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The Spillover effect of non-residents applying for patents on residents applying for patents in Europe from 2000 to 2018.

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Abstract

In this thesis the effect of patent applications by non-residents on the number of patent applications by residents is investigated. The potential mechanism that could drive this effect is because of the publicly disclosed information that patents hold. To investigate if there is such an effect panel data from European countries for the time interval 2000-2018 is used. To determine if the number of patent applications by non-residents induce an effect on the number of patent applications by residents, fixed effects analysis on the panel data is performed. The results show that there is a positive and significant effect of the number of patent applications by non-residents on the number of patent applications by residents. However, for further research it might be interesting to research the differences between industries.

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1. Introduction

Patents are an exclusive right to industrially produce, sell or in any other form exploiting an invention. Recently, the Wall Street Journal, wrote an article about the protection of inventions with patents (Foreman, 2021). The history of patent laws is described and the long and rocky road for intellectual property rights. Already in the Middle Ages, Europeans understood the value of knowledge and expertise. Therefore, the governments saw the necessity of protecting these inventions. However, the medieval attempts of protecting this knowledge and expertise were rough. For example, the Italian Republic of Lucca protected its silk trade technology by restricting emigration. Nowadays, the governments have created patent laws that are more advanced. However, the current patent system has one big drawback. When a patent is granted the new techniques that are described become publicly available, which could induce that the costs of patenting an invention becomes bigger than the actual benefits. So other parties could gain advantage of this knowledge for future inventions. Therefore, some inventors make the choice to use secrecy and other methods to secure their knowledge. However, when firms use secrecy instead of patents to protect their knowledge, this might hinder the spillover of knowledge. As explained by Kim and Valentine (2021), patents grant a monopoly for a certain period. To get that monopoly, in return they have to publicly share the information of their invention. These detailed disclosures aim to help stimulate a rise in innovation. Because of the spread of these detailed information that the patent holds. This thesis aims to take into account if this effect is actually present based on the number of patent applications by residents and non-residents.

This disadvantage of patents could be interesting to resolve, because the history shows that there are knowledge spillovers due to patents. Earlier research has found that during the industrialization of Germany in the time period of 1877-1918, technological process was not continuous but came in waves. These waves of technological process had a visible impact on the geographical distribution of high-value patents. There is evidence that during the German industrialization, industries that were related based on technology, economy and geographic location, show inter-industry knowledge spillovers, which were in turn a major source of innovative activities (Streb, Baten, & Yin, 2006). For this reason, it could be interesting to dive deeper into the effects of patent applications and the snowball effect that could be created due to more patent applications. Therefore, the following research question is formulated:

'What is the spillover effect of non-residents applying for patents on residents applying for patents for countries in Europe from 2000 to 2018?'

In this case, the spillover effect could be described as an externality due to the public disclosure of the patent. Because of the publicly available information that a patent contains, a new patent application might have an effect on the number of patent applications by residents. Due to the knowledge a resident could gain through the patent application of a non-resident. For this thesis economic data of different European countries will be compared. The reason for this is because of the versatility of Europe. For example, the countries in the North-west of Europe are mainly developed countries, whereas in other parts of Europe there are also countries that are considered developing countries. The differences between the economic state of the countries could also be an explanation for differences in the number of patent applications. The time interval that is used for this thesis is 2000-2018. The main variables that will be used for this research are resident patent applications and non-resident patent applications.

There are many ways to transfer knowledge between companies, former literature investigated if it is possible for firms to gain knowledge by strategically hiring new workers from foreign firms, which seems to have a positive effect on the domestic workers (Markusen & Trofimenko, 2009). These findings are supported by Oettl and Agrawal (2008), they show that knowledge flows between inventors are not necessarily restricted by organizational boundaries. Finally, there is also empirical evidence that shows the existence of knowledge exchange via labor mobility, and that this exchange is not only present in research-based firms (Parrotta & Pozolli, 2012). These are just some papers that show some sort of spillover which could help firms improve their firm performance. However, these papers mainly focus on the spillover due to strategically hiring employees from other firms. While this thesis will focus on the spillover effect of patent applications by non-residents on the number of patent applications by residents.

A potential mechanism that could drive this effect is that because of the public availability of patents this might be a resource for further innovation, which in turn could lead to more patent applications by residents. However, on the other hand this could lead to firms that will spend less money on their R&D department, because the costs do not outweigh the benefits. Because of this downside of patents a lot of firms choose to use secrecy instead of patents. However, the findings of this paper could help to examine if it could be beneficial for a country to make those patents more attractive, by improving the surplus between the benefits and the costs of those patents, as it could have a positive influence on the level of innovation in a country. Because, the number of patent applications could be used as a proxy for innovation, so if the findings of this paper shows a positive relationship between the number of patent applications by residents and the number of patent applications by non-residents it could be interesting to revise current patent laws to attract more foreign inventors.

The academic relevance of this thesis is that it will focus on the spillover effects of patents, which is a novel direction that is not investigated earlier for Europe on a country-level. When a particular influence of the number of patent applications by non-residents on the number of patent applications by residents is found this could help future research on innovation, because patents could be used as a proxy for innovation. A similar research has already been done for developing countries (Bilir, 2014), they examined to what extent developing countries should protect intellectual property. Because strengthened laws concerning patents could help to discourage imitation, but the consumers on the other hand will face higher prices. The results of this paper show that when there are stricter patent laws, there will be more multinational activity, which is an important factor in technology transfer, especially of relatively long-lived intellectual property.

Besides, the findings of this thesis could help governments to amplify the gains of spillover effects by creating beneficial policies for these effects in the case there are found positive spillover effects. Ushijima (2013), has found a positive link between Patent Rights Protection and Foreign Direct Investment (FDI), however this link is mainly found in countries with a high ability of imitating foreign technology, this research focuses on Japan. This effect disappears for less-sophisticated countries. Foreign Direct Investment is an investment in the form of a controlling ownership of a business in one country by a firm that is located in another country. The social relevance of this thesis is therefore, that it could help governments to adjust their policies to create beneficial circumstances for innovation. They can take into account how they could attract more non-resident patent applications if the paper finds a positive effect of non-resident patent applications on resident patent applications.

In the next section former literature regarding patents will be highlighted, and used to formulate the hypotheses. This will be followed with a section which explains the data that will be used for this paper. Whereafter, the methodology to obtain the required results will be explained. The outcomes of the used methodology will be explained in the results section. Finally, the conclusion will summarize the findings of the paper and formulate an answer for the research question.

2. Literature Review

In this section former literature about intellectual property rights will be discussed. This section will also help by formulating the hypotheses to answer the research question of this thesis. First the ethics of intellectual property rights will be highlighted. Second, the spillovers of knowledge will be described. Thereafter, different manners of knowledge protection will be explained. Finally, the effects on innovation that could be induced by patents are discussed.

2.1 Ethics of Intellectual Property Rights

There are two types of property rights, physical property rights and intellectual property rights (IPR). Property rights are considered to be the key to economic activity and prosperity. However the two types of property rights differ substantially. Physical property rights are more straightforward, as it could be a plot of land or an object. For example, as you have a plot of land you could put a fence around it to make it impossible for strangers to make use of it. However, IPR are ideas and therefore it is impossible to claim it like a plot of land. Ideas are non-rivalrous and non-excludable (Reiss, 2013). There are two main forms of intellectual property rights; patents and copy-right. The differences between those forms are that patents exclude other parties from making, using, selling and importing an invention, for the period that the patent is given. Copyright on the other hand gives the holder the 'right to copy' the invention. This also includes the right to be credited, to determine who can use it for other forms and, who can financially benefit from it, etcetera (Reiss, 2013).

