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The Effects of Corporate Taxation on Innovation

An empirical analysis on the effects of corporate taxation on innovation in Europe

Isabella Maier

Supervisor: Steffen Juranek, Floris Tobias Zoutman

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Abstract

This thesis aims at analyzing the relationship between corporate income taxation and innovation in Europe to further the discussion about which policy tool is optimal to encourage innovation. This was done using a fixed effects regression on a panel of data of European OECD member states for the time period 1981-2017, using the statutory corporate tax rate and the number of patents per million inhabitants. The results of both regressions fail to show a significant effect of corporate income taxation on the number of patents. This is in contrast to previous findings of studies using U.S. data, which could be for a few different reasons, such as differences in patenting systems, economic and cultural structure, but also methodology. The obtained results point to corporate income tax not being the optimal instrument to encourage innovation and decreasing it to be unlikely to have the desired effect, which means more granular and directed research is required into what instruments, which could be tax or non-tax, have the best effects on innovation in Europe.

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1. Introduction

More and more, innovation is becoming a central topic in both business and the economy as a whole. Innovation is generally considered as the act of creating something new or improved, most commonly a product or process, that adds value or more specifically, can be made available for use.[1] As technology progresses at an exponential rate (Kurzweil, 2001), keeping up with innovation is the only way for companies to stay competitive. Indeed, nowadays, innovation is regarded as one of the main drivers of economic growth. Although innovation has always been the key to societal advancements, it was only in the 20th century that it entered into economic considerations. One of the very first to recognize the role of innovation was Schumpeter, who coined the term "creative destruction" (Hospers, 2005). Today, the works of Solow (1957) and Romer (1986) are seminal in economics, and the widely accepted endogenous growth theory has become the primary model of economic growth.[2]

In Europe, the EU has set the goal for its member states to invest 3% of the GDP into R&D. This goal was first formulated in 2000 in the Lisbon strategy, but most countries hadn't reached it by the specified end point of 2010, so it was reformulated for 2020 as 'Europe 2020' (Armstrong, 2012). Since this goal failed to be reached by most members again, the EU has now re-affirmed the same target for 2030 (Zubascu, 2021). The fact that the goal still hasn't been reached, clearly shows that there is a need for finding the appropriate instruments to encourage private R&D in the future. In fact, the EU wants to double down on low R&D in businesses and increase incentives (Council of the European Union, 2021).

There are different ways to encourage R&D and innovation. Patents, R&D tax incentives, subsidies and patent boxes are commonly regarded as the options governments have to address the underinvestment of private R&D due to the gap between private and social returns

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[1] There is no "right" definition of innovation and there are many interpretations of innovation. For standardized, somewhat official definitions of innovation, we can look to the ISO 56000:2020 and the Oslo Manual 2018 (4th edition). The two definitions have in common that they both require an outcome that adds value (ISO, 2020) or can be made available for use (OECD/Eurostat, 2018). Further, both assume that an innovation is a new or improved process or product.

[2] Solow is the name associated with the "residual" or total factor productivity, the up to that point by standard macro-economic models unexplained part of economic growth. His work is now considered the basis to endogenous growth theory. Romer (1986) developed a model where growth resulted from endogenous accumulation of knowledge rather than regarding the technological progress as exogenous, giving rise to the endogenous growth theory, which Aghion & Howitt (1992) and Grossman & Helpman (1994) further contributed to.

of R&D (Nussim & Sorek, 2017).[3] However, there has been discussion in literature whether those instruments are effective at encouraging innovation. Gaessler et al. (2021) for example, call into question whether patent boxes serve the intended purpose with regards to innovation. The patent box schemes, they conclude, merely encourage cross-border transfers of patents, but don't increase the innovative activity. Authors that study R&D tax credit more in detail, also find that their effectiveness is very dependent on circumstances of the firm (Kasahara et al., 2013, Cappelen et al., 2012, Sterlacchini & Venturini, 2019).
If some of the instruments currently used are shown not be as effective as intended, research into other avenues to encourage innovation must be conducted.

Achieving a higher level of innovation is not only central to achieving continued economic growth and remaining competitive, as well as hitting the EU targets, it is also the only way to successfully manage the transition towards becoming a sustainable economy. The OECD's green growth strategy, for example, highlights the importance of a shift towards more mindful consideration of resources and potentially damaging practices. Innovation is described as one of the sources of growth in this strategy and is considered the core of transforming an economy (OECD, 2011). With climate change taking a more central role in consumer awareness and political discussions, and governments imposing stricter restrictions, for companies with a large carbon footprint, innovation is the key to survival. Particularly, a groundbreaking court decision in Den Haag has recently shown that companies could be forced to change their practices through lawsuits. In the ruling, Shell has been obligated to reduce their emissions by 45% until 2030 (Spiegel, 2021, de Rechtspraak, 2021). This is a clear sign for other companies to step up their game and work on a reduction of their emissions, which in many industries is not possible to achieve without considerable innovations.

Much research has been done to determine the effect of R&D tax credits on innovation. However, there is much less on how the effective corporate tax rate affects the innovative activity of an organization. As economic growth slows down in the developed countries, which includes the European countries, and the importance of sustainable economies increases, policy makers must identify all possible avenues to encourage innovation. It is

[3] Some issues surrounding the topic of innovation are considered, in economic terms, market failures. This is due to innovation being similar to a public good in terms of non-rivalry and costly excludability (Nussim & Sorek, 2017). Since firms have difficulty appropriating the benefits from an innovation, they invest less than socially desirable. In addition to that, there is a gap between the private return to the innovator and the cost of external capital (Czarnitzki et al., 2011). This causes under-investment in innovation activities that results in market failures, which policies aim at reducing.

therefore of particular importance to clearly understand the interdependences that exist between innovation and the policy tools available to governments. This thesis aims at contributing further insight into the effects of taxation on innovation, measured by the level of patenting, for the European member countries of the OECD. It achieves this by conducting a regression analysis on a panel of data for the observed countries in the period from 1981 to 2017. The results fail to find a significant effect of corporate income tax and the number of patents, which contrasts what previous publications have shown (Akcigit et al., 2021, Atanassov & Liu, 2020, Mukherjee et al., 2017). It is concluded that several reasons for such differences exist, which will be elaborated on in later chapters.

The thesis is structured as follows: In chapter 2, an overview over relevant literature will be given. Chapter 3 will provide background information on the specifics of corporate taxation and patenting in Europe. The reasoning behind the analysis, the data used and the empirical analysis will be explained and conducted in chapters 4 to 6, with the results then being presented and discussed in chapter 7. Suggestions for future research will also be given in chapter 7, while the thesis will be concluded with chapter 8.

2. Literature Review

As innovation is the main driver of economic growth, R&D incentives, be it in tax credit or in subsidy form, aim at increasing innovation in a country. As such, most of the literature concerning R&D incentives aims at determining the success of such measures. There is a vast array of literature studying the link between tax rates and innovation, with different authors approaching this in different ways. The existing literature in this area can be divided into several categories. However, even within those, researchers take very different approaches in their analyses. The review of existing literature will therefore be structured as follows: since the bulk of literature focuses on the effects of R&D tax credits, the first section will be devoted to this field. Secondly, as this paper focuses on the effect of overall taxation on innovation, the next section will give an overview of this literature. Lastly, further literature pertinent to the subject matter will be presented.

