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A study of factors relevant for the generation of new technology in OECD countries.

A cross-sectional analysis of the relationship between stock of knowledge, research effort, competition and knowledge accumulation.

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ABSTRACT

This thesis investigates, at the country level, the relationship between innovation output or generation of new technology and input factors such as stock of knowledge, research effort and institutional factors such as competition and intellectual property rights.

It is shown that variations in generation of new technology reflect differences in knowledge stock, research effort, product market competition and other institutional factors of OECD countries. The available stock of knowledge and the research effort was shown to have a linear and positive effect on technology generation. It was also shown that the degree of product market competition has a nonlinear effect on technology growth, thereby confirming on a country-level an inverted-U relationship between competition and innovation.

Generation of new knowledge was examined using a knowledge production function with annual and accumulated knowledge measured with a patent indicator based on a worldwide count of patent priority filings. A cross-sectional linear regression model was used with secondary data. Independent variables included were the main variables accumulated stock of patent priority filings, the number of FTE researchers in R&D and the Product Market Regulation Index. Institutional bias was accounted for by including the independent variables Index of Patent Rights, administrative patenting fees and a Global Competitiveness Index. The Global Competitiveness index was found to have positive effect on patent productivity and the administrative patenting fees relationship was found to be negative. The results are consistent with theories and empirical findings. The results also highlight the importance of innovation policies that keep costs of patenting low and of adjusting the competition policy of a country to the type of economy in question.

Keywords

Technology accumulation, knowledge production function, patent count, product market competition, knowledge stock

CONTENT S

1. INTRODUCTION

1.1 Background to the Study

The exponential growth in standard of living during the last centuries has in large part been due to an accompanying exponential growth in technology. Technological improvements in new and better products and production processes have made it possible to achieve a higher output with given resources and has helped in providing for a growing population while at the same time achieving rising living standards. But it is important that technological progress don't halt here. We need to continue to develop new and more efficient ways of supplying our needs to ensure a reasonable standard of living for the entire population without depletion of natural resources and with less environmental effects than today. From the view of our society, it is important to understand what factors promote and support innovation, both in the advanced and the developing economies.

Technological change, taking the form of invention, innovation or diffusion of knowledge is one key input in the production function which describes the economic output. The technology factor has however been described differently in economic theories. Neoclassical theory has been focusing on the short run and maximization of rents and allocation efficiency, and sees technology as constant and given exogenously. The Solow Swan exogenous growth model considers technological progress as an exogenously given variable. The longer perspective is studied in endogenous growth theory which tries to explain the factors behind technological growth (Romer 1990).

In order to promote generation of new technology and to develop and maintain appropriate policies, we need to understand the relevant factors behind this generation and how policies can impact on it. For example, more recent studies and theories show that there are ambiguous relationships between technology generation and competition as well as between technology generation and the achieved stock of knowledge. Other factors that may be of importance are of institutional character in the form of intellectual property legislation and competitiveness. Measuring product market competition or the current stock of knowledge are not straightforward processes and there are not that many studies done using country level data on competition (Schiantarelli 2005, 2), or that measures the stock of knowledge as patent counts with low geographic and value bias (de Rassenfosse et al 2013, 731).

Innovation has also been seen as a path-dependent, evolutionary process, where past capabilities and knowledge have a high impact on current performance (Rickard 2006, 482). It therefore makes sense to study how more innovation in advanced and highly innovating economies, like the OECD (Organisation for Economic Co-operation and Development) countries, can be achieved in order to understand how we can innovate and meet our future needs. This thesis contributes to the literature by examine how innovation output is affected by innovation input, competition and institutional factors, starting with the natural logarithm of a knowledge production function and a) examine the usefulness of a worldwide patent count free of geographic and value bias, b) studying the effect of a number of institutional factors on generation of new technology and c) including competition and showing the nonlinear relationship between competition and technology accumulation on a country-level.

1.2 Study Objective

The aim of this thesis is to study the generation of new technology in the OECD countries. The aim is to determine how innovation input, institutional factors and competition affects the generation of technology accumulation. Relevant theories on technology accumulation will be examined and the parameters of a patent production function at the macroeconomic level will be determined. The models used will study if there are any significant relationships between the accumulated knowledge stock, number of researchers in R&D, product market competition, other institutional factors and the generation of technology in OECD countries measured as annual patent priority filings in year 2010.

1.3 Problem Statement

What factors are relevant for the generation of new technology in OECD countries?

1.4 Methodology

This study is based on econometric cross-sectional linear regression analysis to examine how new technology generation measured as knowledge accumulation is affected by the current stock of knowledge, research effort and product market competition and other institutional factors. The dependent variable is the annual patent priority filings for year 2010 of the inventors of a particular country. Independent variables included are accumulated patent priority filing for years 1991 to 2010, the number of researchers in R&D, Product Market

Regulation Index, Index of Patent Rights, administrative patenting fees and the Global Competitiveness Index. Secondary data is used, collected from acknowledged institutes and organizations such as World Economic Forum, UNESCO Institute for Statistics (UIS) and OECD or from literature published in peer-reviewed journals.

Accumulated patent priority filings for years 1991 to 2010 are used in the study, due to data availability but it also has the positive effect that the major time period included take place after important strengthening and harmonization of patent rights were implemented in the 1980s and early 1990s. Japan and South Korea were excluded from the sample due to their relatively high numbers of patent priority filings. Occasionally data is missing for some countries, making the samples smaller. The 34 OECD countries of the sample are presented in Table 1.1 in Appendix 1, together with detailed data on all observations in the sample.

1.5 Scope of the study

This study focus on the OECD countries since the R&D model by Romer (1990) used is developed for advanced R&D driven economies. In these economies are patents supposed to be an important outcome in the process of knowledge accumulation thereby making it possible to proxy generation of new technology with annual patent priority applications, and to proxy knowledge stock with accumulated patent priority applications. Furthermore, by looking at patent applications in a cross-sectional dimension, any difficulties associated with changes in patenting policies, firm size or granting policies by patent authorities over time can be avoided. By looking at patent applications on the aggregate country level, samples will be fairly large thus letting firm-level differences in propensities to patent and innovate even out.

1.6 Thesis Structure

Section 2 presents previous studies relevant to the problem statement. Section 3 presents theoretical background to the regression analysis, starting with endogenous growth theory followed by institutional theory and a model for competition and innovation. The theoretical discussion is followed by a presentation of the patent system and patent count indicators in section 4. In section 5 the hypothesis to be tested and the empirical model are introduced together with a presentation of the dependent and independent variables. Section 5 is finished with a presentation and analysis of results from the regression. Section 6 discusses the findings and concludes.

2. PREVIOUS STUDIES

Griliches (1990) have summarized literature on the use of patent data for measuring the rate of technological change in the review "*Patent Statistics as Economic Indicators: A Survey*". Griliches describes the nature of patent data and major concerns when using them in economic analysis and also reviews the literature up to 1990. The use of patent data, Griliches notes, is not straightforward as the shares of innovations that are patented as well as the innovative and commercial impact of patents differ among industries and also the granting procedure can differ among countries and over time. Nevertheless, patent statistics have proven useful in a number of studies to indicate the innovation performance, or the output of inventive activity. One, at the time, interesting conclusion in this survey is the tendency for patent statistics to be less useful in time- series compared to cross-sectional studies. In cross-sectional studies, a strong relationship between patent numbers and R&D costs and investments was found across firms and industries with a median R-square of 0.9, whereas the correlation in time-series was weaker with a median R-square of 0.3. Another conclusion is on the returns to R&D which was found to be not at all constant but varying with firm size, small firms having substantially higher patents per million R&D dollar rates than larger firms. These differences can be attributed to different firm structures and incentives to patent among small and large firms. This now classical review by Griliches points out the possibilities when using patent statistics in the knowledge production function. It also highlights the advantages of doing cross-sectional studies on the country-level, compared to time-series and industry-level studies.