The view of Reiss is in line with the view of Boldrin and Levine (2008). They state that the basic problem of creating a new idea or design is costly. They suggest that after the discovery is done it will be efficient to make it freely available to third parties. However, this practice fails to provide the incentives for further inventions before this invention takes place. Therefore, a trade-off arises, between the restrictions on using existing ideas and the benefits of inventing.

Reiss (2013) shows that the problem of intellectual property rights is that you get stuck between two types of market failure. The first type of market failure which they try to overcome is the undersupply of a public good, by using intellectual property rights. However, this source creates another type of market failure, namely monopoly power. Reiss, states that in his opinion intellectual property rights are harmful persuasive. But he also states that for a large and growing segment of the economy it is impossible to apply the invisible-hand hypothesis.

2.2 Knowledge Spillovers

An important part of the accumulation of knowledge are knowledge spillovers. Fershtman and Gandal (2011), give two possible mechanisms that facilitate such spillovers. Knowledge spillover could be defined as a positive externality of inventions and ideas, which happens due to the non-rivalrous and non-excludable character of knowledge. The first mechanism they suggest is that an individual or firm observes the outcomes of research and development (R&D) by another individual, in the form of a new technology or patent. And uses these observables to learn from it for their own R&D process. The second mechanism that they discuss is based on the collaboration of individuals that are involved in the same learning process. Finally, they suggest that there is talk of direct and indirect project spillovers. Where direct project spillovers are defined as knowledge spillovers between projects, which have common contributors. Indirect project spillovers are defined as spillovers between two projects for which there are no common contributors. The effects of spillovers as discussed above are shown in a comparable setting by Markusen and Trofimenko (2009). In their paper they investigate the effect of strategically hiring foreign experts to train their domestic personnel. The proxies that they use to measure the effect of the hired experts are the added value and wages of the employees. They find that the wages and value added of the domestic workers increase substantially and show persistent positive effects. The common ground of these two papers is that they both show a positive effect of an expert on the added value of their co-workers.

This paragraph helps to understand what are potential mechanisms driving inventor mobility due to patent protection. Melero, Palomeras and Wehrheim (2020), studied the effect of patent protection on the mobility of the inventors. As a result of patent protection they suggest that, innovation related skills of R&D workers are specific to the firm that holds the patent. In this manner they can create lower mobility of inventors, due to patents, this will help reduce the spread of non-codified knowledge associated with protected technology and other know-how not related to the replicability of a specific innovation. However, this reduction in inventor mobility induced by patents, may have a negative effect on the allocation of inventive skills. It will hold back efficient career moves of the inventor, such as employer-employee match improvements. On the other hand, it could also have a positive effect. They suggest that patents make some inventor skills specific to the patent holder. This result will shift the incentives to invest in human capital from the inventor to the patent holder. Therefore this shift could encourage some efficient investments in training, which are not affordable for the inventor themselves.

Despite the current globalization it seems that knowledge gets more and more centralized which seems to be counterintuitive and it could be correlated with the effect of patent applications by non-residents on the number of patent applications by residents, as the non-residents may be attracted to specific industrial hubs. A study of Singh and Marx (2013), supports this remarkable finding about country-level knowledge spillover and shows that the centralization only has grown stronger over a time of globalization. They found evidence that U.S. inventors seem to rely disproportionately on knowledge that is generated within the country borders of the United states. Even when the fraction of patents overseas has grown. A possible reason for these findings is that the United States became more specialized in a manner that is not captured by the formal technological classification system. Such a classification system is a way that place different patents in groupings based on their industry. In line with these findings Helmsing (2001), shows that despite globalization and the increase in mobility of production and production factors, economic development is increasingly centralized in economic agglomerations. One of the key factors of this phenomena are externalities. Nelson and Winter (1982), formulated their evolutionary perspective on economic change, based on a central proposition that firm behavior could be explained by the routines that are used. They show that when a routine involves more implicit knowledge the more difficult it is to imitate these, especially from a distance. Firms will therefore codify their routines, to lower the problems of replication. However, effective governance could help to exploit externalities more efficiently (Helmsing, 2001).

2.3 Protection of Knowledge

As described earlier in the introduction there are many ways to protect knowledge. The most used form of protection are intellectual property rights, such as patents. Another commonly used form of protection is secrecy. The problem of patents is that when a patent is granted the knowledge is publicly available and therefore it could be used by others. Therefore, some parties choose to use secrecy as a method to protect their knowledge.

Another previous finding which might influence the relationship between the number of patent applications by non-residents and the number of patent applications by residents is that the preferred protection methods differ among industries and countries. As stated by de Faria and Sofka (2010), there seem to be differences of preferred protection methods between high- and low-technology countries.

They have investigated the differences between Portugal and Germany, which are low- and high-technology countries, respectively. They found interesting differences in the choice of knowledge protection methods on country level, however these differences are not found on industry level. It seems that the subsidiary managers of multinational corporations in the low-technology country, Portugal, use broader protection strategies than their domestic counterparts. This effect is not related to the amount of investment by foreign subsidiaries into innovative activities. On the other hand, the results from Germany differ. For Germany, the results show that there are not per se differences between the multinational corporation subsidiaries and domestic firms. Interestingly, the innovation expenditure in Germany, does have an effect on the breadth in knowledge protection strategies, in contrast to Portugal. The findings show that the knowledge protection strategies become narrower, when the multinational corporation subsidiary increases their innovation expenditures in Germany. Although the paper tried to be external validated, they mention that it would be an overstatement to suggest that they represent every other low- and high-technology country. Given these differences, between these two countries it could be interesting to take the differences between the countries in Europe into account. As this could have an influence on the chosen protection strategies by firms in that particular country.

As shown in the last paragraph the preferred knowledge protection methods differs for the countries, Germany and Portugal. However, the paper is not externally validated for other countries. Based on these findings it could be useful for this thesis to add variables such as the expenditure on R&D and the number of researchers in R&D to control for the fact that there are differences in the technological levels of European countries, which following the case of de Faria and Sofka (2010) might influence the preferred knowledge protection strategies. The expenditure on R&D and the number of researchers in R&D could be used as proxies for the level of technology in certain countries. A potential mechanism that could induce an effect of the expenditure in R&D on the number of patent applications by residents is for the reason that more investments will facilitate current researchers to invent new ideas. Because, of the higher expenditure they can offer them more salary, which might attract better researchers and give them the required tools. For the number of researchers in R&D more or less the same holds, whenever more researchers are trying to find the solution for a certain problem the change of actually finding this solution will increase. Therefore the first hypothesis will be formulated in two sub parts;

Hypothesis 1A: There is a positive relationship between the expenditure on Research and Development and the number of resident patent applications.

Hypothesis 1B: There is a positive relationship between the number of researchers in Research and Development and the number of resident patent applications.

2.4 Research on the Effectiveness of Patents

After discussing the effects of knowledge spillovers and different forms of protection this section will dive deeper into the actual effects of patents. First the difference between patents and secrecy will be taken into account. The trade-off between these two types of knowledge protection is taken into account, because the preferred method might differ across industries.

