Schumpeter laid the foundations of modern theories of economic growth. Already Adam Smith raised the questions about the causes of national prosperity. In his book "The Wealth of Nations" (1776), he alleges that country's prosperity should be measured by its production and commerce, nowadays measured by gross domestic product (GDP production less intermediate input in each industry). He also explored the division of labour and how it relates to increase in productivity (GDP per capita). Ideas of all classical economists can be summarized as: competitive behaviour and economic equilibrium where supply and demand are balanced; the concept of diminishing returns evolved from capital and human accumulation; relationships between population growth and gross domestic product (GDP) per capita. In addition to these ideas, classical economists also examined monopoly power as a prerequisite for technological change; the concept of division of labour and production of new products and methods that lead to significant rise in technological change (Robert Barro, 2004).

Economic growth models can be grouped into two main types: exogenous and endogenous models. While exogenous growth models are characterized by unknown technological progress, endogenous growth theories attempt to endogenize the key parameter, namely the technological advance. A major pioneer in exogenous growth models is Solow (1956) who suggests that investments and population growth contribute to output at a diminishing rate, whereas technological progress contributes the long-run growth rates. The model is extended and developed by endogenous growth researchers such as Romer (1986), Grossman and Helpman (1991), Aghion and Howitt (1992), Lucas (1988) who suggest that technological rate is endogenous. A key feature of these models is that the stock of R&D (or knowledge) results in technological progress. Humans create innovations that raise the quality and increase the numbers of intermediate inputs used in production. By doing this, productivity increases (Chirwa and Odhiambo, 2018). The main concepts of Solow's growth model are aggregate production function, aggregate capital stock and the saving/investment function. The neoclassical model of economic growth is used to describe concepts such as human capital development, technological spillover, international trade, and others (Robert Barro, 2004, p.16).

Arrow (1962) and Sheshinski (1967) developed a model named learning-by-doing indicating that a rise in capital stock leads to a rise in its stock of knowledge which is embodied in workers through an external learning process. In this setting the spread of knowledge is unintentional, which firms do not internalize in their decision making. The new knowledge or innovations in a firm will have a spillover effect in the entire economy as knowledge is nonrival (Barro, 2004). However, Aghion disagree with the claims that Arrow (1962) is closest to the endogenous growth theory. He argues that the learning-by-doing model consists of constant endogenous growth, while knowledge accumulation leads to diminishing returns, then growth is no longer endogenous and even stops in the absence of exogenous population growth (Aghion and Howitt, 1998).

The essential difference between the endogenous growth studies of the 1960s and those of the 1980s and 1990s is that the new studies compare theory with empirical results. Some of them emphasize the empirical evidence of the older studies, others investigate the new studies with the role of increasing returns, human capital, R&D activities and technology expansion (Barro, 2004).

In the context of research and development, R&D theories began with Romer (1987, 1990) followed by Aghion and Howitt (1992) as well Grossman and Helpman (1991). The focus of their models is the role of R&D activities in technological change and the necessity of monopoly power as a motivating force for long-time innovative process. The economic growth rate may be positive in the long run if ideas in the form of new products and methods of production do not cease (Barro, 2004).

Profits drive companies to develop a new product, for example, touchscreens used by fingers instead of using a keyboard, computers that fit in your hand, or satellites that help the globalization of the telecommunication services. All these improvements of technological and economic development are considered as endogenous factors of economy. According to this model, economic growth may continue without limits because the returns to capital together with human capital would not automatically imply diminishing returns. The reason is the knowledge that is characteristic of the spillover effect among producers and human capital brings external benefits (Barro). Endogenous growth theory gives a substantial contribution to the theories of economic growth. If ideas are expanded quickly between countries, the study can describe why technology improves overtime within these countries and why economic growth rate in the long run is positive (Mishra, Satyabrata, 2016).

2.2. Innovation and R&D

Innovation and knowledge are considered as a driving force of economic growth, however different countries have different strategies of how they manage innovation and knowledge. Irrespectively of whether innovation is successful or not, investments in R&D are costly. Firms invest in R&D developing new products or processes which might increase productivity and firm performance. Other firms outside the firm that generates the innovation also could benefit from R&D which is known as spillovers. Innovations that spread within and across economies is called technological diffusion. The diffusion of innovation could be divided into disembodied (conveying of ideas, knowledge, expertise) and product-embodied diffusion where other firms use a completely new product as an intermediate product, hence the innovation becomes embodied in other final products (Viale and Etzkowitz, 2010).

Two types of innovation have different influence on knowledge: incremental and radical innovations. Incremental innovations raise the firm's existing knowledge and improve existing products; however, they reduce the technological opportunity for further development. Radical innovations renew technological opportunities by implementing new products and combining previous discoveries and knowledge. Growiec and Schumacher (2012) suggest that the same flow of incremental and radical innovations would contribute to economic growth on the long run. For that reason, technological opportunity needs to be regularly renewed and to be implemented sufficiently fast. Economic growth can cease if technological spillovers are too small in an association with the radical innovations (Growiec and Schumacher, 2012).

At this juncture it is important to understand the term "Technology". There is a wide and a narrow meaning. In a narrow sense, technology includes physical capital: machinery, equipment, buildings, energy, raw materials. Their purpose is to improve human effectiveness, for example, a hammer will give stronger force than human hand and will reduce the time to complete a task. Innovations will allow humans to make things they could not perform otherwise. In a wider sense, technology is an intangible capital. The intangible capital is the human knowledge and skills required to produce technology (Link, A. N. & Siegel, 2003). The water supply network needs to be invented, designed and produced. This requires physical capital or inputs such as raw materials, machinery and labour, in addition to human capital such as know-how, knowledge and skills. Human capital implies the increase in education and specialization of the labour force.

Unlike physical capital, intangible capital is not easily observable as it is embodied in the skilled staff or in firm's organizational structure. In former research intangible capital's contribution to growth in growth accounting was not separately calculated, but it was captured by the Solow residual (Uppenberg, 2009).

In regard to the above mentioned, innovation can be described as output, while tangible or intangible assets are innovation inputs. The nature of intangible assets differs from the one of tangible assets. Intangible assets are characterized by spillover effects which means that an innovator is aware that competitors may benefit from his investment. At the same time, the investing firm can benefit from economies of scale and be in the role of a monopolist which will stimulate him to invest in innovation. The relationship between intellectual property rights and innovation is largely discussed as to whether it stimulates the production of new knowledge, in addition to the fact that intellectual property monopolies raise product prices in the form of patents and copyrights (Thum-Thysen, A., Voigt, 2017).

There are two main risks for those who invest in innovations: the innovative project may fail, and the result could be different than what the inventor expected. The early phases of innovation (invention and experimentation) are associated with possible high sunk costs and failures. In contrast, tangible assets can be easily reproduced and defined in comparison to tacit knowledge. Irrespective of differences between tangible and intangible assets, there exists interaction between these types of assets as in some cases, they cannot exist independently, for example, ICT hardware, software, and training (Thum-Thysen, A., Voigt, 2017).

When knowledge creates an economic added value, then knowledge accumulates. Firms invest in their employees to become more efficient. Knowledge is tacit which means it is in employees' minds and it is the most important asset for a firm. Even though, it cannot be found in financial reports. The capitalization of knowledge has taken a new form in the last years, and many firms understand the importance of scientific research for innovation. Scientific knowledge could be in the form of patents, licenses, copyrights, designs and know-how. The production of knowledge (and especially R&D) and its development has a key role in the innovation process. Growing part of knowledge becomes protected by intellectual property rights, the collaboration between academic and industrial laboratories increases, firms invest more in R&D activities and new organizations take a role in capitalization of knowledge (Viale and Etzkowitz, 2010).

Public R&D has a significant role in capitalization of knowledge and the relationship between university, industry and government is increasingly stronger. Governments provide financial support for research and improve the interaction between science and society. Universities become more research-oriented realizing that research has an important role in economic growth. Combination between teaching and research is more productive and cost-effective. However, this process is still in implementing phase in many countries and needs to be further developed (Viale and Etzkowitz, 2010). Recent research found that investments in university research and high-skilled human capital raises private R&D (Thum-Thysen, A., Voigt, 2017).

R&D investment involves basic research, applied research and experimental development. Basic research implies creation of new science knowledge or discoveries. Applied research endeavors in the practical application of the discoveries in the real world. Experimental development includes a production of new or improved existing products, processes and services. For example, USA is the largest R&D spender in the world and its costs in R&D are divided as follows – 15% of R&D expenses are allocated to basic research, 25% are directed to applied research and about two-third of costs are allocated to development. (Arnulf Grubler, 1998).

The main questions are how knowledge can be defined and how can its economic value be measured. Knowledge is an intangible asset which measures the net worth of an idea and transfers it into realization. Knowledge is a set of theories, hypotheses and empirical statements where individual's skill and abilities are involved in conjunction with interaction between all participators (Viale and Etzkowitz, 2010, p.23).

R&D expenditure is an indicator by which innovation can be measured. Investors are increasingly concerned about economic return from scientific and technological research. However, knowledge cannot be measured by using the Solow model where the production function separates GDP into capital and labour inputs and the residual is associated with the technical change. A limitation of this is the complexity to catch value created in R&D. Research is an investment. However, it appears as a cost in the financial statements, although it raises productivity and economic growth (Viale and Etzkowitz, 2010, p.24).

Capitalization of intangible assets such as R&D is important because knowledge generates an economic added value (Viale and Etzkowitz, 2010, p.24). Investment goods are treated as a capital good in economics. However, R&D does not have the same role as capital input, moreover it is seen as an explanation of the portion of residual. It is difficult to define weather R&D is a part of output or investment good (Corrado, Hulten and Sichel, 2004). For that reason, it is important to determine what investment implies and how to measure the capital in the production function.

The model of Hulten (1979) attempts to endogenize the capital where the object of his interest is intangible assets and the possibility to treat them as capital. This approach uses Solow-growth accounting framework illustrated by aggregate production function to which is added intertemporal framework where output is separated into consumption and investment goods in order to decide how to treat intangible assets. Reduction of the current consumption with the intention to increase the future consumption is known as investment. This shall include intangible assets such as R&D, copyrights, improved organization structures and many others. Corrado, Hulten and Sichel (2004, 2005) framework shows that there is no reason for treating intangible assets as something different from capital, even the unbalanced usage of the two types of capital can distort the factors that drive the growth.

Coad and Rao (2006) find that innovation is of much greater importance to high growth firms. Empirical studies show that cooperation with universities is more important for firms in science-based industries (e.g., chemical, biomedical, and computer industries). However, this evidence concern firms in the manufacturing sector and high-tech industries (Pinto et al., 2015). The United States manufacturing sector is characterized by more research-intensive high-tech industry, and this is one of the reasons for the R&D gap between the EU and the US.

In high-technology and knowledge-intensive industries, firms use the resources of university research in order to improve their internal knowledge by external sources of knowledge (other companies, universities, governmental research institutes). Moreover, multinational enterprises (MNEs) attempt to reach local education institutions to access and recruit the scientific personnel and academic researchers. The distribution of R&D globally is a main incentive for firms to achieve innovation advantage and to be a competitor at a global level (EU Industrial R&D Investment Scoreboard).

The analysis of Sitra Reports shows that firms are more prone to collaboration with universities if they have higher R&D investments and a greater number of R&D personal. It is also applicable for firms that are large and have in-house R&D departments: having own R&D activities firms are more likely to use external knowledge. Finnish firms who use services of university are also high- or medium high-tech firms and have in-house

R&D activities. Firms with in-house R&D departments improve product development, while university research creates generic knowledge (Kaukonen and Nieminen, 2001).