Zachariadis (2003) is using patent data in a three equation model of R&D induced growth in a test of the Schumpeterian endogenous growth model in the work titled "*R&D, innovation, and technological progress: a test of the Schumpeterian framework without scale effects.*" In summary Zachariadas shows that R&D has a positive correlation with innovation, technological progress and economic growth. This is done by using the rate of patenting as a proxy for rate of innovation and R&D expenditures as a measure of R&D intensity. Data from a panel of US manufacturing industries are used. The validity of R&D based growth models is examined by first showing that R&D intensity has a positive correlation with the rate of "innovations output", measured by the rate of patenting. Then the patenting rate is shown to have a positive impact on technological progress, or productivity growth. The productivity growth in turn is shown to have a positive correlation with the per capita output growth. This paper complements the work of Crépon et al (1998) discussed in section 3.1, with a study of these relations at a more aggregate level over a longer time dimension. The work of Zachariadis is important in the context of this thesis, since it shows empirically a connection between patenting rate and technological change and also between patenting rate and economic growth.

The paper of de Rassenfosse and van Pottelsberghe (2009), "*A policy insight into the R&D - patent relationship"*, is a cross-country study showing that variations in the number of patents per researcher reflects differences in propensity to patent and differences in research productivity, contrary to a widespread position among scholars of the subject:

> "*Please raise your hand if you think that patent counts reflect innovation performance*". When the 'provocateur' of the EUPACO conference held in Brussels in May 2007 asked the question, no one raised his hand. Among the audience were respected scholars, senior managers from large and small innovative companies and representatives from the European Commission and national patent offices. Except for a few silent voices, there seemed to be a consensus position that patents are not an indicator of research productivity, or that the number of patents per R&D expenditure would not indicate differences in innovation performances.
> (de Rassenfosse and van Pottelsberghe 2009, 779)

De Rassenfosse and van Pottelsberge show that there is a positive and significant relationship between the strength of the patent law of the country and the patent production, and also a negative and significant relationship between the administrative fees of patenting and the number of patent filings produced. It is also demonstrated that different patent count indicators (explained in section 4.2) should be used depending on if the purpose of the study is to get an understanding of innovative performance (a value-indicating count should be used), or if the purpose is to assess the propensity to patent as depending of policy and institutional factors (a global patent count should be used). A model similar to Romer (1990) and Jones (2005) models is used by de Rassenfosse and van Pottelsberge, with the exceptions that the productivity of researchers is allowed to vary but the available stock of knowledge is kept constant and supposed to not impact the knowledge produced. As will be shown below the model used in this paper approximates an average productivity of researchers and the stock of knowledge is assumed to have an impact on the knowledge produced. It is assumed in this study that the relationship between the available stock of knowledge and the knowledge produced is positive but could be negative, the latter effect resulting from an increasing difficulty in producing new ideas and technology once a certain level already have been discovered.

Another paper of major importance for the theory of this thesis is "*Competition and innovation: An inverted-U relationship*" by Aghion el at (2005). This work shows a nonlinear inverted-U shaped relation between competition and patents. Schumpeter pointed out that imperfect competition was necessary for innovation (1983 {1934}) and it was hinted by Scherer (1967) that the relationship could be an inverted-U. According to the work by Aghion et al however, it seems to be the first model that predicts the inverted-U shape relationship. Aghion et al were able to show that industries characterized by a productivity leading innovating frontier sector dominated when there were low levels of competition, and that higher competition increased innovation. Above a certain level of competition however, there are close competitors and innovating industries can't escape competition by innovating because the competitors can achieve the same productivity. In this latter case, increasing competition will discourage innovation. This thesis includes competition in the knowledge production function and aims at showing the non-linear relationship between competition and innovation on a country-level.

3. THEORETICAL DISCUSSION

3.1 The role of ideas in endogenous growth models

The Cobb-Douglas production function expresses output (Y) as a function of capital (K), technology (A) and labor (L):

$$Y = K^{\alpha}(AL)^{1-\alpha} \qquad \text{(I)}$$

where α is a parameter between 0 and 1. New ideas and more knowledge generate a higher level of technology and make it possible to produce a higher level of output with constant input levels of capital and labor. The production function (Equation I) exhibits constant returns to scale when holding the level of technology constant and increasing returns to scale when increasing A.

In this paper a model based on the knowledge production function of the technology-driven growth model developed by Romer (1990) is used. Equation (IIA) describes how technological progress develops as new knowledge and ideas are accumulated endogenously:

$$\dot{A} = \delta \times L_R^{\Lambda} \times A^{\eta} \qquad \text{(IIA)}$$

Λ, η and δ are constants. $\dot{A}$ is the accumulation of knowledge and L_R is the number of people attempting to discover new ideas (R&D employees). The degree of knowledge spillover is measured by η and the productivity of researchers is measured by Λ.

If $\eta > 0$, it indicates that research productivity, $\dot{A}$, is increasing with given stock of knowledge, A. The case when $\eta > 0$ represents knowledge spillover or the "standing on shoulders effect". On the other hand, if $\eta < 0$, research productivity $\dot{A}$ decreases with the stock of knowledge – generating new ideas and knowledge is becoming increasingly difficult as the stock of knowledge increases. When $\eta = 0$ the productivity is independent of the stock of knowledge. The knowledge spillover is a positive externality. Another, negative, externality can be expressed as duplication of ideas and research effort when $\Lambda < 1$. It is ruled out that $\eta = 1$ or $\eta > 1$. If $\eta \geq 1$, productivity of researchers would grow over time and also generate accelerating growth, something which is contradicted by empirical findings.

The knowledge accumulation function becomes:

$$\dot{A}(t) = C \times A^{\eta}(t) \times L_R^{\Lambda}(t), \qquad \text{(IIB)}$$

where A is the stock of knowledge and $\dot{A}$ the accumulation of new technology or knowledge. In R&D driven economic growth, which is the topic for discussion here, it is anticipated that new ideas and knowledge results in patents. The stock of knowledge is therefore often measured as the accumulated patents and $\dot{A}$ can be measured as annual generation of patents. $L_R(t)$ is the number of employees in R&D and C is a constant (Jones 2002, 96-106).

The links between innovation input/research investment, productivity and economic growth are not obvious and have been the subject of studies on more detailed level using panel data and a set of equations that looks at each step in the chain separately. The work of Crépon et al (1998) gave name to the CDM model which considers the fact that productivity is determined by innovation output, not by innovation input (the latter often measured by research investment). The CDM model explains productivity with three relations that are examined separately; innovation input determines the innovation output, innovation output determines productivity and productivity determines economic growth. Performing a three equation model study with micro level panel data is however outside the scope of this thesis. The model used in this study examines the relationship between innovation input and innovation output on the country level, and how competition and institutions impact that relation.