2.1 The effects of R&D tax credits

A large portion of existing literature revolves around the effectiveness of R&D tax credits (Berger, 1993, Bloom et al., 2002, Cappelen et al., 2012, Czarnitzki et al., 2011, Rao, 2016, Thomson, 2017, among others), measuring different outcomes of the effects. Most studies relate R&D tax credits to R&D expenditures (Berger, 1993, Kasahara et al., 2013, Rao, 2016, Bloom et al., 2002), while some use other measures of innovative activity.[4] Chen & Yang (2019) and Tian et al. (2020) for example, extend their scope of measurement by one further component, namely patents, subsuming these observations under the term firm innovation. Ivus et al. (2021) also use this combination, adding R&D intensity as a third measure. Czarnitzki et al. (2011) also use multiple measures to determine innovation output, but very different ones, such as the number of new products, their sales and the originality of innovations. Cappelen et al. (2012) use a similar approach, but also investigate patenting. While the majority of studies was conducted using U.S. data, particularly before the turn of the century (Hall & Van Reenen, 2000), more recent studies have branched out into including not only other OECD countries, but also emerging economies, such as Argentina (Crespi et al., 2016), Taiwan (Chiang et al., 2012, Yang et al., 2012) and China (Chen & Yang, 2019,

[4] When speaking of innovation, some form of measurable outcome is assumed, in accordance with the official ISO and OECD definitions (ISO, 2020, OECD/Eurostat, 2018). The term innovative activity, on the other hand, will subsume all activity that is related to R&D, inventing and innovating from here on out.

Tian et al., 2020). This newer development in research can be attributed, in part, to the fact that many of these countries have only recently started implementing systems to encourage R&D.

All publications studying the relationship between R&D tax credit and R&D investment have in common that they find statistically significant effects, albeit with different magnitudes (Kasahara et al., 2013, Thomson, 2017, Rao, 2016, Bloom et al., 2002, among others). Considering they have been conducted on a number of countries and for different time periods, with different methodologies, overall, this gives strong indications towards R&D tax credits being a suitable policy instrument to encourage innovative activity. The results are not sufficient to predict an effect on innovation, as R&D investments alone have no value in explaining outcome, which is a prerequisite for the term innovation according to the ISO and OECD (ISO, 2020, OECD/Eurostat, 2018) definition. However, many studies include other indicators of innovative activity, such as patents or new products, also finding positive effects of R&D tax credits (Ivus et al., 2021, Czarnitzki et al., 2011, Tian et al., 2020, among others). Therefore, the effectiveness of R&D tax credits can be concluded to be significant.

There are also publications studying the effect of R&D tax credits on a more granular level, with specific questions in mind. Castellacci and Lie (2015), for example, conduct a meta-regression analysis on the differences of R&D tax credit impact on innovation across industries and find that there are indeed sectors that respond better to tax credit compared to others, in particular SMEs, as well as firms in the service and low-tech sector. Both Makeeva et al. (2019) and Mitchell et al. (2020) focus their question of the effects of R&D tax credit on innovative companies, with the former looking at firm performance of innovative companies, while the latter is interested in the impact of R&D tax credit on young innovative firms. Sterlacchini & Venturini (2019), on the other hand, using a sample of firms from four European countries, study how the research activity of manufacturing firms is influenced by R&D tax incentives, and find that the impact varies by firm size, with small companies driving the observed effect. Chiang et al. (2012) look at the effectiveness on R&D tax credit in dependency of where a firm is in its life cycle, focusing on data from Taiwan and using actual tax credit data rather than a dummy variable. They suggest that tax credits have different effects when firms are in different stages of their life cycle, an interesting insight to keep in mind when it comes to the discussion of optimal policy tools.

2.2 Corporate tax and innovation

The link between corporate income tax and innovation remains fairly unexplored, with only a few pieces of literature on the subject, three of which are on U.S. data. The manner in which this thesis adds to the literature is twofold. Firstly, it extends the overall literature on corporate income taxation and innovation. Secondly, it gives a perspective on the relationship in Europe.

Atanassov & Liu (2020) explore how tax cuts affect innovation and find that large tax cuts on corporate income stimulate innovation, albeit with a two year delay. They focus their analysis on the U.S. and use tax change as their main explanatory variable. Atanassov & Liu juxtapose their findings with the results from a similar study done by Mukherjee et al. (2017), who find insignificant effects for tax cuts, and only significant effects for tax increases, and give convincing arguments on why there do indeed seem to be significant effects of tax cuts. They conclude that tax cuts lead to a higher innovative output, which can in turn lead to a positive effect on firm performance and economic growth.

Akcigit et al. (2021) provide a thorough analysis on the effects of taxation on innovation, examining both macro- and microeconomic effects and exploring multiple indicators of innovation. Their analysis on the macroeconomic level of the relationship between taxation and the number of patents serves as a blueprint of sorts for the empirical analysis performed here. Overall, their results indicate significant effects of the corporate and personal income tax on innovation indicators, such as the number of patents, citations and inventors.

Shao & Xiao (2019) use the 2006 tax reform in China to conduct a similar study on the effects of corporate taxes on firm innovation, measured by the number of filed patents. They, too, find significant and positive effects of tax reduction on innovation.

2.3 Other pertinent literature

While most studies pick a specific instrument and study its effectiveness, some studies compare two instruments in the endeavor to identify which of either gives better results. Busom et al. (2014), for example, pose the question whether R&D tax incentives and R&D subsidies are substitutes. They find that they are not, as they are suitable to companies of varying size that have very different needs and prerequisites. Based on their findings, they suggest an innovation policy that uses these instruments depending on the type of firm. On their own, R&D subsidies are also another category of policy instruments examined in literature. Klette et al. (2000), for example, compare fives studies aimed at finding the effect of R&D subisidies on firm performance, but conclude that more investigation is required. A meta-regression analysis of previous literature conducted by Dimos & Pugh (2016) to reconcile heterogenous empirical effects shows the progress in that field since the work of Klette et al. (2000), finding an overall positive effect of R&D subsidies, even if of small magnitude. However, they can exclude a crowding out effect of R&D subsidies, which at least shows they don’t go to waste.

Gande et al. (2020) approach the question from a legal and institutional perspective and give policy recommendations on how to align private innovation to be at the socially optimal level through corporate tax rates, while the discussion of optimal growth policy through research and taxation is the focus of Gersbach et al. (2018).

While tax incentives have generally been shown to be effective to encourage R&D, the design of the incentives have to be suitable to the tax system of the country implementing them, as Elschner et al. (2011) demonstrate.

A slightly different approach regarding the effects of tax on innovation is taken by Henrekson & Sanandaji (2018), who discuss the effects of stock option taxation on the level of venture capital (VC) activity, comparing Europe and the U.S. Their study gives very valuable insights into possibilities for European governments to shape their R&D policies without resorting to decreasing the overall corporate income tax.