2.4.1 Trade-off Patents versus Secrecy

That there are differences between patents and secrecy is clear. Both methods have their own advantages and disadvantages. Kultti, Takalo and Toikka (2006), show one problem of secrecy. There is a possibility that multiple innovators come up with the same invention independently. In the current economy it happens more often that innovations pop-up simultaneously. They suggest that this trend has major implications for intellectual property policies. In particular, it will influence the decision to apply for patents. Because of the simultaneous innovation, firms no longer have the choice between patenting and secrecy. In this new situation the choice is between patenting or letting competitors patent the innovation. Based on this they suggest a weak patent system. A weak patent system could be defined as a patent system with a low probability that the innovative firm can exclude their competitors, when this probability rises this indicates a stronger patent system. Using this kind of system will encourage innovators to patent their discoveries rather than keeping them secret. So both information dissemination and innovative activity are stimulated.

The effects of patent disclosures on corporate innovation are studied by Kim and Valentine (2021). A powerful force in the economy for the support of employment and GDP are firms in industries with significant intellectual property rights. Patents grant firms a short-term monopoly on their innovation, in return for this monopoly right, they must publicly disclose their inventions. These detailed disclosures must provide the spread of knowledge and stimulate innovation in this way. However, these detailed disclosures could bring costs with them for the firm that granted the patent, which could decrease the benefits of disclosure. Kim and Valentine (2021), found evidence that the American Inventor’s Protection Act, caused both the positive and negative spillovers for the level of innovation.

Despite this paper will not be able to distinguish the different ways a patent can be sold it still might be interesting to note for further research what the possibilities are to arrange the selling of patents. Bhattacharya and Guriev (2006), developed a model of two-stage cumulative R&D. In this model there are two types of units. The first type of unit are research units (RUs, e.g., a biotech company), those companies develop innovative ideas, which are on their own not sellable to consumers. The second type of unit are development units (DUs, e.g., large pharmaceutical companies). Those DUs are the ones who can further develop the innovative ideas developed by the RUs. Normally, the DUs have deeper pockets, which assumes that they could be more efficient in developing the original idea, so that it creates value for consumers. They investigate the two alternative modes a RU can use for selling their ideas; an open sale after patenting their knowledge, or a closed sale. In such a closed sale they suggest that the DU must give the RU a stake in the licensed post-invention revenues. Giving the RU a stake in the post-invention revenues decreases their incentive to disclose the idea to competing DUs. Despite the adverse impact of low intellectual property rights protection on the incentives of licensees, the strength of social welfare keeps decreasing in the strength of intellectual property rights.

It is a fact that not all firms choose patents as their defense mechanism for innovations, however after taking the pros and cons in consideration this might help interpret the estimates of the data analysis of this paper. Cohen et al. (2000), shows in his paper that the average patent application propensity is 33% for process innovation and 51.5% for product innovation in a survey of 1065 U.S. firms. Patent application propensity could be defined as the percentage of innovations that apply for patents. Instead of patents firms often rely on secrecy to benefit from their innovations. They also show that on average secrecy is the most effective system to use, while patents are not identified as the most effective system in any industry. However, despite these empirical findings, patents are still regarded as an important incentive for innovation, and have been greatly strengthened in the last few decades (Kwon, 2012). Kwon's paper aims to identify that when the equilibrium patent propensity is small, strengthening patent protection can decrease the incentives for firms to innovate. Stronger patent protection is defined, when the probability of imitation, or invention around, decreases. Even in the simplest patent race model, without cumulative or complementary innovations, stronger patent protection can decrease the equilibrium research investment. The crux is that when a stronger patent policy causes more patent applications these results hold. This paradox is highlighted in this paper. For example, there are industries which consider patents as relatively ineffective, so if there are more patent applications due to a stronger patent policy, one might consider this as evidence that a strong patent policy could be successful. However, the results of Kwon (2012) show the exact opposite. When patent propensity is small and when a strong patent policy causes more applications. This may reduce the overall research investment and discourage innovations. Especially in the case of complementary innovation, stronger patent policy discourages innovation due to the hold-up effect. This is in line with Kultti, Takalo and Toikka (2006), who stated in their paper that weaker patent protection may increase information dissemination and innovative activity.

Concluding the paragraphs of this subsection, it is found that some firms choose secrecy as the knowledge protection system. Therefore, the knowledge that they acquired does not come publicly available which might stagnate innovation. However, when the opposite takes place, thus people actually choose to use patents this could have a positive effect on the level of innovation in a country. Because as explained by Kim & Valentine (2021), the costs of a patent is that it requires a public disclosure. However, the public disclosure of patent applications by non-residents might have a positive effect on the number of patent applications by residents as they could use this information for their own inventions. Therefore the second hypothesis will investigate if there is an effect of patent applications by non-residents, on the number of patent applications by residents, which could be seen as a proxy for innovation;

Hypothesis 2: There is a positive relationship between the number of non-resident patent applications and the number of resident patent applications.

2.4.2 The Effect of Patents on Innovation

The main goal of the patent system as mentioned earlier is to encourage innovation, this paragraph will dive deeper in how to improve patents in such way that they will help accumulate innovation. However, this assumed positive relationship between patent protection and innovation incentives, are not undoubted in emerging empirical evidence. Krasteva highlighted these findings (2014), most of the former literature has taken two extremes of patent protection into account, namely perfect protection and no protection. The problem with these two extreme forms is that when models involving a single independent innovation cannot account for the empirical evidence. This is because in this case perfect protection will always generate higher incentives for innovation. Krasteva (2014) relaxes this assumption of as he calls it 'ironclad patents' to account for the fact that imitation is everywhere. When innovation is non-drastic, stronger patent protection can have a negative effect on the R&D incentives. The paper shows that imperfect patent protection can maximize the optimal level of R&D incentives, which do not prohibit all imitation. The mechanism that drives this result is the fact that when the innovation is non-drastic, imitation may be beneficial for the innovating firm. The reason that this happens is because imitation involves an efficiency gain, when the superior patent technology is used by a competing firm. So when the level of protection lies between perfect protection and no protection, both the innovator and imitator benefit from this efficiency gain under imitation.

Another characteristic of patents that influence its effectiveness is the length, which in turn might influence the decision to invest in R&D. Horowitz and Lai (1996), investigate this influence. Their purpose is to find the 'optimal patent length'. This optimal length that they are looking for must maximize both innovation and welfare. In their model they identify an unique patent length that maximizes the rate of innovation. Innovative incentives will be weaker when the patent length deviates from this optimal length. What is remarkable is that the optimal length of a patent is longer, for innovational maximization than for consumer welfare. Because of these different maximizing lengths, there must be a trade-off when governments are designing patent laws. Do the government want to maximize innovation or do they choose for the more intuitive objective of maximizing consumer welfare. However, when adjusting the length of a patent could help maximizing innovation, this occurs due to different characteristics of innovation. Specifically, when the length of a patent increases, there seem to be countervailing effects on the size and frequency of innovation. The size of innovation benefits by longer patent lengths. On the other hand, the frequency of innovation decreases by an increase in length. The maximizing patent length therefore balances these two different characteristics of innovation. This same mechanism also occurs in the case of welfare maximization.