2.3. Measuring of technological change and productivity

Developing countries have a better opportunity for higher economic growth rates compared to advanced countries if they launch new technologies which have been already utilized by technological countries. A country (China, Korea or Singapore) that introduces new products or services and improves technology in a local market, will be more successful compared to a country that imports technology and investment (Korres, 2008). The aim of science and technology is to increase the efficiency of already existing products, processes and services, or develop new ones. This will result in increased technological productivity and reduction in the costs of production, and therefore will increase competitive advantage and profits (Hülya Kesici, 2015).

Current modern theory argues that technological change leads to permanent differences in economic growth and income inequality between countries. Barro (2012) shows evidence that developing countries are likely to catch up to developed countries at around rate of 2.4% per year which will take 115 years for 90% to fill the initial gap (Barro, 2012). According to Keller (2004), sources of technological change based on foreign innovation efforts are important for developing countries where technological innovations are spread by the developed countries (Barro and Sala-i-Martin, 1995). Keller (2004) argue that technology investments take time because of a time lag between technology adaptation and productivity growth. Thus, some developing countries can grow faster than others, such as China and India where adaptation process takes less time. This might be due to the cheaper cost of adaptation, differences in cultural and international trading characteristics, differences in government policies on the protection of intellectual property rights and many more (Misra, 2015). According to Barro (2012), poor countries such as North Korea, Venezuela, sub-Saharan African countries might not catch up at all to developed countries if these counties do not improve the quality of human capital and institutional policies.

Changes in technology are a major source for sustainable productivity. Productivity is a measure of the ability of a firm to produce. It can be defined as a ratio between output (products and services) and inputs (labour, raw materials, machines). To increase the productivity, numerator (output) can be raised, or denominator (inputs) can be decreased. Similar effect would be achieved if both input and output increase, but the output increases at a greater rate, or both decrease but the input decreases at a greater rate. This productivity analysis can explain how well resources are being used in the production process and it can be utilized in corporate planning, strategic implementation, organizational changes. In such a case, economic performance can be raised via organizational changes accompanied by technological change.

One productivity measure is partial factor productivity. It is a ratio of total output to a single input, for example - output per labour hours, output per capital, output per machine. The same level of output can be reached by a small amount of input if the ratio (output/input) rises while the other factors stay unchanged. In such a case, the picture will be incomplete because other factors cannot be changed. Therefore, the total factor productivity is necessary to be measured (Korres, 2008).

Growth accounting deconstructs economic growth into components in relation to changes in capital input, labour input and a residual that is a measure of technological change by using the neoclassical production function

(1) $$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

Where output Y_t is a function of level of technology A_t or Hicks neutral technology index, capital K_t and labour L_t, and $0 \leq \alpha \geq 1$.

Productivity growth can be measured taking logs of the production function (1) on the left-hand and right-hand sides and after this, taking differences between time t and time t+1. The final step involves the approximation of $\Delta Y_t = \Delta A_t + \alpha \Delta K_t + (1-\alpha)\Delta L_t$. Barro (1999) and Barro and Sala-i-Martin (2003) introduce TFP in discrete time as follows

(2) $$A_t = \frac{\Delta Y_t}{Y_{t-1}} - \alpha \frac{\Delta K_t}{K_{t-1}} - (1-\alpha)\frac{\Delta L_t}{L_{t-1}}$$

Standard growth-accounting studies consider the Solow residual as a measure of technological progress and R&D spending as a determinant of the TFP growth rate. Recent theories of endogenous growth see the residual as an adjustment that allow for increasing returns and spillovers; and implement models where technological advance is generated by purposeful and successful research.

Kydland and Prescott (1991) compute the Solow residual to demonstrate the role of technological shocks which are treated by RBC theory as the main source of aggregate fluctuations.

Butler and Pakko (1998) generate a R&D model which is developed by C. Jones (1995). They differentiate a productivity shock that causes changes in the production function and a technological shock which is connected to new knowledge generation. The model consists of capital, household choice between labour and leisure, and a combination between formerly accumulated knowledge and current efforts to innovation. Then, current level of technology would be

(3) $$A_t - A_{t-1-} = z_{A_t} \eta L_{A_t} A_t^{\phi} \bar{L}_{A_t}^{\lambda-1}$$

Where z_{A_t} is a exogenous shock, η is the innovation rate, L_{A_t} is a labour in the R&D process , $\bar{L}_{A_t}$ are externalities of R&D. Formerly accumulated knowledge A_t is associated with exponential parameter ϕ showing that the innovation rate increases (ϕ>0) or decreases (ϕ<0) with the level of knowledge, λ measures external diminishing returns. Furthermore, they use the production function with labor-augmenting technological change in order to calculate the real wage, rate for capital, profit and the price of patents (Pakko,1998).

Economists attempted to define the explanatory factors that move the technological parameter A_t. Measuring of productivity residual from (2) is essential, but the importance of its explanation will contribute to identifying these factors and implementing the policies necessary to increase economic growth. In this way, researchers will not make mistakes in technological change measuring. Correct measurement of inputs is urgently important to the increase of productivity growth, especially in growth accounting whereby economists measure the contribution of each of the factors to economic growth, deducting all factors other than pure technological-change element from the A_t parameter. This concept can be explained by splitting the total output growth into parts in respect to measurable factor inputs. The unexplained part of output represents or measures technological change (Link, A. N. & Siegel, 2003). In general, technological change is difficult to estimate. For that reason, it is important to identify the indicators that signal technological change. Based on the published growth accounting data for OECD countries in the period between 1985 and 2010, the average growth rate of GDP per employee was 2.58 %, and the multifactor productivity (MFP) was 45.5 % which was calculated as average contribution proportion. It means with regard to economic growth, MFP contributes nearly half of the total contribution of all factors of production (H. Kato, 2016).

The abovementioned growth accounting studies emphasized technological change as an essential driver of productivity growth affecting economic performance. Based on these findings the focus is moved to the ingredients of technological change especially to R&D activities (Link, A. N. & Siegel, 2003).

Output indicators are another way to measure the technological change and productivity. The main indicators of technology output are patents. Patents are intellectual property protection and their role is to encourage firms to invest in R&D and contribute to the technological progress. R&D activities play an essential role in launching and utilizing new technologies. Many researchers have shown that there is a strong positive correlation between R&D activities and patenting. Limitations of the approach is that this indicator has a closer relationship with innovations than technological change and few results from R&D activities are eligible to be patented. Inventive and innovative behaviour of a company depends on the direction and price of the underlying technology and patents do not influence this behaviour. The role of patents is also to be a predictor of knowledge transfer. (Link, A. N. & Siegel).

Another output indicator is a count of the major innovations over time in the order in which they happened. In this way researchers can quantify the diffusions of innovations in association with the economic performance and understand how economic growth is generated. (Link, A. N. & Siegel).

3 Schumpeterian theory of economic growth

Schumpeter is widely viewed as one of the greatest economists in explaining economic growth. The key concepts in his theory are entrepreneurship, innovation and economic development. In contrast to other traditional economic theories such as Keynesian theory, where economic models are presented by theories of equilibrium of a static economy, Schumpeter explains the features of modern economies by technological change which is endogenous to the economy.

Technological change in a dynamic economy is a result of innovation in the production process. Innovation is the driver of the economy. In Schumpeter's theory two types of changes are distinguished: progressive improvements accumulated by small changes and completely new changes. Innovation drives economic development by creating new technologies, but at the same time, it damages the effect of former innovation by making it obsolete. There are different forms of innovation that can be summarized as follows:

1. A new product or a new quality of a product.

2. New methods of production that could be invented through research and development or a new way of trading the products commercially.

3. Expanding into a new market: entering an entirely new market or taking positions into existing market by a new creative marketing idea.

4. The sourcing of a new supply of raw materials or intermediate goods. These sources might be newly founded, or they already exist.

5. Creation of new forms of organization. (Schumpeter, 1934: 66)

According to Schumpeter, technological change is not merely “more of the same”, but the change alters the correlation between inputs and outputs, and it also removes constraints, allowing for development. Technological change happens through new opportunities for entrepreneurship, incentives that generate new technologies, R&D efforts, process of experimentation that enables the firm to create its products, marketing activities and efforts. Schumpeter described these changes by technological progress which is evaluated separately from growth due to the rise of capital and population (Grübler, 1998).

According to Schumpeter, large firms have a greater advantage in implementation of innovation in a concentrated market. In other words, larger firm size generates more innovation activities where growth increases more than proportionally. This statement might be explained by several reasons. Firstly, larger firms usually have effortless access to capital markets compared to small firms, and they invest in riskier innovation activities. In this connection, empirical findings often examine the effect of firm size on market concentration. Secondly, larger firms may face increasing returns to scale from R&D projects, because of specialization, accumulation of human capital and efficient utilization of resources. Thirdly, expenditures in R&D or other innovation activities are fixed costs in larger firms, and they are diffused over higher sales volume. Fourthly, management activities and structure are more developed in larger firms (Bettina, 2008).

Schumpeter claims that there is a negative relationship between market competition and innovation, because monopoly increases rents and stimulates the innovations. When a firm has a market power, it has ability to manipulate the market price and increase the firm’s profits which will stimulate innovation activities. Competition is also associated to growth of uncertainty due to redundant rivalry that may result in reduced incentives for innovation. (Bettina and Wolfgang, 2008).

3.1. The Schumpeterian model

The structure of innovation is heterogeneity because an innovation can be split into fundamental and secondary. Aghion supposes that the fundamental innovations are R&D activities which is a result of research in new products and processes, and secondary innovations are learning by doing which are related to improvements of existing products. While growth equation controls for evaluation of knowledge over time, and have an effect on growth rate, the arbitrage equation is a result of efforts to choose the most profitable innovation activity assuming the growth rate, no matter research or learning by doing.

According to Young (1992) allocation of many resources to research related to learning by doing might lead to slower long-run rate of growth. Aghion argues that the reason for this might be the nature of technology spillover, however the reason that growing rate tends to decrease could be in a situation when other firms benefit from the innovation (Aghion, 2009).

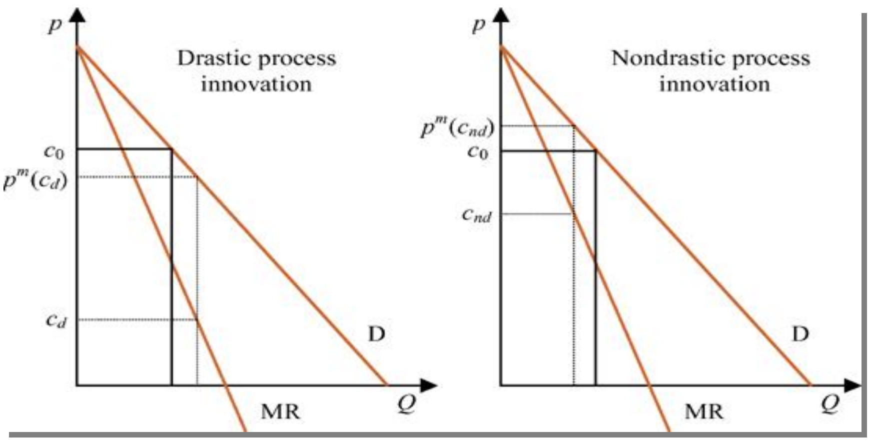
The following models that I present are taken from the book of Aghion, Howitt (2009) "The Economics Of Growth". The research arbitrage is found through the equilibrium profit equation as the innovating firm wants to maximize the net profits by determining the costs for research R_t.

(4) $$\phi'(n_t)\pi L = 1$$

This means that the marginal cost of research is equal to 1 where the marginal benefit from R&D expenditure is expressed as multiplication of a cumulative probability of innovation and the return on successful innovation. The marginal benefit in n_t grows less as a result of the diminishing innovation function. In every case where the marginal costs fall and the marginal benefit tend to rise, the change will impact the equilibrium research intensity n_t to rise (Aghion, 2009, p. 85-100).