Cheng et al. (2021) turn the question around and, using a U.S. sample, ask what role patents play in corporate tax planning in comparison to R&D. Their results suggest that while R&D tax credits and deduction serve the intended purpose, patents are used by taxpayers to shift their income to lower tax countries and therefore partake in aggressive tax avoidance practices. Belz et al. (2017) conduct a meta regression analysis on existing literature to identify the effect that R&D expenses have on the effective tax rate. They find a slight decrease in effective tax rate for a company with increased R&D intensity, which stems from both profit shifting and tax accounting and criticize that in many examples of literature, the authors consider only one of them, respectively.

The OECD also provides literature on the topic of taxation and innovation. Palazzi (2011) gives a conceptual overview over the linkage between the two, showing which factors impact innovation that may be influenced by tax policies. Suggestions for tax policies are also given, among which is the reduction of corporate income taxes.

3. Patenting and Taxation in Europe

3.1 The mechanisms of applying for a patent at the EPO

The European Patent Office (EPO) was founded in 1977 on the foundation of the European Patent Convention (EPC), which is an international co-operation set up with the aims of strengthening cooperation between the member states, now 38, unifying the patent application process for its member states in terms of patent application procedure and standards and establishing the EPO (EPO, n.d.)

Filing a patent to the EPO requires an invention to be new, involve an inventive step and be industrially applicable. More specifically, patents apply to technical and functional aspects of an invention. Everything outside of this categorization may be protected under different intellectual property (IP) rights, such as copyright, trademarks or design rights (EPO, 2016).

Important to note is that computer programs or software, are not considered patentable in Europe and are instead covered by copyright (EPO, 2016). This is in contrast with the U.S., where software has been patentable since the 1980s. The U.S. Patents and Trademark Office (USPTO) started viewing software as patentable in the 1980s, although their patentability had to be well argued in the beginning. During the 90s, the acceptance of patents for software grew until it became established that software can be patented (Bessen & Hunt, 2007). Additionally, whereas business models are generally considered to be patentable in the U.S., they are a further category that is not considered eligible for patenting in Europe (Ovans, 2000, EPO, 2016)

The advantage of filing a patent to the EPO is the possibility to obtain patent protection in all EPC member states with one application, resulting in a centralized, and therefore more effective, time and cost wise, process (EPO, 2016).

3.2 Regional distribution of innovation

In Europe, innovative activity is distributed very unevenly across regions. Eurostat uses R&D intensity as a measure. The most R&D intense region in Europe is Braunschweig in Germany, followed by Stuttgart, also in Germany and Brabant Wallon and Vlaams Brabant in Belgium. Other R&D intense regions, among others, are East Anglia in the UK and Trøndelag in

Norway. In terms of R&D intensity, 10% of regions are responsible for 50% of Europe's R&D spending (Science Business, 2019). The distribution of patents across regions roughly follows the distribution of R&D patents, showing great regional disparity within countries (Eurostat, 2021).

There seems to be a strong link between large companies' headquarters and the R&D expenditure in that region. For example, the most R&D intensive region in Europe is Braunschweig in Germany, which includes Wolfsburg, the location of Volkswagen's headquarters. This region is followed by Stuttgart, where Daimler, Porsche and Bosch have their headquarters. In France, the Toulouse region stands out, which is where Airbus is located. Similarly, in Vlaams Brabant in Belgium, AB InBev has its headquarters. In those regions, there is usually also the presence of strong technical universities, which might contribute to the R&D intensity of that region.

3.3 Corporate Taxation on the European continent

Taxation of corporations is different in every country in Europe. The differences lie in the total effective rate, but also in the way taxes are calculated and which entities of the country receive those taxes. In general, we can differentiate between the corporate income tax and a capital gains tax (European Comission, 2019). The corporate income tax applies to profits a company makes, while the capital gains tax regards any gains derived from assets, such as the sale of real estate. Not all countries in Europe differentiate between the two when they tax companies. While Ireland, for example, applies the capital gains tax to companies in certain gain scenarios, Germany regards capital gains in the same way as profits and includes them in the standard corporate tax (European Commission, 2011). Table 1 aims at giving the reader an overview of how corporate income taxes vary from country to country.

All observed countries have in common that they have decreased the overall tax burden on corporate income over time. Some countries, such as Great Britain and Ireland, have employed a more progressive approach, slowly lowering the tax rates year by year, whereas other countries, such as Austria or Germany, lowered the taxes considerably at certain points in time, creating a "step" in the tax rate curve.

3.4 R&D tax credits and patent boxes

There are large differences in how each of the European countries handles tax credits for R&D and patent box schemes. Table 1 gives an overview of both. As of now, 14 countries in Europe offer a patent box regime. Patent boxes are tax schemes, where the profits for IP are taxed at a lower rate than usual corporate profits. Each country has chosen to offer a slightly different scheme, with some charging higher taxes and some lower. Among the countries with the lowest taxes within a patent box scheme are Hungary and Luxembourg, while countries such as Italy and Portugal have a considerably higher tax even with the patent box regime.

Table 1

Country	***Statutory Corporate Income Tax (2020)***	***Max Tax Rate in observed period***	***Tax credit in observed period (2000-2017)***	***Patent box introduction year (current tax rate under patent box regime)***
Austria	25%	55% (1981)	Since 2002	--
Belgium	25%	48% (1981)	Since 2005	2007 (4.44%)
Czech Republic	19%	45% (1993)	Since 2005	--
Denmark	22%	40% (1981)	Yes	--
Estonia	20%	26% (2000)	No	--
Finland	20%	61,75% (1982)	2013-2014	--
France	32%	50% (1981)	Yes	2000 (10&)
Germany	29,9%	60% (1981)	No	--
Greece	24%	49% (1985)	Since 2004	--
Hungary	9%	50% (1989)	Yes	2003 (0% or 4.5%)
Ireland	12,5%	50% (1982)	Since 2004	1973 (6.25%)
Iceland	20%	30% (2000)	Since 2011	--
Italy	27,81%	53,2% (1994)	Yes	2015 (13.95%)
Latvia	20%	25% (1995)	2014-2017	--

Lithuania	15%	24% (2000)	Since 2008	2018 (5%)
Luxembourg	24,94%	37,45% (2000)	No	2008 (4.99%)
Netherlands	25%	48% (1981)	Yes	2007 (7%)
Norway	22%	50,8% (1981)	Since 2002	--
Poland	19%	40% (1992)	Since 2016	2019 (5%)
Portugal	31,5%	55,12 % (1983)	2003, since 2006	2014 (10.5%)
Sweden	21,4%	58,1% (1983)	Since 2014	--
Slovenia	19%	25% (2000)	Since 2008	--
Slovak Republic	21%	45% (1993)	Since 2015	2018 (10.5%)
Spain	25%	35% (1984)	Yes	2008 (10% - federal)
Switzerland	21,15%	33,05% (1981)	No	At cantonal level (up to 90% exemption from corporate tax)
United Kingdom	19%	52% (1981)	Yes	2013 (10%)

Data from Atkinson & Andes (2011), Asen & Bunn (2020), OECD (2021a)

3.5 Comparison with the U.S.

Since much of the literature concerning the interplay between R&D tax credits, corporate taxation and innovation revolves around the U.S., it seems relevant to give a quick overview over the differences between the U.S. and the European systems of corporate taxation. The U.S. taxes companies at a federal level and at state level, which causes quite a few differences between states in terms of tax burden. In contrast to the EU, however, these differences do not occur across national borders, which makes taking advantage of lower taxes in a different state easier. In Europe, language barriers and larger cultural differences might inhibit companies from making such a choice (CILT, 2006).