Because ideas are non-rival anyone who knows about its existence can use it. Assuming there is a fixed cost involved in realizing the idea, it is essential that ideas can be protected from free usage by others if an inventor or idea generator wants to make a profit of it. Once fixed costs are paid the good is produced with a decreasing average total cost, which is the same as having increasing returns to scale. In a market characterized by non-rival ideas and increasing returns to scale, imperfect competition becomes necessary to make ideas excludable and to make it possible to charge prices above marginal cost. Ideas and inventions are made excludable by intellectual property rights (patents, copyright and design protection), by keeping trade secrets or by being first mover in the market. In the endogenous growth model, innovation is driven by temporary monopoly profits, and innovation in turn increases the growth of output by higher level of technology. The growth in output and in increased utility is made possible by imperfect competition in endogenous theory, whereas in neoclassical theory perfect competition is what produces maximum output and utility for the members of the society. The impact of the level of competition on innovation is discussed further in section 3.3.

3.2 Institutional economic theory

In an economic context, institutions are the rules or mechanisms that determine how people behave as economic individuals. Formal institutions in the form of legislation, contracts, the state or property rights as well as informal institutions such as norms and conventions determines our behavior and set rules for what is allowed and what is not. The two most important roles of institutions in an economic system is to lower transactions cost associated with performing economic transactions and to define property rights in order to give incentives for performing activities such as entrepreneurship and innovation.

3.2.1 Institutional Economics and New Institutional Economics

During the nineteenth century in Germany and in the early twentieth century in the US thoughts were developed regarding the economic reality as being more complicated than in the classical theory presentation. In classical and neoclassical theory the role of institutions and economic history is absent and the outcome of the economic market is explained by the selfish actions of many perfectly informed individual actors. The German Schools and the American Institutionalism criticized the classical view and preferred to explain economic behavior such as incentives or tastes as a result of the political and social context, and also emphasized the role of social policy (Sandelin et al 2008, 100-119).

In the early twentieth century, Institutional Economics lost popularity in favor of neoclassical theory. New Institutional Economics has however become important after the mid-twentieth century, with a theory that combines the neoclassical theory with institutional theory. Neoclassical theory fails to explain the economic reality according to institutional theory, because information is incomplete, the reality is dynamic and the market, the object of study in neoclassical theory, is only one part of an entire economy. New institutional economics emphasizes property rights and transaction costs as important institutions which give background to the acting and incentives of individuals and organizations (North 1993).

3.2.2 Transaction Costs and Property Rights

Organizations if the form of firms was first investigated by Coase (1937). The internal organization of firms was the target of his work in which he concludes that firms are founded to lower transaction costs by replacing market transactions and lower insecurity related to transactions. The work of Coase was further developed by Williamsson (1985) into “the

Governance approach to the firm". The lack of perfect information impacts on how firms organize in order to minimize transaction costs and ensure enforceable contracts (Alchian and Woodward 1988). Of central importance to lower uncertainty and transaction costs are well defined and enforceable property rights, an institution which in a capitalism economy also determines the willingness to invest and innovate and therefore affects economic growth (Demsetz 1967). Property rights can thus explain achievement of economic growth or its failure. Property rights have evolved as societies have evolved, as the result of an evolutionary process that strives towards social economic efficiency. Better defined property rights can also accommodate externalities associated with harmful or beneficial effects that arise for example as a result of new technology or changes in market values (Demsetz 1967), as summarized in the Coase theorem (Coase 1960).

In R&D driven innovation, incentives and profits are determined by intellectual property rights. The concept of intellectual property rights such as a patent is better understood if compared to (physical) property rights as defined by Alchian and Demsetz (1973). They state that having property rights to a resource (e.g. a piece of land) defines the rights to use the resource and exclude others from using it, but it is not the resource itself that is owned. The same distinction is made by Coase (1960). Patents are property rights which protect ideas, they give the owner the right to prevent others from e.g. making or selling the product that is protected by the patent.

In this thesis, the independent variables of the regression model are all related to institutional factors, directly or indirectly. The accumulated knowledge and research effort are related to incentives to innovate (created by appropriate institutions). The index of patent rights is a measure of the strength of intellectual property rights, and patenting fees is related to the transaction costs involved in obtaining those rights. The Competitiveness and Products Market Regulation indexes are related to productivity and competition levels of the countries and are thus the outcome of several institutional factors such as various legislation and educational system.

3.3 Ideas and Competition

Not only can the stock of knowledge have different effect on research productivity. As discussed in section 3.1, can imperfect competition be seen as necessary for increased generation of new technology and output. A model developed by Aghion and Howitt (1998) takes on the arguments by Schumpeter (1983 {1934}) and discusses the influence of competition on the production of new knowledge and ideas. Schumpeter's theory was that new and better goods and processes push out current ones in what he referred to as a process of "creative destruction". In growth theory based on quality improvements, Schumpeter's theory is formalized into a model of endogenous growth (Aghion et al 2001).

Technological progress, x, can be modelled as a function of innovative activities;

$$x = \lambda\sigma q \qquad \text{(IIIA)}$$

where λ = probability that each unit of R&D spending yields a successful innovation, σ = the extent to which each innovation raises the productivity parameter. The R&D intensity, q, is a function of the discounted value of the expected return and depends on economic determinants such as λ, σ, the real interest rate, the level of competition, capital per efficiency unit and protection of intellectual property rights.

In a simplified version of the Aghion & Howitt model, final goods are produced with intermediate goods only (no labor). Innovation raises A to γA where $\gamma > 1$; $A_{n+1} = \gamma A_n$. The incremental size of innovation is determined by (γ-1) and the equation for technological progress, x, becomes:

$$x = \lambda(\gamma-1)q \qquad \text{(IIIB)}$$

An assumption is made that there is perfect competition in the final goods market, but in the intermediate goods market there are transient monopoly profits before imitation catches up. A non-innovating producer in the intermediate goods sector has a higher production cost, χ, than the innovating firm. The extra profit the innovator can make becomes:

$$\pi = (\chi - 1) \times cost\ of\ production \qquad \text{(IV)}$$

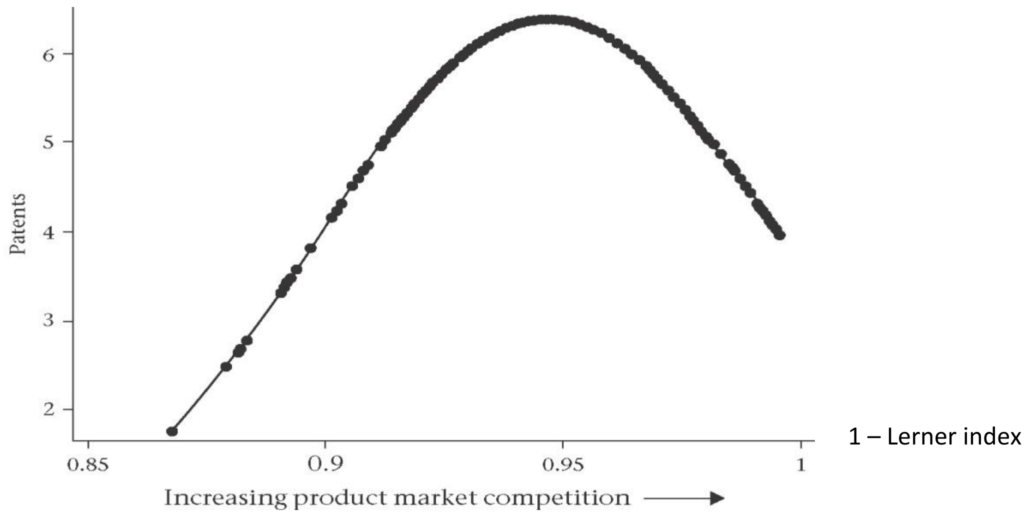
3.3.1 The inverted U – a model by Aghion & Howitt

The Aghion and Howitt model (1998) explains how competition is good for innovation and how too much competition can dampen innovation. The model assumes that in each industry there is a sector at the technology frontier and sectors one and two steps behind the frontier Aghion et al (2005). Focus is on the frontier and one-step behind sectors. In each of the different sectors there are also two groups; the innovating leaders and the competitors (referred to as the leading edge and competitive fringe respectively by Aghion and Howitt (1998)).