Process innovations are connected to the development of new technologies or new delivery methods. They could be separated into two categories: drastic and non-drastic innovations. Drastic innovations are connected to the monopolist who can charge price without constraint. In non-drastic innovations, a follower can introduce an innovation, however, the previous leader is not entirely replaced, and both have positive profits. The follower can suggest a perfect substitutable product to the monopolist's one. This product costs $c > 1$, therefore the monopolist cannot raise the price higher than c in equilibrium, because the competitor can undercut that price (Aghion, 2009, p. 85-100).

Figure 1. Drastic and non-drastic innovation (Industrial organization, Paul Belleflamme)



From figure 3. the limit price constraint is $p_c^m \leq c_0$ where firms produce at c_0. When the R&D spending decline, then the costs of innovation are below c_0.

As a result of the comparative statistic could generalized the following:

- The productivity of innovations tends to raise growth. Countries with investments in higher education will possess more educated labour force, increasing the productivity of the successful research and development.

- The dimension of innovation is measured by the productivity factor γ (where $A_t^* = \gamma A_{t-1}$) which affect the growth. The repetitiveness of innovation is unconnected to the productivity factor γ. These countries that are behind the frontier can grow faster by innovating processes and products that the technological leader expand.

- A stronger patent protection would stimulate the inventor to discover innovations and invest more intensively in R&D due to higher costs of imitation of their new technology. More intensive R&D activities resulting in successful innovations will increase the firm profits and in turn, will lead to economic growth.

- Increased competition tends to reduce growth. Less R&D activities of monopolist might affect entering of other firms decreasing the value of innovation.

- Growth of population leads to more workers (increase in the supply of labour) and this allows growth (Aghion, 2009, p. 85-100).

The theoretical framework considers a multisector model in which are involved more than one intermediate products x_{it}, measured on the interval [0, 1], with differences in the productivity parameter A_{it} by which can be improved the quality of the product.

Factors of productivity changes over products that are used in the production process for each period as innovation is a random process. The production function is exactly alike the one presented in the one-sector model. In the multisector model, every single intermediate product has a monopoly power, where the price p_{it}, the equilibrium quantity x_{it}, and the maximized profit Π can be solved.

In this context, the aggregate productivity parameter will have an impact on the aggregate economic behaviour expressed by the unweighted arithmetic mean of each productivity parameter (Aghion, 2009).

As mentioned before, the economy's output is the market value of all final goods Y_t produced within an economy in a given period of time, deducting the costs of production of the intermediate products.

The same results in the multisector model shall arrive at the same conclusion as in the one sector model, that the economy's output is proportional to the effective labour supply A_tL. All implications in the one sector model are valid for the multisector model, with a difference that the costs of research in sector i are denoted by n_{it} and productivity in sector i is denoted by A_{it}. The most important characteristic of this model is that regardless of the level of productivity at the beginning, the likelihood of successful innovation μ would be identical in all sectors although the profit in the advanced sector tend to be higher (Aghion, 2009).

The economy growth rate g_t in both models is identical but the aggregate growth rate in the multisector model would not be random anymore since the unsuccessful innovation in one sector could be balanced by the successful one in another sector.

(5) $$A_t = \mu A_{1t} + (1 - \mu)A_{2t}$$

where the expected value μ is multiplied by the average A_{it} in sectors that innovate at a given time t, and adding $(1 - \mu)$ multiplied by the average of the sectors that do not innovate at a given time t (Aghion, 2009, p. 85-100).

The average A_{2t} in (5) might be replaced with the average of the whole economy in the past period A_{t-1} because sectors have the same productivity as in the last period, and by reason of the random selection from the economy. Respectively, A_{1t} will be replaced by γA_{t-1} where the average A_{1t} for sectors that did not develop an innovation is equal to γ multiplied by the average of their productivity in the past. A conclusion is that the economy growth rate will be a constant as in the one sector model.

One of the most interesting questions is how the rate of innovation behave when the size of economy increases. What is the reason that smartphones' price decline while their functions and quality are always on the rise? The answer is the reduction of the cost of production which is the main object of the economies of scale. The increase of economies of scale is connected to the greater rate of long run innovation. They can be measured by aggregate income, population, or resources (Aghion, 2009).

Many R&D-based growth theories suppose that the increase of population will raise the size of the market along with the rise of the numbers of researchers. This is inconsistent with the empirical evidence such as C. Jones's (1995). He showed notwithstanding that the number of researchers L is increased, the rise does not mean directly that per capita growth rate of output will increase. For example, in the United Stated the numbers of scientists and engineers involved in R&D were around 200 000 in 1951 and their number in 1987 was already raised to approximately one million. At the same time there was no significant increase in productivity growth (Charles I. Jones, 1995).

The reason for this inconsistence could be explained by this, that theory predicts g and L in a long run, not in a short run. Therefore, empirical evidence needs to control for business cycles and waves, and additionally to detect every change in g and L which could impact the rate of innovation altering the economic scale.

A model of Aghion and Howitt omitted the incorrect scale effect using both horizontal and vertical innovations. They considered the A. Young's (1998) stand that the rise of population affects a reduction of successful research meant to improve quality. The reason for this decrease is a result of a large number of product varieties that are spread more slightly over many different sectors causing a diminishing effect on the total rate of productivity growth.

The impact of a single intermediate input to the final output demonstrates that although the number of unfinished products increases, the labor used in the production stays unchanged, therefore the impact of intermediate inputs to the final output will be less. Contribution to the final output can be realized only if the quality A_{it} or the quantity x_{it} is increased (Aghion, 2009).

However, we are interested of the process whereby the product variety might rise. The assumption of the simple model involves stable population, where the number of the intermediate products will change every year. Aghion (2009) found that if the population grows, the sum of intermediate products will grow proportionally (Aghion, 2009, p. 85-100).

The results from calculation of output, equilibrium quantity, price of the intermediate products and profit will be the same as in the one-sector model, but the difference will be in this, that the L is substituted with ε / Ψ where ε is the portion of products that leave every year and Ψ is the probability of discovering new intermediate products without cost of research (Aghion, 2009, p. 85-100).

As the demand function is independent of L, the equilibrium quantity and profit of the monopolists are independent of the economies of scale. This will have an impact to the net benefit to R&D, equilibrium R&D intensity, innovation frequency $\mu = \varphi(n)$, and the growth rate $g = \mu (Y - 1)$, because they will also be independent of economies of scale.

Schumpeterian growth theory could be compared with the two alternatives of endogenous growth: the AK model and the product-variety model. Product-variety model is characterized by innovation aroused from new, but not necessarily improved varieties of products resulting in productivity growth. AK model considers not innovation but thrift and capital accumulation for the main driving forces behind economic growth. The main problem of this model is that long-run growth is determined by exogenous forces and it cannot explain where these improvements come from. Learning by doing is supposed to be external to the firms where technological progress relies on the aggregate production of capital and firms take the rate of technological progress as a given. Therefore, firms maximize their profits only in respect to K and L. Unlike the innovation-based models make the difference between capital accumulation and technological progress underlying long-run growth and convergence. In contrast with the product-variety model, Schumpeterian model predicts determinants of growth across firms and industries (exit and turnover of firms and workers) which is consistent with various studies' arguments that labour and product-market mobility are main components of the policies that enhance the growth around the technological leader (Aghion, 2009, p. 85-100).

Disadvantages of Schumpeterian model is the scale effect due to population growth, but it could be fixed by Schumpeterian paradigm. Other issues are related to convergence, the absence of the capital which is very important and the assumption of the perfect financial markets as the firms that invest in R&D depend on capital markets (Aghion, 2009, p. 85-100).

3.2. Competition and growth

A wide range of studies have examined whether competition has a positive or negative effect on growth. Some empirical and theoretical studies believe that large firm size and high market concentration has a positive correlation with higher level of innovation activities and growth. Numerous researchers along with Schumpeter contend that competition reduces the motivation for innovation by decreasing the monopoly rents in the presence of imitation. The value of monopoly rent declines until the next successful innovation which is provided by competitors. Patent protection of technology is essential since intellectual property protection supports the return on investment for certain time assuring that ideas and concepts of the technological leader will not lose their potential value. However, researchers such as Nickell (1996), Blundell, Griffi Van Reenen (1995) and Porter (1990) got opposite results and found a positive correlation between growth and competition arguing that firms strive to innovate among the competitors to be able to survive.

In order to identify empirical advantages and disadvantages of competition in relation to innovation and growth, Aghion and Howitt (2009) represent innovation as a step-by-step process. They replace the leapfrogging assumption in Schumpeterian model (a laggard firm innovates and leapfrogs the leader) with a step-by-step assumption where technological leaders and their followers are involved in R&D investments and which implies that the gap between firms is always of one step. If innovation is successful, the technological level will grow by one step and patents protect only the latest technology. This suggests the knowledge that pioneer obtains cannot be used by other competitors unless they invest in their own R&D activities. If they do this, they can outperform the former leader and his intellectual property will no longer be protected (Aghion, 2009, p.267-283).

For the purpose of analysis, it is necessary to distinguish neck-and-neck (or level) and unlevel sectors. Neck-and-neck (level) sector is characterized by firms that operate at the same technological level, while unlevel sector is characterized by a leader firm that is one step ahead before the followers. In a level sector each firm is encouraged to innovate in order to escape competition between head-to-head rivals which stimulates R&D activities. In unlevel sectors, the laggard firm is not motivated to invest in R&D in a short run as the expected profits for catching up decrease by the intensity of competition (Aghion, 2009, p.267-283).

Investments in knowledge impact the others by exchange of ideas between firms. It is known as knowledge spillover. R&D investments are usually intangible and other firms are likely to benefit from other's innovation. This way, the firm that invest in R&D does not alone enjoy all the positive outcomes from the investment.

The cost of R&D can be denoted as

(7) $\varphi(n) = n^2/2$

n denotes the probability of the technological leader that moves a step ahead and implies the R&D intensity of the firm. The probability that a follower firm moves a step ahead is denoted by *h*. This move ahead of the follower does not exactly mean that he invests in R&D activities, moreover he moves by copying and imitating from technological leaders. Imitation is easier way to try to improve an existing idea than inventing something new. The R&D cost of the follower firm is $n^2/2$ and probability to move ahead is *n + h* (Aghion, 2009, p.267-283). Assumptions are the following:

- n_0 is the R&D intensity of firms in a level sector
- n_{-1} is the R&D intensity of follower firms in an unlevel sector
- If $n_1 = 0$, it means that the leader firm does not have an opportunity to create further value by innovating (Aghion, 2009, p.267-283).

Competition is grouped by level and unlevel sectors. An unlevel sector is characterized by a leader who stays one step ahead of its competitors (followers or laggard). Then, the equilibrium profit and competition should be identified. The cost per unit for the leader is *c* and he is forced to limit and set a price $p_1 \leq \gamma c$, where γc is the competitor's cost per unit. Assumption of the model implies that customers choose the products only on the basis of price. Therefore, the competitor is likely to gain a larger market share if leader suggests higher price. In case that the leader controls the whole market share, firm's sales will be equal to the total consumption in that sector. If the price is lower, the firm's revenue would stay unchanged, however, the cost will grow $cx_1 = c/p_1$. If the follower firm charges higher prices, customers will stop to buy its products. Thus, its profit will be zero: $\pi_{-1} = 0$ (Aghion, 2009, p.267-283).

Furthermore, in the model with level sector, two firms may collude to set prices in order to maximize their profits. Then, both will operate like the leader in an unlevel sector. If there is no collusion, the equilibrium price is likely to decrease to the unit cost *c* which will lead to zero profits. For that reason, firms are motivated to collude, where the price is $p = c$, profit is $\pi_1/2$ and every third firm behaves like a follower in an unlevel sector (Aghion, 2009, p.267-283).