4. Theoretical reasoning

A lot of focus has been put onto R&D tax incentives and how they affect innovative activity. Less research has been conducted on the overall corporate tax rate and how it affects innovation. The studies that exist suggest that the overall tax rate also influences companies' decisions to be innovative (Akcigit et al., 2021, Atanassov & Liu, 2020, Mukherjee et al., 2017).

Indeed, from an economical point of view, a higher net of profit means more possibilities for companies to reinvest some of their profits, which they can choose to do in R&D. Not only that, the motivation to invest in R&D also increases if the net returns of the final outcome are higher. For U.S. companies, as suggested by Sougiannis (1994), an increase in R&D investment leads to an increase in profits and an even higher increase in market value in the long term. A similar result is found by Garcia-Manjon and Romero-Merino (2012), who examine European top R&D spending firms. Following this logic, if a company retains a higher net of profit, increasing the investment in R&D is a smart move. Therefore, it can be expected that a lower tax leads to an increase in R&D, and ultimately, in patents.

5. Data

To conduct the analysis, a panel dataset was constructed compiling data from different sources. The resulting panel data contains data of the number of patents, the population, the statutory corporate income tax rate, as well as information on tax credits and patent box schemes, for the years 1981 to 2017 for all 26 European member states of the OECD.[5] Some of the data is not available before 1990 for countries previously part of the Warsaw Pact. Equally, the data on tax credits was only available from the year 2000. For this reason, two separate regressions were conducted. The main regression follows the equation laid out in chapter 6, using all 26 countries for the time period 2000 to 2017. For this first regression, the joining date to the European Patent Convention (EPC) is also considered, to eliminate a rise in patent applications, resulting from the entry into the EPC, from the analysis. A further benefit of starting with the EPC joining date is that events such as independence, and reunification of Germany in the 1990s is left out of the analysis as well. To conduct an analysis on a balanced panel and over more years, a secondary regression is conducted on all countries for which patent and tax data was available for the time period 1981 to 2017,[6] which means that the tax credit dummy has to be left out of the equation as the data is not available for the full time period.

5.1 Number of patents

5.1.1 Patents as indicators for innovation

Innovation is something that is difficult to measure on its own. Not only are there many different definitions of innovation, the innovative activity itself is also difficult to quantify. It is impossible to say how many hobby inventors might be tinkering in their garage at any given moment. However, to measure any effects that are in relation to innovation, it is important to find a good proxy that depicts innovative activity as accurately as possible. Different measures are used in scientific literature, such as R&D expenditure and R&D

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[5] The mentioned countries are following: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Iceland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Sweden, Slovenia, Slovak Republic, Spain, Switzerland & United Kingdom

[6] In this case, 16 countries could be analyzed: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Sweden, Spain, Switzerland & United Kingdom

intensity. Bloom et al. (2002), for example, study the effect of tax credit on R&D investment. Similarly, Rao (2016) looks at the link between R&D tax credit and investments. Griliches (1990), in particular, studied what one can infer from patent data and found that patents are a suitable measure of inventive activity. One reason for this is that the data is easily accessible, available in large quantities and quite detailed. Quite a few authors follow this approach. Shao & Xiao (2019) for example, use patent as a measure for innovation in their research regarding corporate taxes and innovation in China. Patents are similarly used in a study conducted by Atanassov & Liu (2020). The Oslo Manual 4 also gives an extensive overview on how innovation can be measured and lists intellectual property rights (IPRs), which patents are a part of (OECD/Eurostat, 2018).

It should be mentioned that choosing one of these measures has to follow a specific reasoning, as these depict very different stages in the innovative process. In fact, while many publications measure R&D investments, the Oslo Manual clarifies that innovation requires implementation, which means investment alone is not a suitable measure for innovation per se, but rather for innovative activities undertaken by businesses (OECD/Eurostat, 2018). R&D investment shows how much a company is spending at a given moment for their R&D department. What it fails to show, however, is whether the investment is successful, that is whether it results in an innovation that brings the company returns, or whether that investment came to naught. The number of patents, on the other hand, is a tangible outcome and shows the success of the innovative activity. Still, by looking at the number of patents alone, one cannot determine where an increase may potentially stem from. While it is likely that, if the number of patents increases across multiple companies and for a longer period of time, the average investment in R&D has also been increased, there might also be very different reasons for an increase in the number of patents. This could be a new category of intellectual property becoming patentable, bureaucratic hurdles being removed or pressure from competition fueling the motivation to apply for patents.

Following the mentioned cosiderations, for the analysis, patents will be used as the chosen proxy for innovation. As the objective is to find out how taxation influences innovation, it makes sense to use a measure that is directly impacted by taxes. R&D investment is an expense, and therefore only directly impacted by taxes if it is deductible from them. This is, as laid out in Table 1, not the case for all countries in Europe. The motivation for the application for a patent, on the other hand, stems from expecting returns. The rate at which these returns are taxed, is therefore certainly relevant for the decision to apply for a patent.

5.1.2 Data compilation

The data on patent applications to the EPO was available through the OECD, which provides a range of statistical data on IP. One of the databases, the one used in the present analysis, is the REGPAT database, which is available to researchers upon request and offers data on EPO and PCT applications at a regional level. It contains three datasets for each the EPO and the PCT applications, one on inventors, one on patent applications as well as one that contains the application year, all starting in the year 1977. The datasets have been compiled using data from PATSTAT, which is the worldwide statistical database. The REGPAT version used is from January 2021 and contains PATSTAT data from autumn 2020.

To determine the number of patents per country per year, the first dataset, spanning about 4 million rows of applications to the EPO and containing the application ID, the name of the applicant, their address including city, post code, regional code and country code, and the application share, was merged with the second dataset. This second dataset contains the year of first filing to the EPO and the application ID, which can be used as the matching variable. Then the dataset was further transformed, first eliminating applications of applicants from countries outside of the European OECD member states that wouldn't be part of the analysis, for example countries located outside of Europe, such as South Korea and Japan. After this a matrix was created that depicted the number of patents per country per year.

When first surveying the data, it became clear that the years 2018 to 2020 showed a significant drop in numbers of patents per country, indicating that the database might not be complete for those years. The analysis will therefore be conducted only up to the year 2017.

It is worth mentioning that identifying which of the applications was submitted by private inventors was nigh impossible with the given dataset, so the assumption is made that corporate taxes apply to all applications. Furthermore, the applications used are merely the applications made to the EPO, which don't include patents registered through national patent offices. Therefore, the single countries' patent application numbers are only considered after they joined the European Patent convention (EPC), to avoid a distortion of data and to account for the increase that might have occurred from the entry alone.