In the one step behind sector, the competitors can catch up with any quality improvements (higher γ) that the innovating leaders come up with, they are close competitors. The leaders can still produce at lower costs and get a higher profit (determined by χ-1) than the close competitors. In the frontier sector on the other hand, the competitors can’t keep up with innovation, they are slow competitors. The leaders have a higher productivity, γ, as a result of innovation as well as a cost advantage.

The model is summarized in the Figure 3.1 below, with empirical findings of the relationship between competition and innovation for UK-firms as illustrated in the work of Aghion et al (2005). The figure illustrates that the structure of industries differs at different levels of competition, and how that difference in structure impact on the relationship between competition and innovation. There are different types of industry sectors dominating on different sides of the “peak” in the competition versus innovation curve. In the one step behind sector increased profit opportunities are associated with more innovation when competition lessens - the Schumpeter effect dominates. But in the frontier sector, the leaders experience different productivity than their competitors. When profits decrease because of more competition, a higher productivity from increased quality of intermediate goods, higher γ, becomes more important and forces the innovating firms to innovate more - the escape competition effect dominates.

From the model presented above, it is evident that competition presumable has an effect on the ideas and knowledge production, as well as the available stock of knowledge. Also, there are not that many studies of the relationship between research productivity expressed as annual generation of patents and competition on country levels (Schiantarelli 2005, 2). In this work, the OECD Product Market Regulation Index (OECD 2012) is used as a proxy for competition to study the relationship between annual generation of patents and competition in a cross-country study of the OECD members.



Frontier sector	**One step behind sector**
More competition increases innovation and economic growth. Escape competition effect dominates. (χ-1) and γ are higher for the leaders than for the slow competitors. When competition increases, profit (χ-1) decrease and γ becomes more important and therefore innovation increases.	More competition dampens innovation and economic growth. Schumpeter effect dominates. (χ-1) is higher for the leader than for the close competitors. The same γ applies for the innovating leader and for the close competitors. When competition increase, profit (χ-1) decreases, leading to decreased innovation.

Figure 3.1. The relationship between innovation and competition for UK firms (Aghion et al 2005) and a summary of the model of product market competition and growth, where profit is determined by (χ-1) and γ stands for productivity.

4. PATENTS AS TECHNOLOGY INDICATOR

Descriptions of patent law and the patenting system can be found in numerous sources, among others the homepages of patent authorities. A convenient source in this context is the OECD Patent Statistics Manual (OECD 2009), part of which is briefly summarized in section 4.1 below.

4.1 Short overview of the patent system

Patents are temporary and territorial property rights which confer on its owner the exclusive right to prevent third parties from making, using, offering for sale, selling or importing the product or the product of a certain process that is protected by the patent. The role of patents in the economy have increased, starting in the early 1980s with strengthening of patent holders rights and growing impact of technological products in the market, and increased further during the 1990s and 2000s when more harmonized patent rights among more countries were introduced 1994 as a result of the TRIPS (Trade-related Intellectual Property Rights) agreement.

The first application filed for an invention is referred to as the *priority application* and the priority date is the date closest to the date of invention. Once the patent application is filed it is normally published after 18 months and if requirements are fulfilled, it is granted after two up to eight years. There are basically three alternative routes for a patent applicant to choose among; national, international or regional routes, as explained below, which among other things makes using patent statistics complicated.

National route – An inventor files an application to the national office (of the inventor). The office initiates the search and examination process which leads to a grant or refusal after a time of two up to eight years. The patent application is published after 18 months, from now the application is public.

International route – If the patent applicant wants to protect the invention in other countries under the Paris Convention, he can file an application in which he can use the priority date of the first national application, if the international application is filed within 12 months from that date. The applicant can also choose to file an international application under the PCT (Patent Cooperation Treaty) directly in which procedure the national states are designated first and the national applications are fully completed in a later stage. The international PCT application is relatively cheap and the priority period is as long as 30 months, facilitating the applicant's investigation on the potential market value of the invention before going into the more costly national phases. The patent application is published after up to 31 months. *Regional route* – There are also regional patent authorities such as the EPO (European Patent Office) that works in a manner similar to PCT but the search and examination is for a certain region (OECD 2009, 17-24).

The formal requirements to get a granted patent are that the invention is a patentable subject matter (in essence a product or process resulting in a product), is novel (not described elsewhere in the public domain) and is inventive (contains an inventive step or is non-obvious to a person skilled in the art). The formal requirements is one of the direct reasons why patents are found to reflect inventive output and company performance in R&D related activities and technology driven innovation. Another reason is the financial assets needed to get and maintain a patent, from filing to grant and maintenance fees (de Rassenfosse and van Pottelsberghe 2009).

4.2 Patent statistics as indicator of inventive activity

Patent data are a huge amount of public available information that is collected by the patent authorities for legal or administrative purposes. It contains, besides the technological description of the invention and its classification, a waist array of information including names and affiliation of owner and inventors, dates for priority filings and application and grant dates. Patents also have the advantage of covering broad ranges of technologies, the data covers a unique array in time and geography, data is readily available for free and there is patent statistics already compiled by patent authorities and international organizations (OECD 2009, 29-30).

There is however a number of drawbacks with using patents as indicators of technological change, which should not be taken lightly. Not all ideas are of a technological, patentable, nature and all ideas are not patented but kept as trade secrets. Also, there is no direct relationship between a certain number of patent counts, the size of a patent portfolio, and its value. This circumstance can be circumvented by using citation weighted counts or by using a triadic patent count indicator when patents of a certain value and international performance comparisons are the target of study (OECD 2009, 59-76).

Comparing patent counts across countries is difficult due to different patent law and practices. (For example, in Japan and Korea there is a relatively low limit on the number of patent claims allowed in a patent application, which leads to more applications being filed and relatively high patent counts.) To avoid the institutional bias, patents filed at a large national or at a regional office can be counted. A strong geographic country bias is introduced however, since the propensity to patent at your own patent authority is much larger than the propensity to patent in another country and therefore national applicants dominate over applicants from other countries. Over time there are also changes in patent laws, which make it difficult to do time-series analysis. There are different propensities to patent among industries, making it necessary to study relatively large samples or to introduce industry dummies in the regression model (de Rassenfosse and van Pottelsberghe 2009).

4.2.1 Worldwide count of patent priority filings

The worldwide count of patent priority filings has been used in some relatively recent studies (de Rassenfosse et al 2013, 731). The indicator counts the patent priority applications filed at as many as 52 patent authorities, including national and regional (EPO) and international PCTs filed at WIPO (World Intellectual Property Organization). The country of the inventor is the information that is collected, making it an appropriate indicator for assessing the inventive performance of countries. This is the most complete patent count and is particularly useful for small countries, new technologies and emerging economies. The geographic bias is eliminated, but at the cost of an institutional bias originating from the different laws and procedures of patent authorities. The country of the inventor has to be collected from the PATSTAT (Worldwide Statistical Patent Database) database by an iterative algorithm which has been developed by the group of de Rassenfosse and van Pottelsberghe (de Rassenfosse et al 2013). The Worldwide count of patent priority filings (WWC) is used in the regression presented in this work (Section 5).