Thus, the profit of the leader firm in level sector is $\pi_0 = (1 - \Delta)\pi_1,$ where Δ measures the competition with range $1/2 \leq \Delta \leq 1$ depending on what is the fraction of a leader's profits between firms in collusion. Simultaneously, it also denotes the incremental profit of the firms that innovate (Aghion, 2009, p.267-283).

Aghion and Howitt (2009) argue that the overall impact of competition on innovation depends on the proportion of level sectors and situation. Furthermore, the competition Δ in an unlevel sector will suppress innovation due to existence of Schumpeterian effect causing the reduction of rents. However, the increase of competition in level sectors will stimulate innovation through escape-competition effect (Aghion, 2009).

The "composition effect" and the "inverted U" can be explained by the following. In steady state, the portion of firms that become levelled are equal to the portion of firms that become unlevelled:

(8) $$(n_{-1} + h)\mu_1 = n_0(1 - \mu_1)$$

where μ_1 is constant and implies the portion of firms in unlevel sector. $\mu_0 = 1 - \mu_1$ denotes the portion of firms in level sector. The movement of sectors from unlevel to level is the portion of all sectors $(n_{-1} + h)\mu_1$, moreover the movement of sectors from level to unlevel sectors is $n_0\mu_0$ as one of the firms innovate with probability n_0 (Aghion, 2009).

Aghion and Howitt (2009) measure the effect of competition on innovation and find that the correlation between competition and innovation is positive when there is a low degree of competition ($\Delta = 1/2$) and negative when the competition increases. The help factor *h* has a huge influence on the correlation. This follows two assumptions:

If $h < \pi_1$, then according to the inverted-U model the aggregate innovation will grow even with small values of competition and will decrease with enough large values of competition (Aghion, 2009, p.267-283).

If $h \geq \pi_1$, then innovation grows with competition, however, the increase will occur at a declining rate (Aghion, 2009, p.267-283).

When the degree of competition is low, the leader firm will not have incentive to innovate, thus, the innovative rate will increase at a higher degree with increasing competition. The innovation rate will be highest in unlevel sectors. Therefore, firms will strive to spend more time in the level sector where the escape competition effect dominates (Aghion, 2009, p.267-283).

When the degree of competition is very high, the follower firm will not have incentive to innovate in unlevel sectors and will stay longer in this unlevel sector because in the level sectors leader firms share the large profits from innovations with a slower average innovation rate. Then, the Schumpeterian effect will dominate in the unlevel sectors. Overall, the impact of increased competition on growth will be ambiguous (Aghion, 2009).

Step-by-step model can be generalized by the following: the assumption of escape-competition effect model is that competition encourages innovation in level sectors with the same technological level; competition reduces pre-innovation rents making the incremental profit to grow due to a leader position as a result of innovating. The next assumption of the model is a negative Schumpeterian effect on follower firms in unlevel sectors as the rise of competition lowers the reward of followers and their motivation to catch up with the leader. However, this effect can be neutralized in the case that the follower has caught up with the current leader. Schumpeterian effect in addition to escape-competition effect where the equilibrium fraction of level sectors depends positively on the motivation of followers to innovate in unlevel sectors and negatively on the motivation of leaders to innovate in level sectors, indicates that the equilibrium fraction of level sectors will decrease with competition, which is so-called composition effect (Aghion, 2009, p.267-283).

4 Firm dynamics and productivity growth

Firm performance is an essential source of sustainable economic growth. Successful firms are profitable, they increase shareholder value, create new jobs, innovate, pay taxes and benefit society. For this reason, firm growth has been the central topic for many researchers for many years. The essential research questions are concerned with the factors that contribute to firm success, what moves a firm from one stage to another, what makes one firm grow faster than others: is it a result of innovation in production and processes, or is growth more likely because of an effective management team and techniques, or maybe something else. Additionally, we may observe that some firms in the sector grow at 5% a year, and others grow at 20% a year. A firm that grew very quickly in one year possesses a greater market share from that moment forward compared to firms that were merely a part of the average growth in their sector. Thus, we are interested not only in the growth rate above the industry average, but also with the period where additional growth occurs. In this connection, it is important to note that the growth process must be demonstrated over several years to be defined as a growth.

Firm entry and exit are essential for economic growth; new firms enter the market and succeed while unsuccessful firms are forced to exit the market by transferring their know-how to surviving firms. These processes happen as a result of changes in market supply and demand, level of production of goods, quality, different products offered by a supplier, technological advance, scale economies, competition and policy changes.

Contrary to growth, resource misallocation towards less productive firms can affect negatively the aggregate productivity as efficient firms produce less output and employ fewer workers. The process of misallocation could cause firm size distortions. For this reason, growing firms that acquire new knowledge and resources should know how to use the resources which will help the identification of changes in market expectations.

4.1. How to measure growth

Firm growth can be measured by inputs such as employees, by values such as assets or by outputs such as turnover and profit. Generally, the most used measurements for growth from empirical studies are labour productivity growth (growth of value added per employee), employment growth or sales growth. However, when only sales are taken into consideration to the calculation, there is a risk that sales do not show the real company value-added. The reason for this could be, for example, a firm that buys products manufactured already by others and ready to consume. This firm could repackage or modify them slightly and sell to others. In this case, the sales could be misinterpreted because firm will rather have high turnover due to high costs of the product, but value-added to the economy is low. Therefore, value-added is a proper indicator to measure firm size, but researchers face a problem of data collection for this measurement (A. Coad, 2009, p.9-10).

Growth can be measured in absolute growth rate or in relative growth rate. Relative growth rate refers to two time points t_1 and t_2 defining the relative change per unit size. The growth could be measured by taking log-differences of size of firm S_{it}:

(17) $$G_{it} = \frac{1}{\Delta t}\frac{S_{t_2}}{S_{t_1}} - 1$$

Another way to measure growth is the log differencing

(19) $$\mathrm{G} \approx \left[\ln(S_{t_2}\right] - \left[\ln(S_{t_1}\right]$$

Log differencing reduces the significance of outliers and is symmetric with respect increases and decreases of a variable. Tradition growth measure could be a poor indicator of growth if the model is not exponential and two time points are not close enough to each other. For example, when firm's initial size is very low due to a temporary shock. Growth could be incorrectly recorded as extremely high when the shock is controlled over the time and followed by growth, because the comparative initial size was too low compared to the next period. Another method of measurement of growth rate is the use of Törnqvist index also known as DHS index (Davis, 1996) where the denominator in (17) would the average size over the two periods instead of initial size. This ranges from +2 (entrant or firm that has zero size at time *t-1*) to -2 (a firm that exits and has zero size at time *t*) (A. Coad, 2009). It can be shown that growth is then between growth rate and log difference.

Absolute growth is measured in absolute increase in numbers of employees at time *t* by using following formula (Reford, 1967):

(20) $$AGR = \frac{x_{t_2} - x_{t_1}}{t_2 + t_1}$$

Absolute growth is used in the literature analysing small firms. This method also could be used when policy makers are more concerned with the creation of jobs rather than firms' performance (A. Coad, 2009, p.9-10).

The Birch index is a weighted average of relative and absolute growth rates where E implies the employment in firm *i* at time *t*. Therefore, it will be relatively neutral with respect to firm size.

(21) $$Birch\ Index = \left(E_{it_2} - E_{it_1}\right)\frac{E_{it_2}}{E_{it_1}}$$

The Birch index can be calculated as a change in employees, a change in value added or as a change of mixture of both. Birch index is relatively neutral in respect to firm size, because if absolute growth in employment is taken into consideration, large firms would be classified as fast growing. However, if relative growth is used, then mainly small firms would be classified as fast growing. According to Birch, high-growing firms should have minimum 20 percent growth over a five-year period.

The most important question in my thesis is what creates growth. Factors for this creation could be various, but special attention is paid to firm performance and its changes over the firm size distribution. This raises other questions: do small and young firms grow faster than old and larger firms? Do large firms face more regulations compared to small firms such as tax differentiation between small and big firms, compliance costs and others?

Firm size distribution is a central focus in different empirical and theoretical studies by reason of its power in the processes in a market: growth (or reduction), firm entry (new firms enter the industry) and exit (firms face losses). Firm size is an important factor that needs to be examined. By this indicator we could determine the market concentration. This means that the increase in share of small firms will increase the competitiveness on the market while the increase share of large firms will build a market concentration (A. Coad, 2009).

One of the first models of firm growth is Gibrat's law also known as Law of Proportionate Effect which describes the dynamics of firms with a geometric motion

(22) $$S_t - S_{t-1} = \varepsilon_t S_{t-1}$$

where ε_t is a random variable implying the proportionate rate and S_t is firm size at time t. Finding x_t from the formula (17) and calculating the logarithms in order to approximate log (1+ ε_t), the result takes the following form

(23) $$log(x_t) \approx log(x_0) + \epsilon_1 + \epsilon_2 \ldots + \epsilon_t = log(x_0) + \sum_{n=1}^{t} \epsilon_n$$

Because the log (x_0) becomes too small when the amount of t grows, then the equation yields

(24) $$log(x_t) = \sum_{n=1}^{t} \epsilon_n$$

This equation shows that the firm size can be explained in respect of idiosyncratic shocks. If the further assumption is that firms in a specific sector are independent and shocks are equally distributed, then the distribution of $log\ x_t$ will be approximated by normal distribution. However, the results of many empirical evidences show that the distribution of growth rates is not even (A. Coad, 2009).

By a simple formula Gibrat assumes that firm growth is characterized by random process and attempts to explain what causes it. He analysed the distribution of French firms in terms of employees showing that it is skewed to the right that resembled lognormal. It means that there are numerous small firms and a few large firms. Robert Gibrat (1931) stated that the expected growth rate does not depend on the firm size at the beginning of the period examined. Some economists do not agree with Gibrat, because the law does not hold in all cases. Some of them consider the Gibrat's law as a special case that can explain Pareto distribution (Simon and Bonini, 1958). Ijiri and Simon (1964, 1971, 1974) used Pareto distribution to analyse the upper tail of distribution of large US firms.

A shortcoming of Pareto distribution is the concave shape of firm size distribution due to the empirical density that has numerous middle-size firms and fewer large firms. Empirical studies showed another problem in relation to the upper tail of size distribution that is too thin in respect to lognormal. According to Marsili (2005) Pareto distribution is applicable for aggregate firm size distribution and lognormal is applicable for smaller firms (A. Coad, 2009).

Other studies (Cabral and Mata, 2003) found the progress of the shape of the distribution over time. In this situation, when the new company enters in the market, the distribution is skewed to right, but over time it tends to become more normal. It is compatible with the assumptions that small firms grow more rapidly compared to larger firms (A. Coad, 2009).

It is important to mention international differences that can affect the size distribution regardless the robust findings that firm size distribution is skewed. This kind of difference is the structure of industries across countries. For example, the share of large firms on the French industry is significantly greater compared to Italy, where smaller firms prevail. There are various objections to Gibrat's law due to different reasons such as the presence of autocorrelation in the growth shocks (Chester, 1979), the negative connection between firm size and growth rate variance (Bottazzi and Secchi, 2006b), the non-symmetric annual growth distribution (Reichsten and Jensen, 2005), and absence of steady state, where the firm size tends to infinity over time (de Wit, 2005). Even though the Gibrat's law does not hold in all cases and it is not completely accurate, it could be an appropriate first approximation (A. Coad, 2009, p.14-20).

There are only a few studies that have examined the age distribution of firms. The low interest of research could be explained by difficult data availability and lack of data reliability. Alex Coad predicted in his book "The Growth of firms" that future studies will assert more efforts to investigate the influence of firm age on growth, because it could provide information that will help to understand events such as entry and survival rates, and probably the age of technology that is treated in the industry. One of the few researchers of age distribution is Coad and Tamvada (2008) who analyze the small business structure in India. They found that firm size and age have a negative effect on firm growth. Firms, especially young firms have lower growth in general. Firms engaged in international trade, especially young firms have a positive impact on firm growth. However, many small firms face difficulties to convert their know-how into growth (A. Coad, 2009).