5.2 Tax rates

The data on the statutory corporate income tax rate per country was derived from OECD statistics platform (OECD, 2021b) and matched to the patent data using the country code. The OECD provides two different statistics on corporate tax data, one with the recent two decades, covering the years 2000-2020, and another with historical data, covering the years 1981-1999. The latter contains data for fewer countries, resulting in data for some European countries lacking, although this goes only for non-OECD members. Of the different tax rates depicted in the statistics, the combined corporate income tax rate is used, which contains sub-central government taxes. When the corporate income tax rate is progressive, the marginal rate is displayed (OECD, 2021b). The tax data is only distinguished on a country level, which means that regional differences are not accounted for. While observing the effects on a regional level might have given more insight, it would have resulted in quite some challenges. The reason for this is that corporate taxes are made up of different sub-taxes in some countries, but not in others, and each country has a different system of calculating the individual tax rate. For example, Germany has a tax rate at the municipal level, which means differences in tax rate at post code level. The compilation of this level of fragmented data, matching it to the patent applicants through post code etc. would have had to be done manually, exceeding the scope of this paper.

The capital gains tax is not considered in the present analysis. This is because income that results from a patent, or a product that results from the patent, is usually not regarded as capital gain, but rather corporate income (European Commission, 2019).

5.3 Tax credits

The data on tax credits was also retrieved through the OECD statistics platform. The data is available for the years 2000-2020. Many countries have multiple incentive schemes for R&D in place, which might apply to different situation, firm sizes or R&D intensity rates. Additionally, the data from the OECD includes some forms of R&D tax credits, but not others (OECD, 2021a). Therefore, working with a variable depicting the true value of tax credit wasn’t viable and a dummy variable was instead created. The limited availability of the tax credit data means that the dataset for the main analysis will consist of the years 2000-2017, while a secondary analysis consisting of the years 1981-2017 will not include the tax credit dummy variable.

5.4 Population

The data on the population of all countries included in the dataset is available through Eurostat. France is a complicated case, as they use two different ways of counting their population, which is also reflected in the Eurostat data. However, neither of the two ways was continuous for all years represented in the dataset. While France métropolitaine is the population number for mainland France, the newer counting method in the Eurostat data is for France including their territories. As these territories have different country codes and are shown separately in REGPAT, the newer population numbers in Eurostat couldn’t be used. Therefore, for the population of France (métropolitaine), the author drew upon data from the National Institute of Statistics and Economic Studies of France, Insee.

5.5 GDP per capita

Data on the GDP per capita of the included countries was taken from Worldbank. To account for inflation, the data chosen was the real GDP per capita, displayed in constant 2010$. For all countries in the dataset, numbers on the real GDP per capita were available.

5.6 Patents per population

To account for differences in population, and the resulting number of patents across countries, the analysis will use the number of patents weighted by the population of that year, resulting in a variable of patents per million inhabitants. This also controls for increases in patents resulting from an increase in population.

5.7 Missing values

Although patent data is available for more European countries, the dataset will be limited to the European OECD countries, which are Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom. Other EU countries such as Bulgaria and Croatia had to be left out of the data set after its compilation due to missing data, such as the tax rate. Both of those countries have a very low number of patents, however. Similarly, Liechtenstein could not be considered due to the lack of information on adjusted

GDP per capita and corporate income tax rate beyond the past 5 years. Since the number of patents in total, and particularly per capita, is considerable in the case of Liechtenstein, the statistics agency of Liechtenstein was contacted, but they couldn't provide the information either. A similar situation exists for microstates such as Malta, Cyprus, Andorra and San Marino.

Additionally, as only patent applications after officially joining the EPC are regarded, the dataset contains limited data for countries such as Norway, who only joined the EPC in 2008. This unfortunately results in the dataset for the main regression having a different number of observations for each country, making it unbalanced. For the secondary regression, joining date to the EPC was ignored, and the panel is therefore balanced, containing data of 16 countries for the years 1981-2017.

6. Methodology

To estimate the effects of taxes on innovation, a panel two-way fixed effects regression is used, which follows the study design presented by Akcigit et al. (2021). The number of patents per million inhabitants in the given year and country as dependent variable. The main independent variable is the net of tax, or (1-tax). GDP per capita and a dummy for tax credits are also included to minimize omitted variable bias.

6.1 Dynamic effects

Whenever a change in tax rate becomes public, it takes time for a company to react to those changes. While some innovations in reaction to such a change might be done very quickly, as they are the result of an inventive process that had been on-going, or even an incremental improvement to already existing products, which are simply accelerated by the new incentive, other innovative processes will take much longer. Take, for example, a complicated new idea that requires a high level of skill and specialization and which might require new researchers to be hired, as well as a lengthy period of fine-tuning. In this case the process from the idea to a patentable product might take several years. It makes sense therefore to lag the tax variables of net of tax (net_inc) and tax credits (tax_cred). In the present analysis, a 3-year lag was used. This should appropriately represent the average time it takes an inventor to react to a tax change and develop a solution to the point where filing for a patent is viable.

6.2 Equation

To find the effect of taxes on innovation, the following specification is estimated:

$$\ln pat\_num\_pop_{it} = \alpha + \beta \ln(1\text{-}cit_{it-3}) + \gamma \ln gdp\_cap_{it} + \delta\, tax\_cred_{it-3} + \varepsilon_i + \varepsilon_t + u_{it}$$

The variable $pat\_num\_pop_{it}$ is the number of patent application per million inhabitants, per country and year. Rather than using the statutory corporate income tax rate (cit) as it is, it is transformed into the net of tax by subtracting from 1. The net of tax is additionally lagged by three periods, resulting in $(1\text{-}cit_{it-3})$. As control variables, GDP per capita (gdp_cap_{it}), the real GPD per capita in constant US$ per year and country, as well as a dummy variable for tax credits (tax_cred_{it}), per year and country and lagged by three periods, are used. ε_i and ε_t are country and year fixed effects, included to separate the differences between the individual countries and the time trend from the effect of the independent variables, while u_{it} constitutes the error term. To be able to predict the effect in percent change rather than units, the model is estimated using the natural logarithm of each of the variables.

Since fixed effects regression is a form of OLS regression, the assumption of homoskedasticity, the variance of the error term being constant across individuals, must be fulfilled. The presence of heteroskedasticity doesn’t cause biased OLS estimates, but produces wrong standard errors. To account for heteroskedasticity, which is present in this dataset, robust White standard errors are applied.

7. Results

7.1 Regression results

7.1.1 Main regression

The results from the main fixed effects regression can be seen in Table 1. The coefficient suggests a negative relationship between net of tax and number of patents, although at a small magnitude. However, the coefficient is not statistically significant, which means an effect of a change of tax on the number of patents cannot be inferred. This is contrary to what was expected. The same is the case for the coefficient of the tax credits, from which we can derive that the presence of tax credits doesn't explain a change in the number of patents either. The only variable with explanatory power is therefore the GDP per capita.

7.1.2 Secondary regression

As can be seen in Table 2, for the dataset with the longer time period, the same conclusions can be drawn from the results of the secondary regression in comparison with the main one.