5. EMPIRICAL ANALYSIS

5.1 Regression model

Taking the natural logarithm of the knowledge production function (IIB) gives:

$$ln\dot{A} = lnC + \eta lnA + \Lambda lnL_R \quad \text{(V)}$$

Including competition and control variables gives the regression model to be estimated empirically:

$$ln\dot{A} = \alpha + \beta_1 lnA + \beta_2 lnL_R + \beta_3 IPI + \beta_4 lnFEES + \beta_5 GCI + \beta_6 PMR + \beta_7 PMR^2 + \varepsilon \quad \text{(VI)}$$

Explanation of variables

$\dot{A}$ = annual generation of patent priority filings.

α = intercept

β_n = correlation coefficient

A = accumulated patent priority filings.

L_R = the number of employees in R&D.

IPI = index of patent rights

FEES = administrative patenting fees

GCI = competitiveness index

PMR = product market regulation index

$(PMR)^2$ = product market regulation index squared

ε = error term

The work presented in this thesis center around two main set of hypotheses:

Hypothesis A

H_1^A: "The available stock of knowledge and the research effort have a linear effect on generation of new technology through a patent productivity effect." The null-hypothesis to be rejected is:

H_0^A: $\beta_1 = \beta_2 = 0$

Models 1 to 6 are used to investigate Hypothesis A.

Hypothesis B

H_1^B: "The degree of product market competition has a nonlinear effect on generation of new technology through a patent productivity effect." The null-hypothesis to be rejected is:

H_0^B: $\beta_6 = \beta_7 = 0$

Models 7 to 10 are used to investigate Hypothesis B.

For the individual coefficients, the hypothesis that there is a relationship between the variable in question and the patent productivity is not rejected if the coefficient is found significant at the 10 % level or less.

Table 5.1 Regression variables, data sources and expected outcome

Variable	Description	Source	Expected Outcome
$\dot{A}$	Annual generation of patent priority filings	University of Melbourne 2014	Dependent variable
A	Accumulated patent priority filings	University of Melbourne 2014	+
L_R	The number of full time equivalent (FTE) researchers in R&D	UIS 2014[a]	+
IPI	Index of patent rights	Park 2008	+
FEES	Administrative patenting fees in 2003 US PPPs[b]	de Rassenfosse and van Pottelsberghe (2007, 2009)	-
GCI	Global Competitiveness Index	World Economic Forum 2010	+
PMR	Product Market Regulation Index	OECD 2012	+
PMR^2	Product Market Regulation Index squared	OECD 2012	-

[a]Data is from year 2010, when available, otherwise closest available data. [b]Purchasing power parity.

5.2 Data and specification for chosen variables

Annual generation of patent priority filings

The dependent variable is annual patent priority filings, $\dot{A}$, for year 2010, by the inventors of a particular country. The “worldwide count” of priority patent has been developed recently by de Rassenfosse et al (2013) and values are also obtained from the homepage of de Rassenfosse (University of Melbourne 2014). The worldwide patent count indicator is discussed in more detail in section 4.2.1 The year of interest is 2010, allowing for a time lag before publication of patent applications but also due to data availability. When using patents as the dependent variable, it is assumed to be a proxy for the generation of new knowledge and to be dependent of the available stock of knowledge and the research effort as expressed in equation (IIB) and in Romer's R&D model (Romer 1990).

Accumulated patent priority filings.

The accumulated knowledge in equations V and VI is measured as the accumulated stock of patent priority filings, A. Data are obtained by summing the annual worldwide counts of patent priority filings for years 1991 to 2010. Data are obtained from the homepage of de Rassenfosse (University of Melbourne 2014) and from de Rassenfosse et al (2013). The expected outcome of the lnA coefficient is positive. According to endogenous growth theory (Romer 1990), the available stock of knowledge is an input factor is the knowledge production function (equation IIB) and has a positive impact on generation of new ideas.

The number of employees in R&D

The research effort is included to test the hypothesis of the endogenous growth model that more research effort, or more labor in the R&D sector, will have a positive impact on the generation of knowledge, $\dot{A}$ (Romer 1990). The expected outcome is therefore a positive coefficient. The research effort is measured in full-time equivalent scientists and engineers, L_R. Data are taken from the UNESCO Institute for Statistics (UIS, 2014) for year 2010. In doing so, no time delay between R&D effort and patent filing is accounted for, this assumption is based on the findings that the L_R variable is found to be relatively stable over time (de Rassenfosse and van Pottelsberghe 2009, 783).

Product Market Regulation Index

According to theories by Schumpeter (1983 {1934}) and empirical studies at firm-level by Aghion et al (2005), the level of competition experienced by firms affects their production of knowledge in the form of new ideas and patents. According to Aghion the relationship between competition and patents produced is nonlinear in the form of an inverted U. The level of competition is measured by the OECD Product Market Regulation Index, PMR, which ranges from scale 0-6, from least to most restrictive competition policies in areas of the product market (from most competition friendly to least competition friendly). Data are obtained from OECD statistical database (OECD 2012). Expected sign of the coefficient for PMR is positive and negative for $(PMR)^2$, when accounting for an inverted-U shaped nonlinear relationship.

Index of patent rights

The strength of the patent system is an institutional aspect that indicates the strength of the protection of intellectual property rights. Strong intellectual property rights can be expected to have a positive impact on innovation, and economic growth, since the ability to obtain and enforce patent rights is in essence what makes ideas excludable and profitable (Jones 2002, 96-106). Empirically, the strength of a country's patent system have been found to have a positive impact on its innovation when studying factors influencing the propensity to patent (de Rassenfosse and van Pottelsberghe 2009, 785). An index of the strength of patent rights ranging from 0 to 5 has been used in this study, with 5 representing the highest level of protection. The IPI index has been developed by Ginarte and Park (1997) and values for year 2005 are used in this study (Park 2008, 762-763).

Administrative patenting fees

The administrative fees that have to be paid to patent authorities to obtain a patent have been found to have a negative and significant impact on the number of patent applications filed in earlier studies on the "price elasticity of patents" done by de Rassenfosse and van Pottelsberghe (2009, 786 and 2007). The variable FEES consist of the administrative fees that have to be paid up until grant of the patent; patent application filing, search, examination and granting fees. The variable is expressed in 2003 US PPPs, in Table 1.1. Data are obtained from the studies by de Rassenfosse and van Pottelsberghe (2009, 784, 790 and 2007, 762-763).

Competitiveness

The Global Competitiveness Index, or GCI, has been used as a proxy to measure competitiveness of a country. The Global Competitiveness measures the impact of factors such as institutions, financial system, market efficiency and other factors that determine the level of productivity of a country (World Economic Forum 2010, 3-15), making it a convenient control variable in this study since the method of worldwide count of patent priority filings introduces an institutional bias when patent counts of nations with different intellectual property laws are compared (de Rassenfosse et al, 2013).
The index is reported on a 1 to 7 scale, with 7 representing the highest level of competitiveness, we thus expect a positive sign on the coefficient (World Economic Forum 2010).