Another research of age distribution is that of Alex Coad, Agustí Segarra, Mercedes Teruel (2016) which explored the relationship between innovation, firm growth and firm age in Spanish firms for the period of 2004-2012. They showed that young firms undertake riskier innovation activities which result in more successful firm performance. However, they face greater losses if their innovation efforts decline (A. Coad, 2009).

A wealth of theoretical literature examines two main problems with respect to statistical parameters of firm size and firm growth dynamics. Analyses specified the linearity of the growth rate process to demonstrate Gibrat's law. The investigations were performed on a large sample size of firms at a high level of aggregation where different companies across all sectors were included. But this leads to a problem where the probability of random events demonstrate regularity when repeated many times due to an aggregation process hiding the real features of the firm dynamics in a specific sector (A. Coad, 2009).

One important question that could be addressed here: is the average firm growth rate a good predictor of the aggregate growth rate for the whole economy? Firms are heterogeneous and grow for different reasons. Growth is modelled usually as a stochastic with random shocks. According to Alex Coad, general features in all firms could be found. This could be explained by the resource-based approach. Coad assumed the possibility of growth due to organizational slack. It means that the resources are not fully used at a given period of time due to various reasons and managers will want to use them efficiently aiming at full utilization. If the sources are not fully utilized, then resource scarcity would hinder the growth of firms. The fully utilized resources will require new resources to achieve growth, and firms need to identify the new opportunity to grow. He suggested a model with a Laplace distribution growth rate, where the resources in the firms are considered as independent and firms make efforts to achieve the efficient level of use of these resources to produce their output and reduce slack. Combination of these independent resources in the growth process could drive to non-linearity (A. Coad, 2009).

Bottazzi investigated US publicly traded companies during period 1960-2014. Net sales are the measurement of firm size $S_{i,t}$ and are deflated by the price index based on year 2009. The results of this study showed nevertheless more homogenous sample of firms, there is a slight correlation between the firm growth rate and the aggregate one, however, it is more volatile compared to the aggregate. The researcher replaced the aggregate growth rate of the sample of firms with the aggregate growth rate of the whole economy detecting the differences between companies and draws a conclusion that the aggregate growth rate grows due to a group of firms that outperform and not because of the increase in growth rate as average for the whole economy. The growth is driven by structural change of high productivity firms increasing in size or further improving their productivity level. Therefore, it is not a proper method to examine the average growth rate because it does not account for the different behaviour of low- and high-growth firms. It is important to comprehend the system of heterogeneity of firm-level and examine the micro-economic distribution of firm growth rates to be able to understand the macroeconomic dynamics (Bottazzi, 2017).

In this connection, data that Hymer and Pashigian (1962) examined is more disaggregated across different sectors and discovered that all measures of firm performance such as employment, output and their rates of change refer to high heterogeneity. The distribution of firm growth rates is fat-tailed, and its dispersion is related with firm size. They doubted if any stylized fact could be valid in relation to size distribution (Bottazzi and Secchi, 2006). Research of Stanley et al. (1996) found that firm growth rates appear as a ‘‘tent-shaped’’ Laplace distribution which is identical to symmetric exponential.

The models presented in the literature did not consider interconnection between past experiences of different firms or the behaviour of other firms. The firm is assumed as a monopolist in a sector, and its dynamics is explained by exogenous growth or decrease of demand. Other studies such as Ijiri and Simon (1977) and Sutton (1998) assumed that the odds of a firm on acting on businesses opportunities depends on its size. Although these models do not describe the shape of growth rate, they try to describe the competitive behaviour - how firms make decisions about efficient allocation of resources.

Different from these studies, Bottazzi and Secchi (2006) examined and showed tent shape of firm growth rate distribution in the Italian manufacturing industry using disaggregated data. They showed that this shape is not a result of aggregation. Tests are robust and prove that distribution of growth rates distinguishes from size distribution by a higher regularity. The idea they support is that the different opportunities among different firms increases the returns in growth process when the firm has already detected and used a number of opportunities in the past. To this process could be included, for example, knowledge accumulation, economies of scale, efficiencies formed by variety (economies of scope) as various opportunities. They assume that a firm who operates on the intensely changeable environment is competitive and successful due to its past successful behaviour. (Bottazzi and Secchi, 2006).

Recent evidence finds that distribution of firm growth rates follows the Laplace distribution. Distribution is symmetric exponential and recent studies found that the statement is a robust stylized fact helping to comprehend the growth process. Bottazzi (2001) examined international pharmaceutical industry and discovered that the Laplace distribution is a very good fit to firm growth rates. He went further and assumed the Laplace density as asymmetric exponential power distributions or so-called Subbotin distribution (A. Coad, 2009).

Laplance distribution holds for various firm indicators, however, findings show that its effect reduces over time, when growth is measured for a period longer than one year, becoming less heavy-tailed and more normal (Bottazzi and Secchi, 2006a). There are also assumptions that Laplance distribution is a proper model for larger firms with various products, however, Pareto-distributed is a better fit for small firms (Fu et al., 2005).

4.2. Autocorrelation of growth rates

The study of the serial correlation of growth rates is important because it may explain the firm growth and its persistence. Previous empirical research measured the serial correlation for a period of four to six years, whereas the most recent studies examined the autocorrelation on a yearly basis due to well organized and easily accessed information. The persistence of autocorrelation could be more easily detected when the observed period is shortened. Results of different studies are different, but positive serial correlation has often been examined (A. Coad, 2009).

Another issue that needs to be specified is the number of lags for autocorrelation. Chester (1979) and Bottazzi and Secchi (2003a) showed that the first lag is statistically significant, whereas Geroski et al. showed that autocorrelation is reliable at the third lag. The conflicting results in relation to autocorrelation suggest the need of a new approach which could take into consideration the complexity of autocorrelation of firm growth due to absence of a mutual coefficient that could fit to all firms (A. Coad, 2009).

Bottazzi et al. (2002) made a time series analysis calculating the mean autocorrelation coefficient for a given industry, but results were not statistically significant. Authors continued to exam firm-specific autocorrelation coefficients realizing that idiosyncratic growth patterns at firm level cannot be detected at average across firms. They found that the autocorrelation patterns are characterized by continuous asymmetries in association with growth dynamics across firms.

Coad (2007a) also tried to find any consistency in growth rate autocorrelation across firms. He separated the growth dynamics into firm size and lagged growth rate and concluded that small firms are more likely to face negative autocorrelation. In contrast, there is a greater likelihood for positive autocorrelation among large firms assuming that growth processes require longer periods of time. These findings can explain the different results of researchers in relation to autocorrelation coefficients (A. Coad, 2009).

The next important issue in Coad (2207a) findings showed that autocorrelation coefficient is dependent on growth rates. This means that firms with growth rates around the average in a given industry in one year are unlikely to meet any autocorrelation in the next year. Firms with very high or extremely low growth rates, are likely to face negative autocorrelation, such as fast-growth small firms with unpredictable growth rates (A. Coad, 2009).

According to Garnsey and Heffernan (2005) a small subset of small firms growth repeatedly and explained the positive autocorrelation of large firms regardless the level of growth rate in the past period with effective planning for the long term (A. Coad, 2009).

4.3. Profits, productivity and firm growth

The relationship between firm performance (measured as profits) and firm growth rate is examined by many theoretical and empirical research texts making a large contribution to future work and further explanation. Firms make choices in relation to their marketing strategies, organizational structure, innovation and investment policy, which informs their performance. Two of the most important dimensions of firm performance are firm profits and efficient production. Although theoretical authors suppose that firms with high performance will reinvest their returns into development, empirical evidence shows that the magnitude of the relation between performance and growth is smaller than expected, sometimes it does not even exist.

While neoclassic economists think that current financial performance might have not an impact on investment, evolutionary theory assume that firm growth is related to current profits. Many economists consider the relationship between productivity and firm growth, however, these two indictors – profits and productivity could be substituted for each other in measurement of firm performance (Coad, 2019).

Fazzari et al. (1988a) examined US manufacturing firms which are listed on the equity market and concluded that cash flow is a good predictor of investment. Supposing that firms are not able to forecast the future events because of uncertainty, then they will probably rely on current period indicators instead of stock market indexes when investment decisions are concerned. Interpretation of Fazzari et al. (1988a) findings is that sensitivity of investment to cash flow will be raised in the degree of financial constraints.

There is a suggestion that sensitivity is associated with imperfect market and asymmetric information. Fazzari et al. thinks that firms prefer to use their internal funds to invest rather than to spend them for dividends, when external funds are more expensive. He called firms as “most constrains” when they have a low dividend yield and “least constrains” when they have a high dividend yield (A. Coad, 2009).

Kaplan and Zingales (1997, 2000) criticized Fazzari et al. (1988a) work and introduced a model showing that investment-cash flow sensitivities cannot be a measurement of financial constraints. They analyzed the financial data of firms and draw a conclusion that firms ranked as less financially constrained are prone to higher sensitivity of investment to cash flow. Furthermore, they gave an example that Microsoft would be classified according to Fazzari et al. as “most constrained” because of its $9 billion cash flow which is equal to 18 times its capital expenditure (A. Coad, 2009).

A number of other researchers, such Gilchrist and Himmelberg (1995), Kadapakkam et al. (1998), Erickson and Whited (2000) and Alti (2003) support the findings of Kaplan and Zingales (1997, 2000). Erickson and Whited (2000) and Alti (2003) gave an explanation in relation to Kaplan and Zingales’ findings that less constrained firms are more likely to be prepared for shocks and adjust their investment decisions regarding the information that cash flow brings to them (A. Coad, 2009).

Coad (2009) makes a difference between evolutionary theory and the neoclassical-based approach. Evolutionary theory introduces the principle of “growth of the fitter” and assumes that the most profitable firm has propensity to grow. This implied that economic processes develop where resources are allocated among high productive firms, however, the least productive firms tend to decline and exit. Coad argues against the neoclassical idea of rational profit-maximizing firms where firms are assumed to be perfectly efficient and need to be funded by government as being financially constrained (Coad, 2010).

Evolutionary authors as Coad classifies them measure firm growth in terms of investment (Nelson and Winter, 1982), total output (Metcalfe, 1994) or market share (Dosi et al., 2006).

Bottazzi et al. (2008b) and Dosi (2007) examined the relationship between profitability and growth and identified that there is no a robust relationship. Coad (2007d) examined French manufacturing firms and found relationship between financial performance and growth, but the degree of the coefficient is very small that cannot be taken into consideration (A. Coad, 2009).

The models of Coad et al. (2007) and Rao (2009) studied co-evolution over time of various variables exploring the firm performance and its growth. The results showed a small relationship between profits and productivity with the subsequent development of firms; however, the relationship is greater comparing employment and sales growth with the subsequent growth. They also found that firm performance does not have a significant impact on growth as measured in relation to investment or sales growth. Additionally, models showed a powerful unexplained variation in relation to growth rates, which means that firms are very cautious with respect to their growth behaviour (A. Coad, 2009).

A small difference between neoclassical-based studies mentioned above and evolutionary economists is the different regression analysis. Evolutionary economists give priority to intangible capital in economic change and measure the growth in terms of sales growth, while other studies paid attention to investment in fixed assets. Another difference is the measurement of financial performance, evolutionary economists measure it by current-period financial performance and others by cash flow. Even though the indicators are rather similar (A. Coad, 2009).