Table 2
Regression Results: 2000-2017

	(1) ln_pat_num
ln_net_of_tax_lag3	-.179
	(.393)
ln_gdp_pc	1.33**
	(.478)
tax_cred_lag3	-9.812*
	(4.943)
_cons	354
	.256
Observations	Yes
R-squared	Yes
Country Dummy	-.179
Year Dummy	(.393)

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Table 3
Regression Results: 1981-2017

	(1) ln_pat_num
ln_net_of_tax_lag3	-.053
	(.346)
ln_gdp_pc	1.438***
	(.36)
_cons	-11.748***
	(3.699)
Observations	589
R-squared	.784
Country Dummy	Yes
Year Dummy	Yes

Robust standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

7.2 Discussion

The results seem counterintuitive at first, as previous literature has generally found a link between taxes and the innovation outcome. Considering the case of single countries in Europe, however, the results don't seem entirely unreasonable. While Germany has one of the higher patent numbers per million inhabitants, their corporate taxes are among the higher in Europe and it doesn't offer R&D tax credits. The opposite is true for countries such as Ireland and Hungary, who are generous in terms of overall corporate tax rate and offer tax credits, but have a fairly low number of patents per million inhabitants, making the link with the level of GDP per capita in this case is quite clear. On an individual country level, it would therefore be interesting to see the immediate reaction to tax increases and decreases.

7.2.1 Comparison with Akcigit et al. (2021)

The results obtained in this thesis deviate considerably from the results described by Akcigit et al. (2021) in their similar study conducted on U.S. data. In their study, they found that a decrease in the marginal corporate tax rate leads to an increase in the number of patents. The results of the here presented analysis are, in comparison with Akcigit et al. (2021) as well as additional literature, such as Atanassov & Liu (2020), not significant and therefore don't give any explanatory power to the corporate income tax rate.

Of course, the econometric model of this thesis is simpler than the one presented by Akcigit et al (2021). Furthermore, the data they observe spans over almost a century, while the data observed in the main regression of this work only captures about two decades. However, it is likely that the differences lie not only in the methodology, but also in the differences between the U.S. and the European economy and their patenting systems. Since Europe and the U.S. have moved away from being manufacturing economies to being knowledge economies, services and high tech such as biotechnology, but most importantly software, have become the largest contributors to the GDP (Palazzi, 2011). However, while software and business models can be patented in the U.S., they are not patentable under EPO regulations. With a shift from industrial products that run on mechanics alone to machinery that, despite possibly even having a mechanic mechanism, requires software to run, it is easy to believe that the increase in software, combined with the patentability of software in the U.S., contributed to a steady rise in patents in the U.S. In Europe, software is not eligible for patents. This means that a lot of the innovative activity that was invested into the programming of machines and computers through software, won’t be depicted in a rise of patents in the case of European patents. Blind et al. (2006) mention the patentability of new categories as one possible reason for a surge in patents. This would reflect why the same effects cannot be observed between the U.S. and Europe.

Additionally, cultural and economic differences have to be considered. While most European countries are on the spectrum of being coordinated market economies, the U.S. are a clear example of liberal market economies. In coordinated market economies, not only is the mentality towards paying taxes different, loyalty towards employees also has a high level of importance and employee protection is embedded in the law. And although companies equally engage in tax optimizing strategies, the overall atmosphere that these cultural and institutional differences create is one possible reason.

7.2.2 Limitations

With the data available through the REGPAT database, it was not possible to observe differences across industries, as the patent data is not classified into industries. It would be interesting to see whether there are differences across industries. While both examine the effect of R&D tax credits rather than the overall corporate income tax rate, it is still interesting to see that Thomson (2017) and Chen and Yang (2019) achieve conflicting results in regards to cross-industry differences.

As Mukherjee et al. (2017) find a stronger effect of tax increases on innovation, and, not too differently from the results of this thesis, weak effects of tax decreases, it would be interesting to study this on European data as well. However, due to the nature of European corporate tax development, which has seen a steady decline for most countries in the observed time period, the impact of a tax increase is difficult to measure.

Additionally, this study fails to fully take into account the differences in innovation that exist within a country. There are quite large regional differences in most European countries which this analysis couldn’t reflect. Using firm-level data on individual countries in Europe might help give more insight into how the tax rate plays into the innovative activity of firms.

Similarly, some European countries also have different corporate income taxes on regional levels. An example of that is Germany, where a large part of the tax is levied at a municipal level, with large differences even within neighboring municipalities. In such a case, the statutory corporate income tax rate may not adequately consider all nuances and within-country differences, as well as changes that occur in corporate income tax on a regional level that might have just as strong an impact, if not stronger, on how a company chooses to partake in innovative activity. Additionally, countries with patent boxes have different tax on patents, which may distort the some of the effects if only the statutory corporate income tax rate is considered. On the other hand, a lower corporate tax could still result in more patents because of the higher net of tax that is available for reinvestment.

Lastly, the analysis was conducted using the number of patent applications and doesn't reflect the number of granted patents. A few scenarios come to mind where this might be an issue. It could be, for example, that with increasing availability of data in the past decades, the patent granting process has also become more predictable, leading to a better application-to-grant ratio. This could mean that even though an effect of lower corporate income taxes couldn't be observed, it occurred, but was masked by a lowering number of applications in comparison to the patents granted.

7.3 Suggestions for Future Research

As discussed above, the topic of finding instruments to encourage R&D in Europe is a hitherto insufficiently explored topic. The here proposed areas of future research are closely linked to the limitations on the analysis conducted in this thesis and open up the opportunity to add to the presented results or alternatively take them into a new direction. More insight, particularly more granular insight, needs to be generated to receive answers on how to shape policies in the future. On a first level, studies on corporate income taxation and its effect on innovation on either an industry-level or a firm-level could provide useful insight, such as the possibility to identify if certain groups on either of these levels react differently to different forms of incentive. Valuable insights could also be generated through a more granular study that studies the relationship of tax rates and patent numbers on a regional level.

Even though the effectiveness of R&D tax credit is widely confirmed throughout literature, its effects need to be studied in a more detailed way, with more concrete insights for Europe and accounting for firm size, industry, organizational form, financial situation and asset distribution and similar indicators. With data becoming more easily available through digitalization, this topic might be more easily explored in the future.

Promising results can also be expected from a study into the effects of extending patentable categories in Europe. This would have to be done on a hypothetical basis and could contribute to the discussion on encouraging innovation in a very different way. Most importantly, it might give clues on whether a measure such as that would level the playing field between Europe in the U.S. when it comes to innovation.

A highly interesting field of research that is yet widely unexplored is innovation hubs and their role in the innovative activity of companies, as well as how policy makers can encourage the establishment of innovation clusters in their respective countries. Engel & del-Palacio (2009) provide a characterization of clusters of innovation (COI): heightened mobility of resources, increased speed of business development and a culture of mobility that is associated with an affinity for collaboration are what makes COIs so unique. As Berger & Brem (2017) point out, many European companies have already established an innovation hub in Silicon Valley to utilize the present ecosystem. Innovation hubs exist in Europe as well, but not as concentrated as in San Francisco. Engel (2015) provides a qualitative examination of existing clusters and derives practices for policy makers. Adding a quantitative perspective to this topic could prove very valuable for the future.

8. Conclusion

In this thesis, the aim was to analyze the relationship between corporate income taxation and innovation in Europe to further the discussion regarding which policy tool is optimal to encourage innovation. This was done using a fixed effects regression on a panel of data of European OECD member states for two different time periods, for which the effects of the statutory corporate tax rate on the number of patents per million inhabitants were estimated. This resulted in a larger dataset containing all current OECD members starting with their joining date to the EPC, with the longest observed period being 2000 to 2017, and a dataset with a longer time period from 1981 to 2017, containing all OECD members for which patent and tax data was available for the entire period.