5.3 Regression analysis

Descriptive statistics for the sample are presented in Table 5.2 and a correlation matrix is found in Appendix 2 (Table 5.3). Japan and South Korea were excluded from the sample due to their relatively high numbers of patent priority filings. Also the Netherlands was excluded in models 7B to 10 due to the low value of the PMR index, making the sample composed of 31 to 32 countries. Detailed data on samples is presented in Appendix 1 (Table 1.1). Occasionally data is missing for some countries, making the samples smaller.

Table 5.2 Descriptive Statistics[a]

Variable	Mean	Median	Maximum	Minimum	Std. Dev.
$\dot{A}$ (patent priority filings)	5390.74	1459.53	52389.1	14.2858	11654.4
A (patent priority filings)	104444.	21175.6	1.20871e+006	383.810	246506.
L_R (FTE researchers)	100730.	39872.5	1.19828e+006	2258.00	214916.
FEES (in 2003 US PPPs)	771.500	624.500	2373.00	165.000	548.707
GCI	4.85844	4.91500	5.63000	3.99000	0.456375
IPI	4.36800	4.33000	4.88000	3.51000	0.297790
PMR	1.50197	1.48353	2.23793	0.961971	0.281715
$(PMR)^2$	2.33244	2.20088	5.00832	0.925389	0.929438
ln $\dot{A}$	7.10614	7.28490	10.8665	2.65927	1.87582
ln A	9.90098	9.96013	14.0051	5.95015	1.90078
ln L_R	10.5503	10.5927	13.9964	7.72223	1.38625
ln FEES	6.43086	6.43675	7.77191	5.10595	0.678032

[a]Japan and South Korea are excluded from the sample.

First, Hypothesis A was investigating by estimating the impact of knowledge stock, research effort and institutional factors on the patent productivity in a first set of regressions; models 1 to 6 which are presented in Table 5.4. In a second step the impact of product market competition was estimated to answer Hypothesis B. The most significant variables from the first set of regressions (models 1 to 6) were selected to be included in the more complex model. Also included was the independent variables for competition, PMR and its quadratic form $(PMR)^2$, thereby allowing for a nonlinear relationship between competition and patent productivity according to the theory presented by Aghion and Howitt (1998). The results of regressions 6 to 10 are presented in Table 5.5.

Table 5.4 Cross-sectional regression – knowledge stock and research effort

Model: Dep. Variable ln $\dot{A}$	(1)[a]	(2)[a]	(3)[a]	(4)[a]	(5)[a]	(6)[a]
Constant	-3.54***	-4.04***	-9.00***	-8.34***	-2.74***	-6.19***
ln A	0.75***				0.83***	
ln L_R	0.32***	1.26***	1.19***	1.20***	0.24*	1.19***
ln FEES	-0.02	-0.33*			0.02	-0.35**
IPI			0.82			
GCI				0.57**	-0.21	0.62**
R^2 adj	0.9708	0.8721	0.8674	0.8784	0.9717	0.8928
F-statistic	322.13	99.92	95.89	112.94	248.18	81.54
P-value	1.13e-20	3.32e-13	5.41e-13	2.05e-14	9.50e-20	2.37e-13
Observations	30	30	30	32	30	30

[a]Data exkl JP, KR.
***level of significance at 1%, **level of significance at 5%, *level of significance at 10%

Table 5.5 Cross-sectional regression – knowledge stock, research effort and competition.

Model: Dep. Variable ln $\dot{A}$	(7A)[a]	(7B)[b]	(8)[b]	(9)[b]	(10)[b]
Constant	-4.58***	-6.45***	-5.18***	-6.15***	-5.56***
ln A	0.92***	0.93***	0.91***	0.94***	0.88***
ln L_R	0.13	0.13	0.17**	0.12	0.19**
PMR	1.26	3.27*	2.41	3.28*	2.26
$(PMR)^2$	-0.29	-0.86*	-0.56	-0.87*	-0.48
ln FEES			-0.13*		-0.16*
GCI				-0.05	0.14
R^2 adj	0.9859	0.9874	0.9886	0.9870	0.9887
F-statistic	473.52	511.44	417.75	395.44	349.34
P-value	1.00e-21	2.35e-21	9.77e-19	5.03e-20	1.27e-17
Observations	28	27	25	27	25

[a]Data exkl JP, KR. [b]Data exkl JP, KR and NL.
***level of significance at 1%, **level of significance at 5%, *level of significance at 10%

In most models, the accumulated patent priority filings and the number of fulltime equivalent researchers in R&D have a positive and significant impact on the dependent variable, annual generation of patent priority filings, which supports the knowledge production function (Equation IIA) expressed by Romer (1990). The estimated coefficient for A is in the range 0.75 - 0.94 which correspond to a η well above zero in the knowledge production function (Equations IIA and IIB). A value of $\eta > 0$ signals that $\dot{A}$ is increasing with given stock of knowledge, A, and that we can observe a substantial "standing on the shoulders" or knowledge spillover effect on the average country level in OECD countries included in the analysis. The coefficient determined for number of fulltime equivalent researchers in R&D, L_R, is between 0.12 and 0.32 when both knowledge stock and research effort are included in the model. A level below one corresponds to $\Lambda < 1$ in the knowledge production function (Equations IIA and IIB) which indicates that there is an amount of duplication of ideas in R&D related activities in the OECD economies of the sample and decreasing returns to scale in research effort.

The administrative patenting fees variable was found to have a negative and significant impact in Models 2 and 6 (and also in 8 and 10), which implies that the empirical findings by de Rassenfosse et al (2009) are supported. The fact that the variable was significant in Model 2 and 6 but not in Model 1 or 5 is probably because of the high degree of multicollinearity between A and L_R. The Global Competitiveness Index had a positive and significant impact in models 4 and 6, something that can be expected from the fact that a high level of the competitiveness index mirrors a high level of productivity of a country (World Economic Forum 2010, 4-9). Including A in model 5 changes the sign and removes the significance of GCI, again presumably because of multicollinearity between A and L_R. The coefficient for lnFEES can be interpreted as the price elasticity of demand for patents (de Rassenfosse and van Pottelsberghe 2007). The sign of the coefficient is negative in all models where it is found to be significant which indicates that higher patenting costs leads to less patenting and to less generation of new technology. The IPI coefficient was not significant in any of the models which is inconsistent with other findings (de Rassenfosse and van Pottelsberghe 2009), although it was positive as expected. The lack of significance can be due to a small sample, or to the low diversification in the sample with index values ranging from 3.51 to 4.88 (see also Table 5.2 and Table 1.1 for a complete picture). The coefficient for the GCI index was found to be significant and positive in the study, meaning that on average for these OECD countries, a higher GCI index is associated with a higher annual patent production, when holding all other independent variables constant.

The coefficients for Product market Competition, PMR and $(PMR)^2$, are expected to be positive and negative respectively if there is an inverted-U shape of the relation between competition and patent productivity (Aghion et al 2005). The observed signs of PMR and

$(PMR)^2$ are as expected. When the Netherlands is excluded from the sample due to its low PMR value, there is significance for the PMR and $(PMR)^2$ coefficients (Models 7B and 9). When control variable for administrative patenting fees is included together with competition (and also A and L_R) there is significant and still negative impact of FEES (Model 8). The result when introducing GCI is more ambiguous, with different signs of the coefficients in Models 9 and 10 and no significance. The results from introducing GCI in models 9 and 10 can be explained by that both PMR and GCI, to some extent, measure institutional factors and therefore are correlated (see Figure 5.1 in Appendix 3), or it can also be an impact of other variables being correlated with each other (see discussion regarding A and L_R above). The resulting equation from model 7B with mean values of independent variables accumulated patent priority filings and the number of fulltime equivalent researchers in R&D is plotted in figure 5.2 below. According to the estimated equation ($LnA = 4.10 + 3.27PMR - 0.859PMR^2$), there is a maximum point at PMR = 1.90 determined by the first derivate: $\frac{d\dot{A}}{dPMR} = 3.27 - 1.718\,PMR.$

Illustration of the nonlinear relationship between competition and innovation.