Schumpeter as a neoclassical economist believes that a high degree of market power and high rents would be important factors for the successful innovator, which will motivate him to invest in research and development activities, resulting in technological progress and economic growth. This is consistent with the Aghion and Howitt's (1992) model, according to which more competition harms incentives to innovate and to growth. According to Schumpeter, innovations introduced by leading firms will renew their competitive advantage, which will lead to increase in persistent performance. A follower firm which is able to destroy the competences of leading firm (creative destruction) by innovation may achieve persistent performance. Previous empirical evidence shows that persistent economic performance is rare. For example, Mueller (1986) and Wiggins and Ruefli (2002) found that only small share of firms (around 5%) are exposed to persistent of economic performance for periods that last for more than ten years. In this connection, Baaij, Greeven and Dalen (2004) study 500 computer firms and found a high share of firms who achieve persistent economic growth. Their analysis suggests that the Schumpeter innovation can contribute in two ways: by creative accumulation of leading firms extending their persistent growth and by creative destruction of following firms that introduce innovation achieving persistent growth. Their findings that creative destruction exists in the computer industry support the framework.

The analysis of Piekkola and Rahko (2019) is also related to Schumpeterian growth. They study how innovations contribute to firm performance examining two parameters: initial productivity and market power. Firms with a low market share and low initial productivity are prone to high fixed costs. These costs can induce firms to invest only in innovations with the highest productivity growth described as a negative selection mechanism. However, these negative selection does not operate the same way in high- market-share firms which are characterized with higher profitability and production of innovations, compared to low-market-share firms who have high productivity growth but low profitability with negative selection (Piekkola and Rahko, 2019).

In brief, neoclassical authors assume that firms maximize shareholder value by increasing sales, free cash flows and dividends, while evolutionary theory believe that firms struggle to grow. Neoclassical authors assume that firms are perfectly rational, they invest based on long-term profitability concept and information asymmetry. According to them, if investment is sensitive to present firm performance, the reason will be that something is wrong and should be fixed through policy implications. Whereas evolutionary theory refers the investment-cash flow sensitivity as a strong and healthy economy (A. Coad, 2009).

5. The empirical analysis between the role of R&D activities in growth

This research aims to empirically examine the impact of R&D expenditure on Finnish economic growth, differentiating tangible and intangible expenditure. Important questions that arise - weather R&D and capital spending by Finnish companies affect the firm growth within the company and do companies' size and industry have influence on it. The relationship between R&D expenditure and the autocorrelation dynamics of company growth from one period to another is also separately assessed.

5.1. Introduction

For the purpose of the study, it is necessary to define the R&D activities' distinguishing characteristics. First, firms spend resources in order to develop new products and enhance pre-existing products or processes. However, in the most cases, the lifetime of R&D activities tends to be long. In other words, it takes time, sometimes even 10 years, from idea through implementation of innovation and its realization in the market. Thereby, in the latter stage R&D activity may influence growth and increase sales. The duration of this time lag is different for different firms and industries. Second, it is important to differentiate tangible investments such as capital investments from intangible investments such as R&D spending. The length of time over which the tangible investments is made is longer than intangible investment in general. However, the impact of R&D investment on growth shows delay in general. The scale of the impact on growth of both investments might differ as well and it is not examined sufficiently in previous studies. Third, there are firms that actively invest in R&D activities and others that are R&D-inactive. Thereby, it may be useful to compare the impact of short-term R&D activities with average long-term R&D and their respective effects on firm growth. Fourth, firm size and industry may have influence on R&D activities. For the simple reason that larger companies have greater opportunities to invest in R&D activities and companies from high-tech industries put more efforts in R&D activities compared with low-tech industries Schimke, A. and Brenner, T. (2014).

5.2. Background

A number of studies have found a positive impact of R&D activities on growth (Schreyer, 2000; Autio et al., 2007; Bayarcelik, Beyza and Fulya, 2012; Adamou and Sasidharan, 2007; Yang and Lin, 2007; Del Monte and Papagni, 2003; Coad and Rao, 2008; Banbury and Mitchell, 1995). Results showed that high-tech firms with a strong commitment to R&D activities have a higher firm growth compared to companies whose commitment is weak. For example, according to Banbury and Mitchell (1995) incremental innovation improves growing firms' competitive positions. Schreyer (2000) showed that firm growth can be increased with more intensive investments in R&D activities. Furthermore, Del Monte and Papagni (2003) showed that R&D-performing firms have higher sales growth than firms without R&D activities.

In reference to the autocorrelation dynamics in firm growth, results of different studies showed different conclusions. For example, Bottazzi and Secchi (2003) found that firm growth is positively autocorrelated and they suggest that higher firm performance today will be followed by higher firm performance tomorrow. However, Almus and Nerlinger (2000) did not find a significant positive autocorrelation. Coad (2006) found that auto-correlation of consecutive growth periods varies with firm size. Large firms have a higher probability to repeat their growth performance the following year, while smaller firms are characterized by a negative correlation. The estimation of distributed lags has also been investigated. Studies such as Chesher (1979), Bottazzi and Secchi (2003) and Coad (2007) found that one lag is statistically significant, whereas Geroski et al. (1997) found significant autocorrelation at the third lag.

5.3. Data and methodology

Schimke and Brenner (2014) and this paper test the following hypotheses:

H1. Autocorrelation of company turnover growth varies with firm size – growth patterns of small firms are different from the growth patterns of medium-sized and larger firms. I suggest that there is positive autocorrelation of turnover to its previous values in larger firms and negative autocorrelation in smaller firms.
~~period.~~

H2. There is a positive influence of R&D investments on company growth. This hypothesis stems from former studies which support the suggestions that R&D investments are an essential growth determinant.

H3. Firm size has influence on R&D investments with the impact focused on growth and temporal structure. This hypothesis would be in line with earlier research such as Shefer and Frenkel (2005) and Kafouros and Wang (2008).

H4. The influence of R&D investments and capital investments and their temporal structure on growth differs across different industries. This comparison is necessary because industries such as manufacturing and service have different R&D activities, processes and temporal structures.

In this section I will examine the relationship between R&D expenditures and output of Finnish firms, while my research will be compared with work of Antje Schimke and Thomas Brenner (2014). I make this comparison for a couple of reasons. First, my research is generated on the base of their work. Second, a comparison of two approaches will provide more detailed information and more significant contribution to the topic of concern. Additionally, information about R&D expenditures in Finland is scarce since firms do not want to reveal their R&D data because they believe this can make them vulnerable to competition. Therefore, the limited availability of data on R&D expenditure of firms represents the most significant limitation.

I use the dataset on the Finnish firms collected by Orbis. Each entry is comprised of a firm name, year, and NACE (statistical classification of economic activities within the European Communities). The total number of firm-year observations is 5112 between 2008 and 2017 which gives a suitable period in order to detect time-series dimension of firms' growth dynamics.

As a comparison, Antje Schimke and Thomas Brenner (2014) investigated 1,000 European firms using the European Industrial R&D Investment Scoreboard as the data source. Total growth is focused on manufacturing industries and the Real Estate industry. Additionally, they differentiate high-tech and low-tech firms. The time frame is three years from 2003 to 2006.

Many empirical studies use sales, total assets and number of employees as a measurement of firm size. They investigate whether firm growth rates are correlated with firm size in conjunction with the validity of Gibrat's law. According to it, firm growth has a random effect, and it does not depend on firm size. In my analysis I use turnover (S_t) growth as the dependent variable. This indicator is also used by Schimke and Brenner (2014). In time-series model turnover S_t might have moved up or down in response to changes in different factors. S_t is the current value of turnover and its value in previous period is S_{t-1} which is in practice the first lag. The first difference is the change in S from period $t-1$ to period t, namely, $\Delta S = S_t - S_{t-1}$. The dependent variable in our model is the first difference in logarithms of a series with a lag of one period is

(27) $$\text{Growth}=\Delta\log S_t = \log S_t - \text{l.}\log S_{t-1}$$

I have included categorical predictors in the regression analysis which I converted into dummy variables to fit the model. By using dummy variables, we can test the overall differences between groups. My groups are associated with firm size (small, medium-sized, and large firms) and industry-specific effects. Economic activities are computed from the NACE-2-digit industries classification developed in the European Union. The distribution of firm size and industries in Finland can be seen in appendix 4.

Independent variables which I have used are R&D expenses, tangible assets, other intangible assets, firm size measured in employees (small, medium-sized, and big firms) and industry affiliation.

Company size	**Employees**
Large	250–
Middle	50–249
Small	< 50

Differences between industries are also analysed separately, as certain sectors depend on innovation processes more than others. Growth may change across industries as innovation behaviour differs. The choice between which one of the dummy variables to be dropped is important, because the results of dummy coefficients can be different. However, dropping of the dummy variable will not change the model. Additionally, I measure R&D intensity which is the ratio between R&D expenditure and the firm's sales. The same ratio is calculated respectively for tangible and other intangible assets where other intangible assets exclude R&D expenditure and are used as a control variable. The multicollinearity is tested by the variance inflation factor (VIF). And dataset is declared to be time-series data.

Schimke and Brenner use standard regression analysis since their residuals and independent variables are approximately normally distributed, along with the absence of heteroscedasticity. In order to avoid multicollinearity, they setup different regressions, one with the average values of R&D and tangible expenditure (ratios: R&D/sales and tangible expenses/sales) for the observed period (2003-2006) and one with separate values of R&D and tangible expenditure for each year. They also compare results where temporal autocorrelation is considered versus the results when temporal autocorrelation is not taken into consideration. Their dependent variable is the change in the logarithms of the turnover from year 2005 to year 2006.

I use data panel analysis where I observed the behaviour of firms across time. Panel data modelling is my preferred method because it allows one to explore more issues and to sort out economic effects. By use of panel data, the researcher can distinguish the influence of scale economies from the influence of technological change. Additionally, the researcher can examine the changes in output of a separate firm over time, simultaneously with estimation of the change in profits of various firms at a given time. Another advantage of panel data is the creation of an additional degree of freedom and they also can reduce the problems when a variable is omitted. It is important to organize the data properly before estimation of the relationship between dependent and independent variables and to choose an appropriate panel data model. When dataset has been organized, I reshaped data in long format in order to structure the dataset with many variables. While wide format has either individuals (such as firms) or time variables, the long format is composed of individuals and many time periods. Finally, I include a lagged dependent variable in the right-hand side and run both fixed effects and GMM-type regression with entity-specific intercepts that capture heterogeneities across entities.

(28)

$$Growth_j = a_0 + a_1 RD + a_2 Tang_j + a_3 Inta_j + a_{4-6} FirmSizeDummy_{4-6,j} + a_{7-16} IndDummy_{7-16,j} + \varepsilon$$

I assume that my time-series model is generated by a stochastic process due to the randomness of the series. The reason for this assumption is that turnover and a series of sales figures are not stationary, they can be characterized by periods of relatively low volatility and periods of relatively high volatility trends, therefore the mean of each one is time dependent. In this connection, I have studied the serial autocorrelation of annual growth rates in order to examine the persistence of growth processes along with differences between small and large firm growth. In addition, I examine how growth autocorrelation varies for firms from different industries. As panel data model includes lagged levels of the dependent variable, it might cause a correlation with the fixed effects in the error term, which gives increase to dynamic panel bias (Nickell, 1881). For that reason, I use Arellano and Bond (1991) estimation which transforms all regressions. This method allows the introduction of more instruments and consists of original equation and the transformed one. The system is known as GMM.

5.4. Results

The first assumption is that the impact of R&D activities on growth is positive. Respectively, I found a significant positive impact of R&D activities on growth (Table 1). Schimke and Brenner compare the regressions of temporal autocorrelation with the regression that do not consider temporal autocorrelation and found a positive effect of R&D expenditure on firm growth. However, if the prior period growth is included, then results are insignificant, for that reason they assume existence of autocorrelation and found a positive relationship between R&D expenditure in the previous year and firm growth.

The results of my fixed effect model in Table 1 show that the R&D coefficients of small and medium-sized firms are positive and equal to those in large firms. The coefficient is fairly similar across firm size. This is despite that larger firms invest into projects that take a long period for realization. They have the resources to fund R&D activities and are capable to cover high investments. Phillips and Kirchhoff's (1989) even argue that large firms choose expansion strategies while small firms struggle to survive.