The results of both regressions fail to show a significant effect of corporate income taxation on the number of patents. This is in contrast to the findings of Akcigit et al. (2021), who conducted a similar study using U.S. data, which could be for a few different reasons, such as differences in patenting systems, economic and cultural structure, but also methodology.

The obtained results point to corporate income tax not being the optimal instrument to encourage innovation and decreasing it to be unlikely to have the desired effect. Therefore, more research is required into what instruments have the best effects on innovation in Europe. Two potential avenues are open to future researchers. One is studying the effectiveness of tax incentive or corporate income tax decreases on a more granular level, such as firm- or industry-level. The other option is to study possibilities for fostering innovation that are unrelated to tax, such as the creation of clusters of innovation and the encouragement of VC activity.

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Appendix

Overview of Variables

Variable	***Variable Name***	***Description***
Number of patent applications to the EPO per million inhabitants	*pat_num_pop*	Number of Patent Applications to the EPO per country per year, weighted by the respective country's population of each year
Statutory corporate income tax	*cit*	The statutory corporate income tax rate per country per year
GDP per capita	*gdp_cap*	Real GDP per capita for each country and year, measured in constant 2010 US$
Tax credit dummy	*tax_cred*	Tax credit dummy that depicts the presence of R&D tax credig in any given year and country
Net of tax	*net_inc*	1-cit
Log of Number of Patents per million inhabitants	*ln_pat_num*	Natural logarithm of pat_num_pop
Log of lagged net of tax	*ln_net_of_tax_lag3*	Natural logarithm of net_inc, which was previously lagged by 3 years
Log of GDP per capita	*ln_gdp_pc*	Natural logarithm of gdp_cap
Tax credit dummy, lagged	*tax_cred_lag3*	Tax credit dummy lagged by 3 years

Descriptive Statistics

Table A.1: Main Regression Dataset
Summary statistics: Mean, Minimum, Maximum, Range (by year)
year: 2000

	mean	min	max	range
Number of Patents by Population	181.371	4	529.42	525.42
GDP per capita	43501.268	21497.5	93462.926	71965.426
Net of tax	.653	.484	.76	.276

2001				
Number of Patents by Population	189.849	4.84	578.563	573.723
GDP per capita	44194.559	21761.331	94695.34	72934.009
Net of tax	.668	.598	.8	.202
2002				
Number of Patents by Population	156.202	1.115	599.257	598.141
GDP per capita	38682.497	11161.463	97287.598	86126.135
Net of tax	.69	.598	.84	.242
2003				
Number of Patents by Population	156.637	4.279	610.622	606.343
GDP per capita	37763.072	11782.994	97678.46	85895.466
Net of tax	.701	.604	.875	.271
2004				
Number of Patents by Population	147.637	1.177	645.696	644.519
GDP per capita	36480.374	9612.57	99778.47	90165.9
Net of tax	.725	.617	.875	.258
2005				
Number of Patents by Population	158.864	1.49	767.513	766.023
GDP per capita	36302.564	9954.042	101380.77	91426.733
Net of tax	.74	.616	.875	.259
2006				
Number of Patents by Population	162.187	2.128	753.707	751.58
GDP per capita	37603.557	10571.035	104943.44	94372.404
Net of tax	.741	.616	.875	.259
2007				
Number of Patents by Population	169.822	3.2	810.606	807.406
GDP per capita	39042.392	11323.661	111968.35	100644.69
Net of tax	.748	.616	.875	.259
2008				
Number of Patents by Population	166.138	3.424	754.198	750.774
GDP per capita	40838.885	11797.642	108577.35	96779.709
Net of tax	.759	.656	.875	.219
2009				
Number of Patents by Population	162.503	3.53	753.799	750.269
GDP per capita	38678.609	11551.107	101939.61	90388.506
Net of tax	.759	.656	.875	.219
2010				
Number of Patents by Population	165.797	2.864	804.675	801.811
GDP per capita	39232.351	11383.522	104965.31	93581.784
Net of tax	.761	.656	.875	.219
2011				
Number of Patents by Population	169.063	6.748	855.736	848.988
GDP per capita	39662.776	12342.602	105264.75	92922.148
Net of tax	.761	.639	.875	.236
2012				
Number of Patents by Population	169.303	5.181	819.277	814.096
GDP per capita	39411.543	13027.971	102404.61	89376.641
Net of tax	.762	.639	.875	.236

2013				
Number of Patents by Population	167.489	6.653	750.411	743.758
GDP per capita	39530.202	13472.465	103721.75	90249.284
Net of tax	.76	.62	.875	.255
2014				
Number of Patents by Population	163.489	5.724	733.154	727.43
GDP per capita	40165	13745.954	105658.52	91912.567
Net of tax	.764	.62	.875	.255
2015				
Number of Patents by Population	164.756	8.485	778.033	769.548
GDP per capita	41311.607	14414.254	107638.21	93223.958
Net of tax	.765	.62	.875	.255
2016				
Number of Patents by Population	165.518	7.789	826.032	818.242
GDP per capita	42060.293	14891.767	110162.12	95270.355
Net of tax	.769	.656	.875	.219
2017				
Number of Patents by Population	163.959	8.778	707.758	698.979
GDP per capita	43018.957	15512.725	109452.96	93940.235
Net of tax	.771	.556	.91	.354

Table A.2: Secondary Regression Dataset
Summary statistics: Mean, Minimum, Maximum, Range (by year)
year: 1981

	mean	min	max	range
Number of Patents by Population	44.9	.509	218.776	218.267
GDP per capita	28011.199	12463.936	55466.164	43002.227
Net of tax	.522	.385	.67	.285
1982				
Number of Patents by Population	48.04	.101	230.978	230.877
GDP per capita	28177.542	12652.502	54420.972	41768.47
Net of tax	.515	.382	.67	.287
1983				
Number of Patents by Population	52.116	.101	243.225	243.124
GDP per capita	28624.313	12572.133	54534.426	41962.293
Net of tax	.512	.385	.67	.285
1984				
Number of Patents by Population	59.565	.1	277.232	277.132
GDP per capita	29426.028	12288.433	55973.701	43685.268
Net of tax	.518	.382	.671	.289
1985				
Number of Patents by Population	63.935	.2	279.589	279.39
GDP per capita	30286.863	12598.913	57774.344	45175.431
Net of tax	.513	.382	.681	.299
1986				
Number of Patents by Population	67.469	.199	274.949	274.75
GDP per capita	31025.84	13108.701	58641.979	45533.278
Net of tax	.529	.4	.683	.283