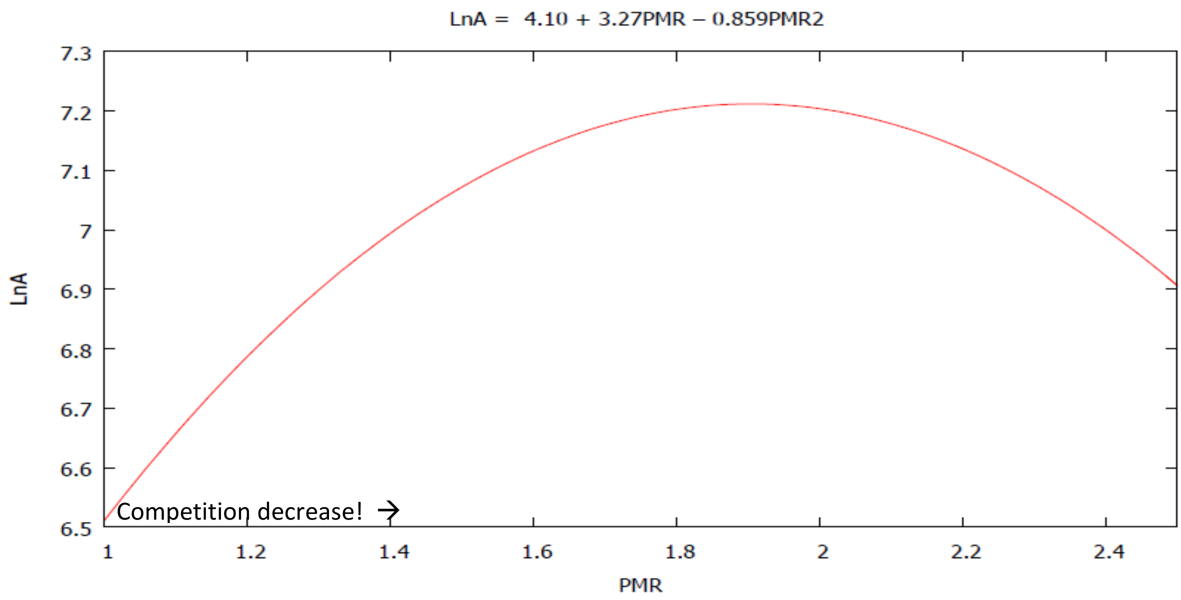


Figure 5.2 Competition and innovation. The estimated regression equation from Model 7B illustrates the relation between competition measured by the PMR Index and innovation measured by annual generation of patent priority filings.

6. CONCLUSIONS

The results of this limited study indicate that both null Hypothesis A and null Hypothesis B can be rejected. In this study with 31 to 32 OECD countries, there is a positive and significant relationship between the accumulated stock of patent priority filings (A), the number of FTE researchers in R&D (L_R) and Global Competitiveness Index (GCI) and the dependent variable annual patent priority filings ($\dot{A}$). There is also a negative and significant relationship between administrative patenting fees (FEES) and the dependent variable annual patent priority filings ($\dot{A}$). It has also been shown that product market competition has a nonlinear and significant relationship with annual patent priority filings ($\dot{A}$). It has thus been shown that competition can have different effect on knowledge accumulation on the country level, depending on the product market competition level in the economy, with escape competition effects dominating for low levels of competition and the Schumpeter effect dominating for higher levels of competition.

Endogenous growth theory explains technological progress as vertical innovation by quality improvements which can be performed both by outside and incumbent producers. Schumpeter (1983 {1934}) pointed out that the process was evolutionary and path dependent and the outcome of the stock of knowledge and capabilities. The model used by de Rassenfosse and van Pottelsberghe (2009) assumes that the stock of knowledge don't have a direct impact on the knowledge produced, possibly it could have the impact that a larger stock of knowledge influences more productive researchers. On the other hand, it could be the other way around if the marginal productivity of research efforts is decreasing with increasing stock of knowledge, making it highly motivated to include a variable for the stock of knowledge in the knowledge production function and in the regression model used in this thesis. As seen in this work, the stock of knowledge seems to have a positive and significant impact on the rate of technological progress since the coefficient for A is between 0,75 and 0,94 which corresponds to $\eta > 0$ in the knowledge production function (equation IIA). It is however evident that it is difficult to study the impact of the stock of knowledge and the research effort on the knowledge production at the same time due to the multicollinearity of the two.

From the nonlinear relationship between PMR and annual patent priority filings, it is evident that there are economies in the sample that are dominated by frontier sector industries but also economies that are dominated by industries in the one-step behind sectors. In the frontier sector economies there are productivity (γ) differences between leaders and the competitors. When competition increase there will be more innovation taking place when the extra profit determined by ($\chi - 1$) decreases - there is a dominating escape competition effect. In countries that have more industries in the one-step behind sector there is no productivity difference between leaders and the competitors. In Equation VI, the negative $(PMR)^2$-term dominates over the positive PMR-term. It seems that for these countries in the sample the main difference between leaders and the competitors is the higher profit ($\chi - 1$) made from innovation. When competition increase, profit will decrease and innovation is discouraged.

As pointed out in Section 3.2.2, the independent variables of the regression model are all related to institutional factors. All of them except the IPI coefficient were shown to be significant which supports institutional theory. The conclusions regarding policies for technology generation and innovation support from this study points first to the importance of keeping costs for obtaining patents low, which includes not only administrative fees paid to patent authorities but also translation cost and costs paid to professional advisers. The other conclusion to be drawn is the importance of the level of product market competition. The appropriate policy has to be designed for each individual type of economy, depending on if its industries are dominated by frontier sectors or one-step behind sectors. In the latter case innovation and growth can be encouraged by protection from competition whereas in the former case more competition is supposed to increase innovation and growth.

Even though a number of significant relationships have been observed in this study, a more robust result could probably be obtained with a larger and more diversified sample. But it might be difficult to extend the regression model used in this thesis to developing countries even though variables to account for institutional differences are introduced in the model, since Romer's R&D model is developed for advanced, R&D driven economies. It would be of interest to extend the regression model to other non-OECD countries and to countries that are small and have fast developing technologies in order to study the patent production function using the "worldwide count of patent priority filings" in a context it has been indicated to be particular useful for (de Rassenfosse et al 2013).

In this study it is assumed that by looking at patent counts at the aggregate country level, firm-level differences in propensities to patent and innovate even out. This is however not true if countries are dominated by industries with very high or low propensity to patent. Other issues to consider in future studies is using other dependent variables such as "innovative sales", generating from sales of innovative products, (Crepon et al 1998) for measuring innovation output instead of patents counts in the study of the relation between competition and generation of new technology and innovation.