When considering the incentives to innovate for a technology leader, they face the decision to improve their currently patented technology. However, when the technology leader faces this decision further improving their current patent could cannibalize the rents of their current product. Therefore, this may weaken the incentive of the technology leader to innovate, this is called Arrow's replacement effect (Parra, 2019). What Parra states is that due to this effect patents lose value when the expiration date approaches. Because of this the incentive to innovate grows when the patent term comes near to the expiration date. Besides the technology leader, there are also followers in the economy who have incentives to innovate. Their incentives are also affected by the expiration date of the patent of the leader. When the patent protection is stronger, this will increase the probability of the follower to infringe on the existing patents. The followers will internalize the license fees they have to pay, which discourages them to invest in R&D. Notable is that towards the end of a patent term, both leaders and followers have greater incentives to innovate. The incentives to innovate in a market could be modified by changing the length and/or strength of patents. The purpose of Parra (2019) is to investigate how patent policy can dynamically impact the incentives of R&D investment and market structure through the replacement effect. Evidence shows that longer patents increase the replacement effect, and therefore the leaders will delay their investments in R&D. The same holds for the followers who will also delay their investments if the patent protection becomes longer. To overcome this issue, forward protection could be desirable. Combining these two factors could help to improve patent laws. However, the optimal level for both these factors differs among industries. Parra (2019) shows that in industries where it is more costly and it takes longer to innovate, patent length is the most appropriate tool for promoting innovation (for example, pharmaceutical sector). In industries where innovation is less costly and time consuming, such as the software sector, forward protection seems to be the best fit. So short patents with good protection against future breakthroughs are more desirable to acquire the maximal innovation pace. As is shown in this last paragraph there seems to be a relationship between investment in R&D and how firms determine their patent strategy. Different industries prefer different patent lengths and/or strengths, which in turn might induce another distribution of the number of patent applications by non-residents. This is also in line with the findings of de Faria and Sofka (2010), they stated that different industries which have either a high- or low-technological character differ in their preferred knowledge protection methods. However, as hypothesis 1A only tests the effect of R&D expenditure on the number of patent applications by residents, it could be of added value to include the number of patent applications by non-residents into the equation. Therefore a third hypothesis will be formulated to investigate if there is an interaction effect between the number of patent applications by non-residents and the expenditure on R&D;

Hypothesis 3: There is a positive interaction effect between research and development expenditure and the number of patent applications by non-residents on the number of patent applications by residents.

This interaction effect could be explained in the following manner; the main aim of this research is to investigate if there is an effect of the number patent applications by non-residents on the number of patent applications by residents. However, the expenditure in R&D might have an influence on the effect between the dependent and independent variable. Because the amount of expenditure on R&D might also influence the quality of the non-residents that apply for patents. Which might influence the overall effect of the number of patent applications by non-residents on the number of patent applications by residents. As shown by Parra (2019), and described in the previous paragraph industries where innovation is time-consuming and costly require different types of patents as industries where innovations are less time-consuming and costly. Therefore, it could be reasonable to suggest that the expenditure in R&D

might induce a change in the effect of the number of patent applications by non-residents on the number of patent applications by residents.

3. Data

As stated earlier this paper will focus on the European market. The data that is gathered to fulfil the regressions is obtained from the World Bank: Data. This database contains data from different countries, and are divided in different 'world development indicators'. In this section the variables that are used to perform the statistical analysis will be shown. First the main variables for this thesis will be described. Then the control variables will be explained. Afterwards, some descriptive data will be highlighted and the correlation between the two main variables will be discussed. The data that is used for this thesis is panel data as the research question aims to investigate the effect of patent applications by non-residents on the patent applications by residents for the time interval 2000-2018.

The data that is used from the World Bank: Data comes in excel-files per different indicator. To make the data useable for the analysis all the different indicators are put together in a single excel-file. The data is formatted as panel data of most of the European countries. The list of the European countries that are included in the data can be found in appendix 1A. The choice for panel data is because panel data contains more information than time series data or cross-sectional data. It gives the opportunity to also control for the differences among the countries that are included in this research. Therefore this paper will investigate the effect over this particular time interval.

3.1 Main Variables

Resident Patent Applications

Resident patent applications are used as the dependent variable for this thesis. Resident patent applications are described as applications that are filed with an intellectual property office in the country where the applicant is residing. For example, if a Dutch applicant, applies for a patent at the 'Octrooicentrum Nederland' this is seen as a resident patent application. This is the definition that the World Intellectual Property Organization (WIPO) gives for resident patent applications, this is also the resource of the data from the World Bank: Data. The measurements are contributed with a yearly interval per country.

Non-Resident Patent Applications

The independent variable in this research is the number of non-resident patent applications per country per year. The difference between the resident and non-resident patent applications is that for a non-resident patent application, the applicant is not residing in the country of the application. For example, when a Belgium resident applies for a patent at the 'Octrooicentrum Nederland'. Because of the public availability of patents this thesis will use this variable to investigate if there is a spillover effect of non-residents applying for patents in a certain country on the resident applications in that particular country.

Research and Development Expenditure

The independent variable that is included for hypothesis 1A in this research is the expenditure as a percentage of GDP on R&D. The data of the World Bank is shown as a percentage of the GDP. However, as the research tries to find out what the influence of non-resident patent applications is on the number of resident patent applications and most of the countries in Europe differ significantly based on population size and therefore on GDP, this variable is transformed to absolute numbers. Because, when you use the percentage of R&D expenditure, 1% percent has a totally different value for countries that differ significantly in size, for example a rise of 1% will be a lot higher value for Germany than for the Netherlands. The used variable is measured in billions ($) per year per country.

Number of Researchers in Research and Development

Alongside the expenditure on R&D, the number of researchers in research and development per country will be added to the variables that are used. The number of researchers is likely to be strongly related to the expenditure on R&D. However, it could be that there exist differences in the budget per researcher. Therefore, it seems reasonable to include both variables. The available data of the World Bank gives the data of the number of researchers per million. Therefore, the data for this research is transformed to the total number of researchers in a country, per thousands, as not all countries have a comparable population size.

3.2 Control Variables

To decrease the change of omitted variable bias, there will also be some control variables included. All control variables are measured yearly per country. For this thesis the control variables are also gathered from the World Bank: Data. The used control variables will be described briefly beneath.

Gross Domestic Product (GDP)

The first control variable that will be considered is the GDP. This is a basic variable that indicates the total amount of money spent in a country. When a country has a higher GDP per capita, this may have a positive influence on the innovation in this particular country. This variables is measured for each country per year and is noted in billions ($).

Expenditure on Education

As a second control variable the expenditure on education will be used. This variable shows the total amount that is spent in billions ($) on education in a country each year. Higher expenditure on education may have a positive influence on the level of innovation in a country and therefore it could be a useful control variable to add.

Population

The third control variable that is included in the different models is the population size of each country. This variable is measured in millions for each country per year that is included in this analysis. The population size will be controlled for as this could have a relationship with the number of patent applications by residents. It will also help to control for the differences that might be induced to the fact that countries differ in size. By doing so it could help unbias the absolute numbers of expenditure on R&D and education and the number of researchers in R&D.

Scientific and Technical Journal Articles

The fourth and final control variable that is added to the equation is the number of scientific and technical journal articles. This variable is chosen for the reason that when there is more scientific and technological research in a country, this might have a positive influence on the number of patent applications by residents. The number of scientific and technical journal articles are also measured for each country per year.