Table 1. The results of fixed effect model

Turnover growth	Small firms	Medium -sized	Large firms
RD	0.651***	0.538***	0.625***
	(0.13)	(0.13)	(0.13)
Other intangible	- 0.069***	- 0.085***	- 0.084***
	(0.02)	(0.02)	(0.02)
Tangible	-0.080	-0.003	-0.031
	(0.06)	(0.06)	(0.06)
Small firms	0.399***		
	(0.08)		
Electricity	0.215	0.008	0.081
	(0.16)	(0.16)	(0.16)
Water supply	0.040	0.043	0.038
	(0.10)	(0.10)	(0.10)
Construction	-0.018	0.001	-0.010
	(0.09)	(0.10)	(0.10)
Wholesale and retail trade	0.021	0.033	0.025
	(0.29)	(0.30)	(0.30)
Transportation	0.002	0.022	0.011
	(0.10)	(0.10)	(0.10)
Accommodation and food services	0.437**	0.147	0.263
	(0.14)	(0.14)	(0.14)
Information and communication	-0.011	0.018	0.029
	(0.03)	(0.04)	(0.03)
Financial and insurance	0.069	0.101	0.151
	(0.15)	(0.15)	(0.15)
Professional, scientific, technical	-0.207*	-0.181	-0.199
	(0.10)	(0.11)	(0.11)
Other service activities	-0.008	0.053	0.160
	(0.29)	(0.30)	(0.30)
Medium-sized firms		0.043	
		(0.05)	
Large firms			-0.16***
			(0.04)
_cons	-0.38***	-0.050	0.005
	(0.08)	(0.06)	(0.02)

* p<0.05, ** p<0.01, *** p<0.001

Schimke and Thomas also found a significant R&D coefficient but not for SMEs. Additionally, they found that the first lag is statistically significant for large firms while also the second lag is statistically significant for very large firms. However, in contrast to our results they do not find any significant relationships for small, medium-sized and very large-sized firms, then they suggest a negative relationship. In this sense, I find a positive autocorrelation for all types of firms - small, medium-sized and large firms in table 2 below. This means that firms are likely to repeat their growth performance in the following period.

AC in table 2 demonstrates that the correlation between the last value of turnover and its value two years ago is 0.5747. PAC illustrates that the correlation between the last value of turnover and its value two years ago is 0. 0941 without the effect of the previous lag. The last column tests the null hypothesis and shows significant autocorrelation in all lags. Negative autocorrelation presents from the seventh to tenth lag. However, too many lags could increase the error in the estimation whereas too few could miss important information. The results are very similar to the test of autocorrelation for small and medium-sized firms in table 2, although negative autocorrelation presents in the earlier stages in the groups of firms.

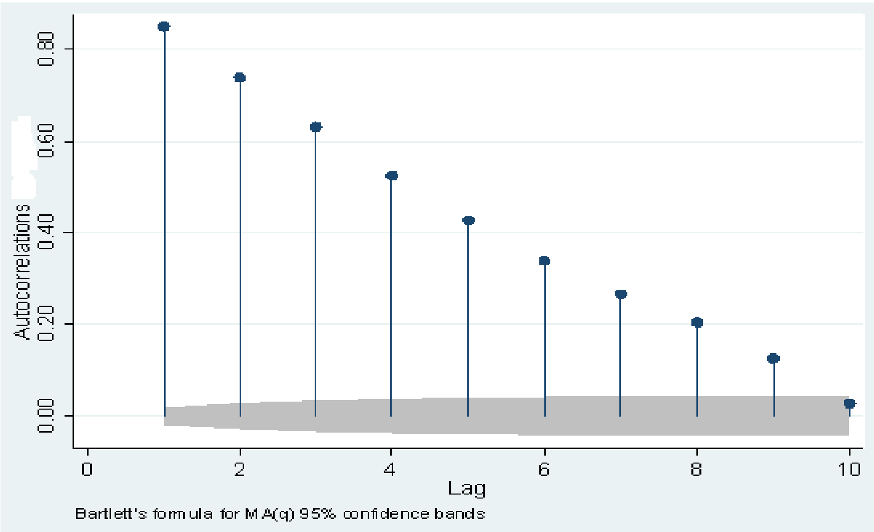
Table 2. Autocorrelation of large firms

LAG	AC	PAC	Q	Prob>Q
1	0.6415	0.9354	2919.3	0.0000
2	0.5747	0.0941	5262.4	0.0000
3	0.4432	0.2901	6656.2	0.0000
4	0.2707	0.1077	7176.2	0.0000
5	0.2458	0.0794	7604.9	0.0000
6	0.1478	0.0959	7760.1	0.0000
7	0.1143	-0.0564	7852.8	0.0000
8	0.0872	-0.1153	7906.8	0.0000
9	0.0618	-0.0539	7933.9	0.0000
10	0.0397	0.1597	7945.1	0.0000

Table 3. Autocorrelation of small and medium-sized firms

Small					Medium-sized				
LAG	AC	PAC	Q	Prob> Q	LAG	AC	PAC	Q	Prob> Q
1	0.6604	1.0766	7013.7	0.0000	1	0.8165	1.0049	9718.9	0.0000
2	0.3936	0.0079	9506.1	0.0000	2	0.6494	-0.1512	15867	0.0000
3	0.1206	0.0624	9740.2	0.0000	3	0.4855	-0.0975	19304	0.0000
4	0.0884	0.1646	9866	0.0000	4	0.3394	-0.0837	20985	0.0000
5	0.0626	0.3526	9929.1	0.0000	5	0.2121	-0.0713	21641	0.0000
6	0.0308	-0.4451	9944.4	0.0000	6	0.1044	-0.1063	21799	0.0000
7	0.0179	-0.1114	9949.5	0.0000	7	0.0704	0.0146	21872	0.0000
8	0.0090	-0.0858	9950.8	0.0000	8	0.0407	-0.0654	21896	0.0000
9	0.0027	0.1443	9951	0.0000	9	0.0319	0.0031	21911	0.0000
10	0.0005	-0.0246	9951	0.0000	10	0.0250	-0.0049	21920	0.0000

Fig.2. Autocorrelation correlogram for large firms



The figure 2 illustrates a high positive autocorrelation that slowly decline with increasing lags. The presence of autocorrelation means that I should correct my modelling. For that reason, I use Arellano-Bond estimator (table 4) to test the dynamic models of panel-data where are included lagged levels of the dependent variable.

Since autocorrelation presents in my data it could cause the results to be less efficient. For that reason, I correct the problem with autoregressive AR(1) model. Furthermore, I use the Arellano–Bond test for first- and second-order autocorrelation in the first-differenced errors.

The model in table 4 includes the lagged differences of turnover as instrument in the level equation. The GMM estimators are valid in the event of absence of serial correlation. As the first difference is autocorrelated, I need to test for second autocorrelation.

Table 4. Arellano-Bond dynamic panel-data estimation

-	Small firms	Medium -sized	Large firms
L.growth	-0.177	-0.126	-0.091
	(0.10)	(0.09)	(0.07)
RD	0.922**	0.938**	0.892*
	(0.30)	(0.35)	(0.36)
L.RD	0.232	0.190	0.083
	(0.18)	(0.17)	(0.15)
Tangible	0.331	0.416	0.399
	(0.34)	(0.41)	(0.55)
L.Tangible	1.509***	1.621***	1.492***
	(0.17)	(0.18)	(0.18)
Small firms	0.918***		
	(0.21)		
L.Small firms	-0.298		
	(0.36)		
Manifacturing	0.552	0.678	0.793
	(0.91)	(1.16)	(1.31)
Electricity	-1.290	-4.208	-5.789
	(6.64)	(11.18)	(11.52)
Construction	-1.349	-2.754	-2.979
	(2.12)	(3.24)	(3.33)
Transporta-tion	-21.037	-30.571	-33.015
	(22.48)	(35.67)	(37.16)

Accomoda-tion and food	9.487	12.470	13.650
	(15.60)	(19.12)	(20.62)
time	-0.013*	-0.013	-0.018*
	(0.01)	(0.01)	(0.01)
Medium-sized		-0.317	
		(0.20)	
L.Medium-sized		-0.188	
		(0.14)	
Large firms			-0.074
			(0.23)
L.Large firms			0.448
			(0.43)
_cons	38.161	50.610	62.453
	(29.35)	(48.99)	(49.55)

* p<0.05, ** p<0.01, *** p<0.001

The output below presents there is serial correlation at the significance level of 0. 05 in the first-differenced errors at order 1, and no significant evidence of serial correlation at order 2. When the null hypothesis holds at higher orders it implies that the moment conditions are valid.

Order	z	Prov > z
1	-1.9916	0.0464
2	1.6668	0.0956

The large p-value (0.0956) shows that there is no second-order serial correlation, which means that there is no evidence of misspecification. The results again shows that SMEs behave similarly to large firms.

Adamou and Sasidharan (2007) also stated that R&D as a determinant of firm growth will impact higher growth irrespective of the industry. Schimke and Brenner instad assume that growth dynamics differ across industries and in addition to this, they compare high-tech and low-tech manufacturing firms. They found that R&D activities in high-tech industries are correlated positively to growth. Capital expenditures are characterized with positive effect only in one industry; however, it is negatively related in others. My results show that growth dynamics differ across industries, however the results are not robust for most cases. The reference group which is dropped from the model in order to show differences between each other category and the reference group is Manufacturing. The choice of this group is due to the following reasons: it is the largest sector in my dataset, and it seems reasonable to compare and evaluate the industry with the highest effort to R&D activities. The regression coefficients show the difference in means between the reference category and the remaining sectors. All coefficients of industries are positive in comparison to Manufacturing excluding three sectors - Construction, Information and Professional, scientific and technical services. One of the results which is statistically significant ($p = 0.002$) show that growth in Manufacturing is 44% lower than in sector Administration and food service activities. The other statistically significant result shows that Professional, scientific and technical services growth is 21% lower than in Manufacturing ($p = 0.045$).

5.5. Conclusions

My paper attempts to explain the differences among sample Finnish firms in respect to firm size and the type of industrial structure. Furthermore, it seeks to complement the existing literature on the role of R&D expenditure on growth. Growth is measured in terms of turnover which I believe is the appropriate indicator. The suggestion that R&D investments increase a firms' productivity is supported by the results showing a positive effect of R&D on growth. Negative relationship is observed between tangible expenditure and growth; however, the results are not statistically significant.

According to Schimke and Brenner (2014) the relation between R&D activities and firm growth varies with firm size. My results show that the coefficients are almost the same for all types of firms. Furthermore, the results of my fixed effect model show that the coefficients of small and medium-sized firms in relation to growth are positive, while the coefficient of large firms in relation to growth is negative. Unlike the assumption that smaller firms have limited R&D investments and they are less productivity, smaller firms put efforts into becoming more productive. This is consistent with Coad (2017) view that small firms being in the early stage of growth advance faster than large firms. In my dynamic and autoregressive panel data model with lagged variables the coefficients of small and medium-sized firms in relation to growth are negative, while the coefficient of large firms is positive. The reason could be that larger firms invest into projects taking a long period for realization.

When I test for autocorrelation, all types of firms (small, medium-sized and large firms) are characterized with positive autocorrelation. These indicates that firms are likely to repeat their growth performance in the following period, which could lead to sustained growth. To fix the problem with autocorrelation, I use autoregressive AR(1) model.

Additionally, the focus of my research is also whether firm growth differs across industries. My results reveal differences between sectors, however for most industries results are statistically insignificant. Robust results show that growth in Manufacturing is lower in comparison to the Administration and food service industries but higher when compared with the Professional, scientific and technical services sector.