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Appendix 1

Table 1.1 OECD Countries included in the sample

Country	Country-code	Observation	'A - Annual generation of patent priority filings year 2010	A - Accumulated patent priority filings 1991-2010	L^R The number of employees in R&D, FTE of researchers year 2010**	IPI - Index of patent rights 2005	FEES - administrative patenting fees	GCI - Global Competitive-ness Index	PMR - OECD Product Market Regulation Indicator	
		OBS	A	AACC	LR	IPI	FEES	GCI	PMR	PMR^2
Australia*[b]	AU	1	1524	20523	92649	4,17	576	5,11	1,43	2,05
Austria	AT	2	2385	35222	36233	4,33	612	5,09	1,35	1,83
Belgium	BE	3	1395	21829	38320	4,67	1069	5,07	1,55	2,40
Canada*	CA	4	4597	90308	149060	4,67	1226	5,3	1,48	2,19
Chile	CL	5	30	515	5440	4,28		4,69	1,71	2,93
Czech Republic	CZ	6	853	11337	29228	4,33	407	4,57	1,50	2,24
Denmark	DK	7	806	14953	37601	4,67	1072	5,32	1,31	1,71
Estonia	EE	8	71	1681	4077		717	4,61	1,38	1,90
Finland	FI	9	2620	50100	41425	4,67	831	5,37	1,34	1,80
France	FR	10	14756	260987	239613	4,67	542	5,13	1,49	2,22
Germany	DE	11	41342	710505	327953	4,5	444	5,39	1,33	1,76
Greece[a]	GR	12	574	8069	24674	4,3	564	3,99	2,19	4,80
Hungary	HU	13	782	19422	21342	4,5	911	4,33	1,40	1,97
Iceland[a]	IS	14	14	384	2258	3,51	694	4,68	1,45	2,10
Ireland	IE	15	408	5735	14175	4,67	575	4,74	1,38	1,91
Israël[a]	IL	16	1723	35673	49797	4,13		4,91	2,24	5,01
Italy	IT	17	10386	187655	103424	4,67	200	4,37	1,49	2,21
Japan*	JP	18	228103	5968882	656032	4,67	1315	5,37	1,54	2,36
Korea (South)*	KR	19	111874	1329397	264118	4,33	1513	4,93	1,88	3,55
Luxembourg	LU	20	94	1735	2636	4,14	293	5,05		
Mexico*	MX	21	917	8767	45045	3,88	1990	4,19		

Country	Country-code	Observation	'A - Annual generation of patent priority filings year 2010	A - Accumulated patent priority filings 1991-2010	L^R The number of employees in R&D, FTE of researchers year 2010**	IPI - Index of patent rights 2005	FEES - administrative patenting fees	GCI - Global Competitive-ness Index	PMR - OECD Product Market Regulation Indicator	
		OBS	A	AACC	LR	IPI	FEES	GCI	PMR	PMR^2
Netherlands	NL	22	2542	45644	53703	4,67	421	5,33	0,96	0,93
New Zealand*[a]	NZ	23	412	7644	16300	4,01	165	4,92	1,22	1,50
Norway*	NO	24	820	22050	26451	4,17	810	5,14	1,50	2,26
Poland	PL	25	2950	46707	64511	4,21	309	4,51		
Portugal	PT	26	284	3378	46256	4,38	637	4,38	1,70	2,91
Slovak Republic	SK	27	220	3332	15183	4,21	436	4,25	1,57	2,47
Slovenia	SI	28	405	4370	7703		174	4,42	1,99	3,96
Spain	ES	29	3259	42818	134653	4,33	762	4,49	1,58	2,48
Sweden	SE	30	2698	47298	49312	4,54	878	5,56	1,64	2,68
Switzerland[b]	CH	31	3086	46101	25142	4,33	1062	5,63	1,55	2,39
Turkey	TR	32	1727	7850	64341	4,01	2097	4,25		
United Kingdom	GB	33	16435	370909	256585	4,54	298	5,25	1,21	1,47
United States*[c]	US	34	52389	1208711	1198280	4,88	2373	5,43	1,11	1,23

FEES are from de Rassenfosse, G., van Pottelsberghe de la Potterie, B., 2007. Per un pugno di dollari:a first look at the price elasticity of patents.

*FEES are from de Rassenfosse, G. and van Pottelsberghe de la Potterie, B. (2009) A policy insight into the R&D–patent relationship.

[a]Data from OECD for year 2011.

[b]Data from OECD for year 2008.

[c]Data from OECD for year 2010.

**Data is from year 2010, when available, othervise closest available data.

Appendix 2

Table 5.3 Correlation Matrix table

Correlation	ln Ȧ	ln A	ln L_R	ln FEES	GCI	IPI	PMR	$(PMR)^2$
ln Ȧ	1							
ln A	0.9837	1						
ln L_R	0.9321	0.9090	1					
ln FEES	0.1338	0.0999	0.2655	1				
GCI	0.4312	0.5027	0.3288	0.1405	1			
IPI	0.6206	0.6470	0.5724	0.0707	0.4345	1		
PMR	-0.2837	-0.3247	-0.2813	-0.1306	-0.4876	-0.3242	1	
$(PMR)^2$	-0.2540	-0.2925	-0.2532	-0.1510	-0.4716	-0.3070	0.9917	1

Appendix 3

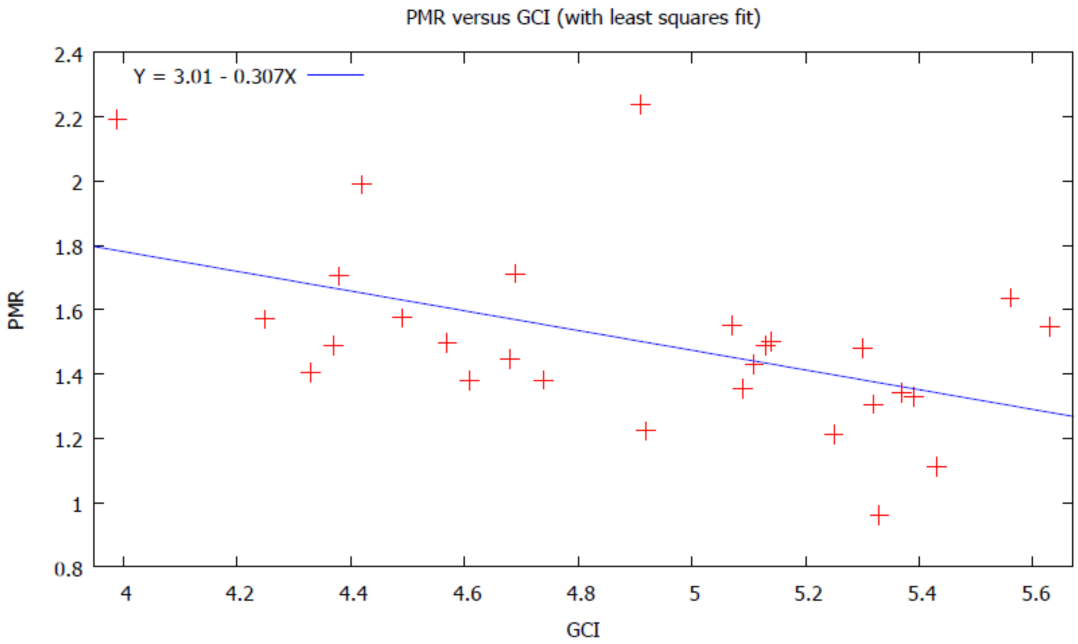

Figure 5.1 Product Market Regulation and Global Competitiveness Index