3.3 Descriptive Data

For this research data of 43 countries is acquired for the time interval 2000-2018. In table 1 some of the characteristics are described to get a better insight in the data that is used to test the hypotheses. These descriptive statistics clearly show that there are significant differences inside of Europe. For the two main variables of this research, namely patent applications by residents and patent applications by non-residents, the difference between the minimum and maximum seems big. However, when you look at the population sizes it shows that the smallest country only has about 281.000 citizens in comparison to the biggest country which has approximately 146.6 million citizens, which could be an explanation for these differences.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Patent residents	767	3590.339	8757.001	2	51736
Patent non-residents	759	1314.141	3269.568	1	21281
GDP(billion)	791	445.749	770.927	.387	3963.768
Population(billion)	817	19.311	28.958	.281	146.597
R&D expenditure(billion)	742	8.355	17.398	.002	122.645
R&D researchers(thousand)	661	.061	.102	0	.507
Education exp(billion)	577	21.24	35.678	.012	192.106
Journal	803	13389.023	22295.887	1.61	108473.690

In table 1 there also seems to be a lot of differences between GDP, R&D expenditure and researchers and education expenditure. However, these differences could be the cause of differences in country size. So to get a more detailed insight in the differences between the countries that may influence the number of patent applications, table 2 shows the differences per capita for GDP, R&D expenditure and Education expenditure. Besides, it also show the number of researchers per million citizens. Nevertheless, it still seems that there are significant differences inside Europe.

Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP per capita	791	24021.924	23432.29	35.773	118981.91
R&D expenditure per capita	742	430.683	561.163	.412	2858.312
R&D researchers per million	661	2798.041	1820.711	61.594	8065.888
Education exp per capita	577	1403.25	1468.547	1.156	7703.432

3.4 Correlation

Another tool to get some more insight in the variables that is used for this thesis is a Pearson-Spearman correlation matrix. The bottom side (left of the diagonal) of table 3 shows the Pearson estimates, while the upper side (right of the diagonal) shows the Spearman estimates. The differences between those two methods is that Pearson estimates a linear correlation between the variables. In contrast, the Spearman estimates, could evaluate a monotonic relationship between either continuous or ordinal variables. The difference of a monotonic relationship compared to a linear relationship is that for a monotonic relationship the variables do not have to move at a constant rate. If there is a linear relationship both methods will give the same estimation. Therefore, this matrix could give some insight in the kind of relationships between the different variables and the strength of the relationship. This can in turn help to explain the outcomes of the tests that are computed in the results section.

Table 3: Pearson-Spearman Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Year	1.000	-0.046	-0.040	-0.256*	-0.064	0.084	0.043	0.109*	0.100*	0.102*
(2) Country	0.000	1.000	0.321*	0.255*	0.379*	0.272*	0.347*	0.210*	0.256*	0.233*
(3) Patent residents	-0.004	0.083*	1.000	0.783*	0.816*	0.888*	0.930*	0.845*	0.874*	0.814*
(4) Patent non-residents	-0.032	0.173*	0.893*	1.000	0.670*	0.695*	0.724*	0.663*	0.682*	0.619*
(5) Population	0.011	0.303*	0.764*	0.757*	1.000	0.770*	0.855*	0.656*	0.716*	0.732*
(6) GDP	0.099*	0.162*	0.818*	0.708*	0.713*	1.000	0.924*	0.962*	0.988*	0.872*
(7) R&D researchers	0.030	0.171*	0.861*	0.850*	0.913*	0.798*	1.000	0.894*	0.910*	0.885*
(8) R&D expenditure	0.089*	0.045	0.844*	0.701*	0.569*	0.939*	0.728*	1.000	0.974*	0.852*
(9) Education exp	0.142*	0.232*	0.804*	0.710*	0.623*	0.989*	0.728*	0.938*	1.000	0.858*
(10)Journal	0.118*	0.191*	0.748*	0.654*	0.696*	0.904*	0.761*	0.834*	0.890*	1.000

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

4. Methodology

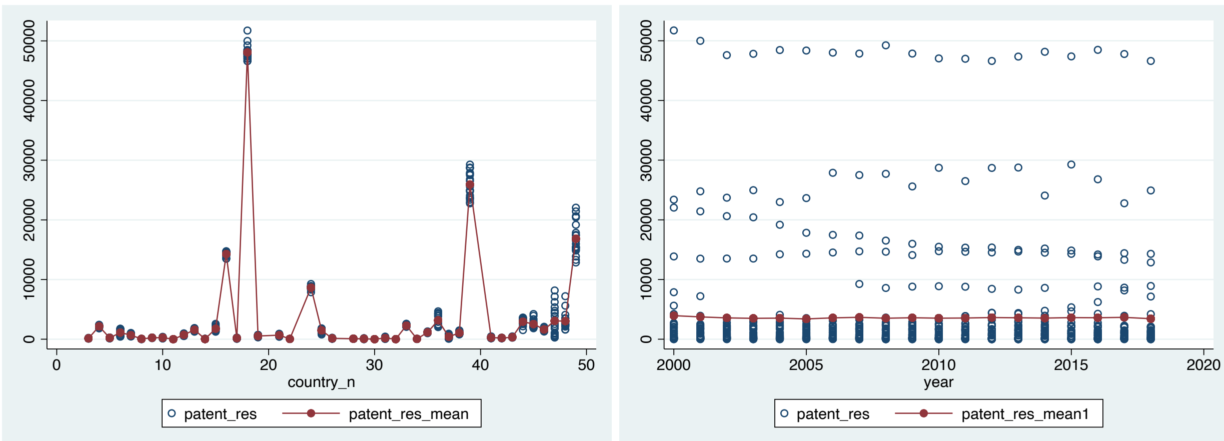
To answer the research question, multiple hypotheses will be tested in this thesis. In the following section all hypotheses that are formulated in the literature review will be repeated and the used methodology will be described as well. First the heterogeneity of the sample data will be discussed. This research tries to investigate an effect over a given interval and therefore panel data will be used. The Hausman test will be explained, which will be used to determine which kind of regression is appropriate for the panel data that is used for this thesis. Which will be followed by descriptions of the different hypothesis and the performed tests in this thesis.

4.1 Heterogeneity

The advantage of using panel data is that it can account for individual heterogeneity. Panel data allows to control for unobservable measures such as cultural differences between countries, or variables that are time-invariant over time, but not across countries. For this reason, panel data is chosen for this particular research. In Figure 1 the different countries and their resident patent applications are compared to its mean. In this figure it is clearly visible that there is heterogeneity across different countries. However, in

Figure 2 the patent applications by residents are compared for each country per year. The red-line shows the mean and in this case it seems that the variables are spread homogeneous.

Figure 1&2: Two-way scatter of patent applications by residents per country (left, figure 1) and a two-way scatter of patent applications by residents per country (right, figure 2).



4.2 Hausman

For every data sample it is important to determine which test is most suitable to acquire the feasible results. As this thesis is using panel data it will investigate an effect over a certain time interval. For this thesis a Hausman test will be performed to determine which model has the best fit for the panel data. The Hausman test, calculates if the appropriate test is either a fixed effects test or a random effects test. While the fixed effects estimate do not use partial pooling, random effects do. This means that random effects replaces the missing values of a country in this case with abundant values from other countries.

The Hausman test will be performed using all variables that are included to determine which test is appropriate. The null-hypothesis of the Hausman test states that there are no systematic differences in coefficients between the tests. The null-hypothesis will be rejected if the p-value is below 0.050. Which then indicates that the appropriate test is a fixed effects test. The Hausman test will already be performed in the methodology section to determine the models that will be used for the different hypotheses.

The Hausman test that is performed to determine whether fixed effects or random effects is the most appropriate test for the panel data is shown in table 4 below. The P-value of the performed Hausman test is 0.000, which is below 0.050. Therefore, the fixed effects model is the best fit for this particular panel data. In appendix 2A a Hausman test to determine if yearly fixed effects are necessary to perform is tested. However, this test shows that this is not the case as it gave a p-value of 0.1182, which is above 0.050.

Table 4: Hausman specification test

	Coef.
Chi-square test value	292.68
P-value	0.000

Note: test result for country fixed effect on patent applications by residents.