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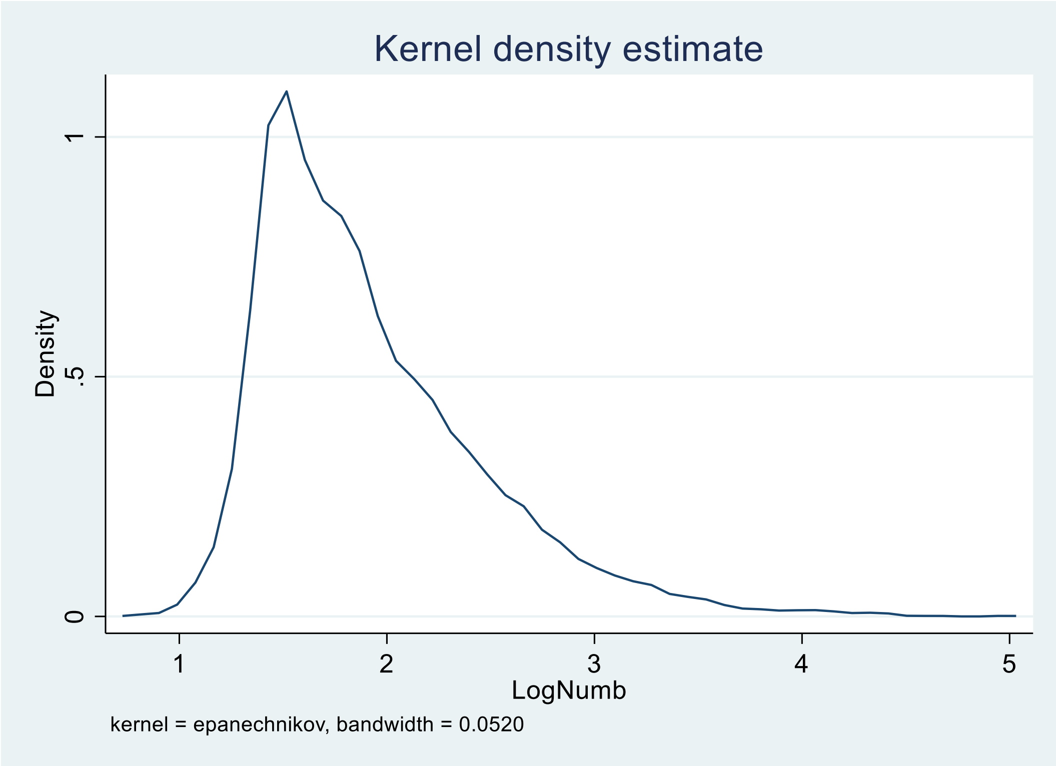
Appendix 1. Kernel density



Appendix 2. Autocorrelation

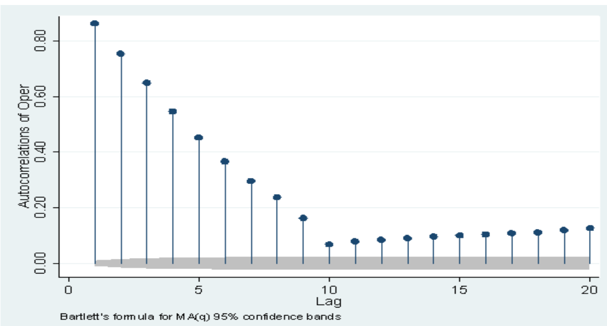
Table A.1 Autocorrelation of small firms

LAG	AC	PAC	Q	Prob>Q
1	0.5688	0.9573	5204.2	0.0000
2	0.2547	0.1551	6247.3	0.0000
3	0.1424	-0.1032	6573.6	0.0000
4	0.0848	-0.0260	6689.3	0.0000
5	0.0623	0.0121	6751.7	0.0000
6	0.0311	-0.0134	6767.3	0.0000
7	0.0157	-0.0101	6771.2	0.0000
8	0.0084	0.0255	6772.4	0.0000
9	0.0033	0.0003	6772.5	0.0000
10	-0.0009	-0.0234	6772.6	0.0000

Table A.2 Autocorrelation of medium-sized firms

LAG	AC	PAC	Q	Prob>Q
1	0.7505	0.9558	8212.6	0.0000
2	0.5789	-0.0200	13099	0.0000
3	0.4510	0.0838	16065	0.0000
4	0.3656	0.2245	18013	0.0000
5	0.2544	-0.0751	18957	0.0000
6	0.1190	-0.0997	19164	0.0000
7	0.0903	-0.0305	19283	0.0000
8	0.0555	-0.0941	19327	0.0000
9	0.0407	-0.1377	19352	0.0000
10	0.0276	0.0224	19363	0.0000

Figure A.3 Autocorrelation using AC



* AC produces a correlogram with pointwise confidence intervals that is based on Bartlett's formula for MA(q) processes.

Appendix 3. Distribution of firms and industries

Table A.3 Distribution of firms and industries

Industry	**Freq.**	**Per-cent**	**Cum.**
Agriculture , forestry, fishing	43	0,84	0,84
Mining	19	0,37	1,21
Manifacturing	1380	27	28,21
Electricity	112	2,19	30,4
Water supply	38	0,74	31,14
Construction	339	6,63	37,77
Wholesale and retail trade	778	15,22	52,99
Transportation	242	4,73	57,73
Accomodation and food services	216	4,23	61,95
Information and communication	396	7,75	69,7
Financial and insurance	214	4,19	73,88
Real estate activities	117	2,29	76,17
Professional, scientific, technical	574	11,23	87,4
Administrative and support services	257	5,03	92,43
Public administration	2	0,04	92,47
Education	69	1,35	93,82
Human health and soical work	214	4,19	98
Arts, entertainment	76	1,49	99,49
Other service activities	26	0,51	100
Total firms	**5112**		

Table A.4 Distribution of firms and industries by industries invested in R&D (numbers of firms)

Distribution of firms by industries invested in R&D (numbers of firms)						
R&D expenses	Manifac.	Electric.	Water supply	Transport.	Information communication	Total
3950	0	0	0	0	1	1
10000	1	0	0	0	0	1
100000	12	1	1	0	3	17
500000	11	1	0	0	3	15
1000000	5	0	0	1	1	7
2000000	1	0	0	0	0	1
4000000	1	0	0	0	0	1
Total	**31**	**2**	**1**	**1**	**8**	**43**

Distribution of firms by firm size and their R&D investments (number of firms)				
R&D expenses	Small	Medium-sized	Large	Total
3950	0	0	1	1
10000	0	1	0	1
100000	0	2	15	17
500000	0	0	15	15
1000000	0	0	7	7
2000000	0	0	1	1
4000000	0	0	1	1
Total	**0**	**3**	**40**	**43**

Table A.5 Growth of turnover

Growth of turnover 2017/2016			
%	Freq.	Percent	Cum.
> -1	1	0.02	0.02
-1 < x < 0	1460	29.51	29.53
0 < x < 5	3451	69.76	99.31
>5	35	1.47	100,00
Total	**4947**	**100.00**	

Growth of turnover 2017/2016 by firm size				
growth	**Small**	**Medium-sized**	**Large**	**Total**
> -1	0	0	1	1
-1 < x < 0	621	578	261	1460
0 < x < 5	1458	1396	597	3451
>5	21	12	2	35
Total	**2100**	**1986**	**861**	**4947**

Growth of turnover 2013/2012			
Growth	**Freq.**	**Percent**	**Cum.**
> -1	5	0.12	0.12
-1 < x < 0	1786	42.84	42.96
0 < x < 5	2342	56.18	99.14
>5	36	0.86	100.00
Total	**4169**	**100.00**	

Growth of turnover 2013/2012 by firm size				
growth	**Small**	**Medium-sized**	**Large**	**Total**
> -1	5	0	0	5
-1 < x < 0	704	718	364	1786
0 < x < 5	1085	890	367	2342
>5	23	12	1	36
Total	**1817**	**1620**	**732**	**4169**

Growth of turnover 2009/2008			
Growth	**Freq.**	**Percent**	**Cum.**
< -1	1	0.03	0.03
-1 < x < 0	1856	56.23	56.26
0 < x < 5	1409	42.68	98.94
>5	35	1.06	100.00
Total	**3301**	**100.00**	

Growth of turnover 2009/2008 by firm size				
Growth	**Small**	**Medium-sized**	**Large**	**Total**
> -1	0	1	0	1
-1 < x < 0	717	734	405	1856
0 < x < 5	680	519	210	1409
>5	20	11	4	35
Total	**1417**	**1265**	**619**	**3301**

Table A.6 Growth of turnover by industries

Growth of turnover 2017/2016 by industries										
growth	Agric. Forest	Min-ing	Manif	Elect.	Water	Cons-truct	Trade	Trans-port	Acc. Food	Inform
> -1	0	0	1	0	0	0	0	0	0	0
-1 < x < 0	15	5	409	44	13	93	222	73	70	112
0 < x < 5	24	12	927	67	23	230	541	165	140	268
>5	0	1	5	0	0	2	3	0	2	6
Total	**39**	**18**	**1342**	**111**	**36**	**325**	**766**	**238**	**212**	**386**

Growth of turnover 2017/2016 by industries										
growth	Fina ncial	Real est.	Prof Scien	Admi nist.	Pub. adm	Educ	Health	Arts	Other	Total
> -1	0	0	0	0	0	0	0	0	0	1
-1 < x < 0	51	32	154	50	1	31	59	20	6	1460
0 < x < 5	142	82	380	192	1	36	149	54	18	3451
>5	2	0	6	5	0	0	1	2	0	35
Total	**195**	**114**	**540**	**247**	**2**	**67**	**209**	**76**	**24**	**4947**

Growth of turnover 2013/2012 by industries										
growth	Agric. Forest	Min-ing	Manif	Elect.	Water	Cons-truct	Trade	Trans-port	Acc. Food	Inform
> -1	0	0	3	0	0	0	0	1	0	0
-1 < x < 0	12	6	587	42	14	100	315	90	70	115
0 < x < 5	18	9	583	56	18	162	364	121	111	182
>5	0	1	12	0	0	1	5	0	1	7
Total	**30**	**16**	**1185**	**98**	**32**	**263**	**684**	**212**	**182**	**304**

Growth of turnover 2013/2012 by industries										
growth	Fina ncial	Real est.	Prof Scien	Admi nist.	Pub. adm	Educ	Health	Arts	Other	Total
> -1	0	0	1	0	0	0	0	0	0	5
-1 < x < 0	65	36	175	72	0	22	34	25	6	1786
0 < x < 5	65	64	263	123	1	21	126	41	14	2342
>5	0	0	4	1	0	0	3	1	0	36
Total	**130**	**100**	**443**	**196**	**1**	**43**	**163**	**67**	**20**	**4169**

Growth of turnover 2009/2008 by industries										
Growth	**Agric. Forest**	**Min-ing**	**Manif**	**Elect.**	**Wa-ter**	**Cons-truct**	**Trade**	**Trans-port**	**Acc. Food**	**In-form**
> -1	0	0	0	0	0	0	0	0	0	0
-1 < x < 0	12	10	731	25	13	117	320	91	59	109
0 < x < 5	13	3	263	63	15	69	241	77	70	128
>5	0	0	7	0	0	3	5	2	1	3
Total	**25**	**13**	**1001**	**88**	**28**	**189**	**566**	**170**	**130**	**240**

Growth of turnover 2009/2008 by industries									
Growth	**Fina ncial**	**Real est.**	**Prof Scien**	**Admi nist.**	**Pub. adm**	**Health**	**Arts**	**Other**	**Total**
> -1	0	0	1	0	0	0	0	0	1
-1 < x < 0	62	20	164	63	9	23	21	7	1856
0 < x < 5	30	51	160	85	18	81	34	8	1409
>5	2	2	3	1	1	3	2	0	35
Total	**94**	**73**	**328**	**149**	**28**	**107**	**57**	**15**	**3301**