Besides the outcome of the Hausman test another reason to use fixed effects is that the countries in Europe do not only differ in observable variables. There are also potential unobservable variables, such as cultural differences, that might affect the results of interest for this research. Therefore, fixed effects also seems to be an appropriate test for the multiple hypotheses that will be tested in this research.

4.3 Hypothesis 1

The first hypothesis that will be used to answer the research question will take into account other factors that might influence the number of patent applications by residents of a particular country and is formulated as follows:

Hypothesis 1A: There is a positive relationship between the expenditure in Research and Development and the number of resident patent applications.

Given the outcome of the Hausman test fixed effects will be added to the regression. The regression that will be tested for hypothesis 1A is formulated beneath:

$$ResPat_{t,i} = \beta_0 + \beta_1 * RDExp_{t,i} + \alpha_2 * X_{t,i} + \vartheta F_i + \epsilon_{i,t} \qquad (1)$$

The dependent variable $ResPat_{t,i}$, shows the number of patent applications by residents, per year t and for country i. The independent variable, $RDExp_{t,i}$, shows the expenditure on R&D for country i and year t. After that a vector variable is added to the regression, $X_{t,i}$, this vector variable contains the multiple control variables for country i and year t. Then F_i is added to the equation, which are the country fixed effects. Finally, the error term is included in the model.

Another factor which might influence the number of patent applications by residents is the number of researchers in a country.

Hypothesis 1B: There is a positive relationship between the number of researchers in Research and Development and the number of resident patent applications.

Also for hypothesis 1B a fixed effects test is required the equation for the regression can be formulated as follows:

$$ResPat_{t,i} = \beta_0 + \beta_1 * RDres_{t,i} + \alpha_2 * X_{t,i} + \vartheta F_i + \epsilon_{i,t} \qquad (2)$$

The variables that are used in this regression model are more or less the same as the variables of hypothesis 1A. However, the independent variable in this regression is $RDres_{t,i}$, which denotes the number of researchers for country i in year t. Another difference in comparison to regression (1) is that in the control vector, the control variable for the expenditure on education is added.

The main goal of the first hypothesis is to determine if there is a positive relationship between the expenditure on R&D and the number of researchers in R&D on the number of resident patent applications.

4.4 Hypothesis 2

For the second hypothesis the goal is to investigate the influence of patent applications by non-residents on the number of patent applications by residents. In order to acquire the desired results the following hypothesis is formulated:

Hypothesis 2: There is a positive relationship between the number of non-resident patent applications and the number of resident patent applications.

To determine if there is a positive relationship between the number of non-resident patent applications and the number of resident patent applications a country fixed effects panel regression is performed. The exact formula that is used is stated below:

$$ResPat_{t,i} = \beta_0 + \beta_1 * NonResPat_{t,i} + \alpha_2 * X_{t,i} + \vartheta F_i + \epsilon_{i,t} \qquad (3)$$

The independent variable in formula 3 is the number of patent applications by non-residents. These values are captured in the variable, $NonResPat_{t,i}$, with the different values given for country i per year t. The vector control variables consists of the following control variables: GDP, population, R&D expenditure, R&D researchers, Education expenditure and the number of journals published for a given country i in year t.

4.5 Hypothesis 3

The third hypothesis will estimate if there is an interaction effect between the number of non-residents that apply for a patent and the amount of money that is spend on R&D. A potential mechanism that could be present is that whenever a country spends more money on R&D, this might have a positive influence on the number of patent applications by non-residents. This could be due to the presence of a hub for a particular industry, which has a sufficient budget to attract foreign researchers. Therefore the following hypothesis is stated:

Hypothesis 3: There is a positive interaction effect between research and development expenditure and the number of patent applications by non-residents on the number of patent applications by residents.

The equation that is used to compute a model to answer hypothesis 3 is almost the same as the equation that is used to answer hypothesis 2. However, in this hypothesis the interaction term, $NonResPat_{t,i} * RDExp_{t,i}$, is added. This interaction term describes the interaction effect between patent applications by non-residents and the expenditure on R&D. The regression that is used to test the null hypothesis is stated below:

$$ResPat_{t,i} = \beta_0 + \beta_1 * NonResPat_{t,i} + \beta_2 * RDExp_{t,i} + \beta_3 * NonResPat_{t,i} * RDExp_{t,i} + \alpha_2 * X_{t,i} + \vartheta F_i + \epsilon_{i,t} \qquad (4)$$

After all the models are computed using STATA (StataCorp, 2019) the results will be looked into. The different models will help to reject, the null or alternative hypothesis. Which will in turn help to answer the research question of this thesis.

5. Results

5.1 Hypothesis 1

For the first hypothesis the relationship between the number of resident patent applications and the expenditure on R&D and the number of researchers in R&D is tested. The hypothesis is split in two different sub-hypotheses. The model for the first sub-hypothesis is shown in table 5. The main variables that are tested in this model are the number of patent applications by residents and the expenditure on R&D. In Table 5 below, hypothesis 1A is tested. To get a more clear view of the effectiveness of the different control variables, the model is separated in four parts. Separating the model gives the opportunity to compare the adjusted R-squared of the different parts of the model. The adjusted R-squared takes the chance a new variable influences the R-squared and the actual influence of the variable into account. Therefore, the adjusted R-squared is a more reliable measurement, than the normal R-squared. So using this method you could describe the changes in the estimates and the added value of the different control variables more precisely. Another reason for separating the model is that some of the estimates are quite remarkable, adding the control variables one by one might help to make it easier to interpret the estimates. For this reason, the models will be separated for every added control variable.

Table 5: Model 1, hypothesis 1A

	(1) Model 1.1	(2) Model 1.2	(3) Model 1.3	(4) Model 1.4
R&D expenditure	-18.229***	-88.474***	-85.008***	-81.644***
(billion)	(6.225)	(12.546)	(12.431)	(12.573)
GDP		1.876***	1.61***	1.602***
(billion)		(.294)	(.298)	(.298)
Population			107.515***	116.653***
(million)			(26.569)	(27.065)
Journal				-0.006*
				(-0.003)
Constant	4042.028***	3762.032***	1560.06***	1433.498**
	(62.011)	(74.466)	(549.114)	(556.075)
Observations	697	697	697	694
Adjusted R^2	-.052	.008	.031	.034
Country Fixed Effects	Yes	Yes	Yes	Yes

Note: regression model of patent applications by residents (dependent variable) on research and development expenditure (independent variable) and control variables, using country fixed effects. Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

The first thing that is noticed is that the expenditure on R&D is negatively related to the number of patent applications by residents, and that this negative relationship is significant with a p-value smaller than 0.01. Another finding that catches the eye is the jump in R&D expenditure from model 1.1 to model 1.2, where the value jumps from -18.229 to -88.474. This jump could be explained by adding the variable GDP and thereafter the variable for population. The reason that these variables impact the estimate of R&D expenditure, could be due to the fact that R&D expenditure is a variable that contains the expenditure on R&D in absolute numbers for each country. However, adding the GDP and population size, will control for the size and total expenditure in a country. In this manner, the estimates in model 1.2 and model 1.3 for R&D expenditure will become more precise.

Another remarkable finding of the first regression model is the low adjusted R-squared. However, adding more control variables seem to have a positive effect on the adjusted R-squared. The reason that the adjusted R-squared is shown instead of the regular R-squared is that the regular R-squared always tends to increase, when more control variables are added, which could give a distorted view of the actual variance of the dependent variable that is explained by the independent variables. The small adjusted R-squared does not have to be a problem, a reason for this could be that there are many variables that explain the number of patent applications by residents. For example, the average patent propensity for process innovation and product innovation differs as described by Cohen et al. (2000).

Hypothesis 1A: There is a positive and significant relationship between the expenditure in Research and Development and the number of resident patent applications.

The hypothesis that is tested using the model in table 5 is described above. Given the results of the model and the significance of the variable, R&D expenditure, the null hypothesis could be rejected. As in the last column, the independent variable, R&D expenditure is still significant with a p-value of 0.000. There seems to be a significant negative effect of R&D expenditure on the number of patent applications by residents.

For the second part of the first hypothesis the relationship between the number of patent applications and the number of researchers in R&D is tested. The model that is computed using STATA is shown in table 6. The first thing that stands out is that the independent variable R&D researchers in this regression model is at least significant on a 95% confidence interval for each separated model. Another remarkable feature of this variable is that the variable gives a negative output for model 2.1 to 2.3, but thereafter the output becomes positive. However, the adjusted R-squared also increases after model 2.3. This increase in the adjusted R-squared indicates that the estimates of the model become more precise and therefore this suggests that the output after model 2.3 are more reliable. The output for researchers in R&D for model 2.5 states that for every thousand extra R&D researchers an additional 6.803 patents are applied for.

There is also a jump in the constant found. The estimated constant for model 2.3 is 223.356, and this estimate jumps to 9017.161 for model 2.4. However, this jump of the constant happens simultaneously with the increase in adjusted R-squared. Therefore, the same holds as stated in the previous paragraph, because of the higher adjusted R-squared, the model can more precisely estimate the results.

Hypothesis 1B: There is a positive and significant relationship between the number of researchers in Research and Development and the number of resident patent applications.

Based on these findings an answer on hypothesis 1B can be formulated. While the outputs for the first three parts of Model 2, seem to give a negative estimate for R&D researchers the 4th and 5th part seem to give a more precise estimated of the independent variable. In model 2.5 a positive and significant effect of the number of researchers in R&D and the number of patent applications by residents is found. Therefore, hypothesis 1B will not be rejected.

Table 6: Model 2, hypothesis 1B

	(1) Model 2.1	(2) Model 2.2	(3) Model 2.3	(4) Model 2.4	(5) Model 2.5
R&D researchers	-5.798***	-8.431***	-17.008***	5.505**	6.803**
(thousand)	(1.915)	(2.246)	(2.514)	(2.651)	(2.723)
GDP		.407**	.338**	6.925***	6.897***
(billion)		(.173)	(.166)	(.464)	(.462)
Population			218.654***	-257.849***	-258.595***
(million)			(32.666)	(42.429)	(42.281)
Education Expenditure				-133.216***	-131.692***
(billion)				(9.238)	(9.238)
Journal					-0.005*
					(0.003)
Constant	4551.361***	4691.874***	223.356	9017.161***	9012.327***
	(125.578)	(134.323)	(679.988)	(835.471)	(832.524)
Observations	628	602	602	445	445
Adjusted R^2	-.052	-.046	.003	.433	.437
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes

Note: regression model of patent applications by residents on research and development researchers and control variables, using country fixed effects. Standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

5.2 Hypothesis 2

The aim for the second hypothesis is to test if there is a significant relationship between the number of patent applications by non-residents on the number of patent applications by residents. To determine if this effect is present a regression model is tested which is shown in Table 7. This model shows 7 separated parts of model 3, for each part an extra control variable is added to the model. Which again gives the possibility to compare the adjusted R-squared of the different parts.

The variable which denotes the effect of patent applications by non-residents is significant on a 95% confidence interval for all 7 parts, given the p-value below 0.050. In Model 3 the 7th part has the highest adjusted R-squared and therefore this part can describe the influence of the number of patent applications by non-residents most precisely. The estimate of this independent variable is positive and significant. Model 3.7 shows that for every patent application by a non-resident, the number of patent applications of residents rises with 0.052. In other words, for approximately every 20 patent applications by non-residents there will be an additional patent application by a resident, all other variables held constant.

Table 7: Model 3, hypothesis 2

	(1) Model 3.1	(2) Model 3.2	(3) Model 3.3	(4) Model 3.4	(5) Model 3.5	(6) Model 3.6	(7) Model 3.7
Patents non-residents	.070**	.072**	.125***	.173***	.168***	.045*	.052**
	(.028)	(.03)	(.03)	(.03)	(.032)	(.025)	(.025)
GDP		-.021	-.41***	1.703***	1.625***	6.459***	6.408***
(billion)		(.148)	(.154)	(.293)	(.37)	(.485)	(.484)
Population			180.09***	148.468***	162.623***	-220.262***	-220.301***
(million)			(26.152)	(27.098)	(38.485)	(44.366)	(44.138)
R&D expenditure				-102.018***	-90.317***	42.892*	41.693*
(billion)				(12.584)	(20.293)	(23.095)	(22.983)
R&D researchers					-4.137	1.769	3.389
(thousand)					(3.842)	(3.362)	(3.42)
Education expenditure						-136.93***	-134.586***
(billion)						(10.043)	(10.045)
Journal							-0.006**
							(0.003)
Constant	3548.891***	3678.032***	52.081	566.494	625.672	8316.62***	8280.429***
	(47.013)	(78.148)	(531.95)	(575.624)	(756.685)	(864.445)	(860.146)
Observations	756	730	730	686	595	444	444
Adjusted R^2	-.051	-.055	.012	.077	.085	.443	.449
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: regression model of patent applications by residents (dependent variable) on patent applications by non-residents (independent variable) and control variables, using country fixed effects. Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

It is also remarkable to see that the expenditure on R&D has a 99% significant and negative effect on the number of patent applications by residents for model 3.4 and 3.5. However, after the expenditure on education is added in model 3.6, the effect of R&D expenditure is only significant at a 90% confidence interval, while the expenditure on education is significant on a 99% confidence interval. This might implicate that the actual variance is actually explained by the expenditure on education, instead of the expenditure on R&D as was found in hypothesis 1A. A potential mechanism that could induce this relationship is that whenever a country invest more on education, this might impact the number of people who want to become a researcher and therefore also affect the expenditure on R&D. The model probably estimates a significant p-value for the expenditure on R&D, because it is strongly correlated with the expenditure on education. This is shown in table 3 in the data section, with a Pearson estimate of 0.928 and a Spearman estimate of 0.947. Also, the outcome in model 3.6 and 3.7 for R&D expenditure gives in contrast to the first hypothesis a positive outcome. A possible explanation for this is the presence of multicollinearity between the expenditure on education and R&D. However, as these variables are not used as the independent variable in this table but as a control variable instead, this does not concern the results for the estimates of the number of patent applications by non-residents. Model 3.7 shows a negative and significant effect of -134.586 of expenditure on education. Which could be explained in words, as for every extra billion invested in education the number of patent applications by residents decreases by -134.586. A possible explanation for this negative effect is that the effectiveness of patents differs across industries. As shown by de Faria and Sofka (2010), the expenditure on innovation does have an effect on the knowledge protection strategies that are used for high-technology country Germany, in contrast to low-technology country Portugal. This could imply that patents might not be the best protection method for high technology countries, which in turn are likely to spend more money on education.

Hypothesis 2: There is a positive and significant relationship between the number of non-resident patent applications and the number of resident patent applications.

The second hypothesis that is tested does not have to be rejected based on the findings of the model. There is a significant and positive relationship between the number of non-residents patent applications and the number of resident patent applications.

5.3 Hypothesis 3

The model that is tested for the third hypothesis is the exact same as the model that is used for the second hypothesis, except that there is added an 8th part of model 3 with the interaction effect between the number of non-resident patent applications and the expenditure on R&D. For this reason not all 8 parts are included in Table 8. The conclusion for the third hypothesis can be brief, as the estimate for the interaction effect is not significant. The model also does not show an increase in the adjusted R-squared between model 3.7 and 3.8.

Table 8: model 3, hypothesis 3

	(1) Model 3.7	(2) Model 3.8
Patent non-residents	.052**	.034
	(.025)	(.032)
GDP	6.408***	6.439***
(billion)	(.484)	(.485)
Population	-220.301***	-205.451***
(million)	(44.138)	(47.219)
R&D expenditure	41.693*	34.121
(billion)	(22.983)	(24.523)
R&D researchers	3.389	2.318
(thousand)	(3.42)	(3.628)
Education expenditure	-134.586***	-134.133***
(billion)	(10.045)	(10.06)
Journal	0.000**	0.000**
	(0.000)	(0.000)
Patent non-residents		
R&D expenditure		
Patent non-residents		.001
* R&D expenditure		(.001)
Constant	8280.429***	8066.845***
	(860.146)	(893.452)
Observations	444	444
Adjusted R^2	.449	.449
Country Fixed Effects	Yes	Yes

Note: regression model of patent applications by residents (dependent variable) on patent applications by non-residents and the interaction effect of patent applications by non-residents and research and development expenditure (independent variables) and control variables, using country fixed effects. Standard errors are in parentheses

**** p<.01, ** p<.05, * p<.1*

Hypothesis 3: There is a positive interaction effect between research and development expenditure and the number of patent applications by non-residents on the number of patent applications by residents.

The findings of model 3.8 show that the interaction effect between R&D expenditure and the number of patent applications by non-residents is insignificant. Therefore, hypothesis 3, as shown above, can be rejected, there is no interaction effect between these variables. In other words, when one of the two variables changes and the other will be held the same this does not affect the overall effect differently as there is no 'interaction' between the two variables.

6. Conclusion

The goal of this thesis is to estimate if there is a significant effect of the number of patent applications by non-residents on the number of patent applications by residents. And if this effect could be explained as a so called spillover effect. The research question as formulated in the introduction is as follows:

'Is there a spillover effect of non-residents applying for patents on residents applying for patents for countries in Europe from 2000 to 2018?'

To answer this research question multiple hypothesis are tested to determine, which factors influence the number of patent applications by residents. To test these hypotheses data from the world bank: Data is used. The findings of these different hypotheses are discussed in the results section. The first hypothesis finds that there is a significant effect of the amount of expenditure on R&D and the number of researchers in R&D on the number of patent applications by residents. The expenditure in R&D shows a negative result which could be declared by the different technology levels between European countries. For example, Cohen et al. (2000) shows that the average patent propensity is higher for product innovation than for process innovation. So a possible explanation is that countries that invest more on R&D spent a bigger part on process innovation, which results in a negative effect on the number of patent applications by residents. But the seemingly contrasting results for the number of researchers in R&D also needs some further discussion. Because the results show that the number of researchers in R&D has a positive effect on the number of patent applications by residents. This looks contrary to the findings of hypothesis 1A, because whenever you have more researchers this also influence the expenditure on R&D due to the wages those researchers are paid. A possible explanation is that these differences in expenditure are not only based on the wages of the researchers but also for the tools that are necessary for their particular research, which might have resulted in these contrary results. However, these effects seem to resemble only a small part of the variance. Thereafter the second hypothesis is tested, which also shows a significant effect, in this case for the number of patent applications by non-residents on the number of patent applications by residents. Also in this case only a small part of the variance is explained by the independent variable. For the third hypothesis, there is not found any evidence for an interaction effect between the number of patent applications by non-residents and R&D expenditure.

Based on the findings of the multiple hypotheses that are investigated in this paper an answer on the research question can be concluded. With the findings of the second hypothesis, a positive effect of the number of patent applications by non-residents on the number of patent applications by residents is observed. However, the low- adjusted r-squared indicates that the patent applications by non-residents do not explain a lot of the variance. A potential clarification could be that the performed model, does not have the right fit for the used panel data.

Although there seems to be a positive and significant effect of the number of patent applications by non-residents on the number of patent applications by residents it cannot be stated with hundred percent certainty that there is a causal relationship between the dependent and independent variable. In the Pearson-Spearman table (table 3) it is shown that there is a strong relationship between the patent applications by residents and non-residents. However, this is not enough to prove that there is a causal relationship. One of the assumptions that is required to determine such relationship is that there is nothing else besides the control variables that accounts for the relationship between the dependent and independent variable. Based on the low adjusted R-squared it seems that there are still missing control variables, and this in turn might indicate that there is an omitted variable bias.

The performed research for this thesis also seems to have some limitations. A first limitation is the lack of previous research on this particular topic. Because, there were no previous papers about this exact topic, the methodology had to be created from scratch. On the other hand, the lack of previous research studies also shows the importance as it might find some relationship, which could help countries to attract more researchers and boost their national innovation-level. Second, the limited access to data is a limitation of this research paper. As this paper only compares the total number of patent applications per country, while there might be differences between industries. Unfortunately, this data was not available on the World Bank: Data.

For further research it could be interesting to improve the cons of the current used methodology. This might be done using a different type of model to investigate if there could be an significant effect detected. Or by transforming the data in such a manner that it could explain a bigger part of the variance. Another suggestion for further research is to gather data from different types of industries, to take into account what the differences are among these industries. For example, as shown by Parra (2019), the most effective patents differ among industries. In that paper there is shown that for industries where innovations are more costly and time consuming, patent length is the most appropriate tool for promoting innovation. While in less costly and time consuming industries, forward protection seems to be the most appropriate tool. Which might influence the effect of current patents, as for some industries there is currently no perfectly convenient patent available.

7. References

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8. Appendix

1A List of European countries included in the research.

- Armenia
- Austria
- Azerbaijan
- Belgium
- Bulgaria
- Bosnia and Herzegovina
- Belarus
- Switzerland
- Cyprus
- Czech Republic
- Germany
- Denmark
- Spain
- Estonia
- Finland
- France
- United Kingdom
- Georgia
- Greece
- Croatia
- Hungary
- Iceland
- Italy
- Kazakhstan
- Lithuania
- Luxembourg
- Latvia
- Moldova
- North Macedonia
- Malta
- Montenegro
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- Russian Federation
- Serbia
- Slovak Republic
- Slovenia
- Sweden
- Turkey
- Ukraine

Appendix 2A Joint test to see if all parameters on the indicators are the same for each year. Because the p-value 0.1182 is above the 0.050 time fixed effects are not necessary for this panel data analysis.

```
( 1)  2001.year = 0
( 2)  2002.year = 0
( 3)  2003.year = 0
( 4)  2004.year = 0
( 5)  2005.year = 0
( 6)  2006.year = 0
( 7)  2007.year = 0
( 8)  2008.year = 0
( 9)  2009.year = 0
(10)  2010.year = 0
(11)  2011.year = 0
(12)  2012.year = 0
(13)  2013.year = 0
(14)  2014.year = 0
(15)  2015.year = 0
(16)  2016.year = 0
(17)  2017.year = 0
(18)  2018.year = 0
      F( 18,   381) =    1.42
           Prob > F =    0.1182
```