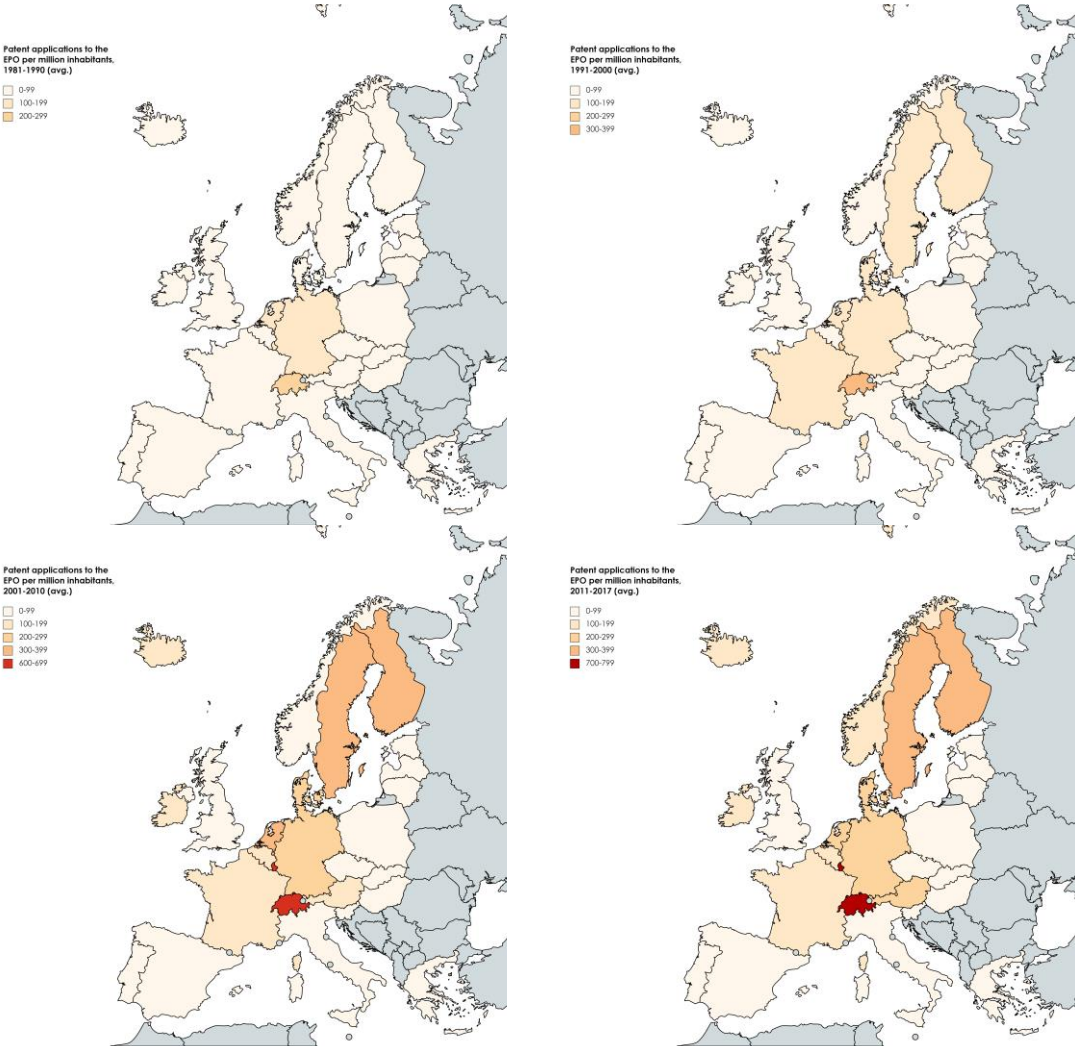
1987				
Number of Patents by Population	70.031	.598	287.733	287.135
GDP per capita	31660.933	13948.976	59391.574	45442.598
Net of tax	.532	.4	.683	.283
1988				
Number of Patents by Population	78.035	.898	315.983	315.086
GDP per capita	32603.269	15009.225	60588.597	45579.373
Net of tax	.536	.4	.694	.294
1989				
Number of Patents by Population	83.986	.699	337.161	336.462
GDP per capita	33594.605	15999.244	62703.529	46704.285
Net of tax	.563	.399	.7	.301
1990				
Number of Patents by Population	89.673	.5	351.671	351.171
GDP per capita	34371.77	16667.585	64343.519	47675.934
Net of tax	.584	.455	.7	.245
1991				
Number of Patents by Population	78.366	.501	315.96	315.458
GDP per capita	34579.974	17435.799	62962.391	45526.592
Net of tax	.605	.438	.723	.285
1992				
Number of Patents by Population	82.243	1.407	321.946	320.539
GDP per capita	34769.203	17639.468	63629.689	45990.221
Net of tax	.628	.418	.72	.302
1993				
Number of Patents by Population	83.988	1.507	321.224	319.717
GDP per capita	34631.788	17257.922	65051.798	47793.875
Net of tax	.64	.435	.75	.315
1994				
Number of Patents by Population	86.582	2.907	302.645	299.737
GDP per capita	35595.515	17377.609	67952.427	50574.818
Net of tax	.641	.468	.75	.282
1995				
Number of Patents by Population	93.291	2.183	318.136	315.953
GDP per capita	36544.277	18059.224	70409.719	52350.496
Net of tax	.639	.449	.75	.301
1996				
Number of Patents by Population	99.712	2.091	342.379	340.288
GDP per capita	37386.946	18621.914	73575.993	54954.079
Net of tax	.638	.441	.72	.279
1997				
Number of Patents by Population	116.13	2.281	400.771	398.49
GDP per capita	38713.675	19354.835	77045.295	57690.46
Net of tax	.636	.432	.72	.288
1998				
Number of Patents by Population	132.071	2.368	448.251	445.883
GDP per capita	39962.857	20183.147	78597.916	58414.769
Net of tax	.647	.44	.722	.282
1999				

Number of Patents by Population	144.171	4.516	473.501	468.985
GDP per capita	41207.625	20853.33	79632.82	58779.49
Net of tax	.656	.48	.749	.269
2000				
Number of Patents by Population	160.543	4	529.42	525.42
GDP per capita	42763.17	21497.5	81653.345	60155.844
Net of tax	.659	.484	.76	.276
2001				
Number of Patents by Population	170.308	4.84	578.563	573.723
GDP per capita	43459.023	21761.331	82926.769	61165.437
Net of tax	.674	.597	.8	.203
2002				
Number of Patents by Population	171.929	3.944	599.257	595.313
GDP per capita	43870.869	21809.324	83673.637	61864.313
Net of tax	.681	.597	.84	.243
2003				
Number of Patents by Population	172.893	5.266	610.622	605.356
GDP per capita	44155.518	21525.423	83941.366	62415.942
Net of tax	.687	.604	.875	.271
2004				
Number of Patents by Population	180.702	6.684	645.696	639.012
GDP per capita	45310.849	21858.124	86759.142	64901.017
Net of tax	.692	.617	.875	.258
2005				
Number of Patents by Population	191.335	6.381	697.63	691.249
GDP per capita	46147.118	21988.189	88432.62	66444.431
Net of tax	.707	.616	.875	.259
2006				
Number of Patents by Population	198.589	10.814	753.707	742.894
GDP per capita	47432.379	22305.244	89828.425	67523.181
Net of tax	.709	.616	.875	.259
2007				
Number of Patents by Population	204.742	9.589	768.305	758.715
GDP per capita	48608.845	22819.504	91565.733	68746.23
Net of tax	.719	.616	.875	.259
2008				
Number of Patents by Population	205.291	9.949	754.198	744.249
GDP per capita	48327.764	22859.369	90862.4	68003.03
Net of tax	.731	.656	.875	.219
2009				
Number of Patents by Population	198.483	10.906	736.316	725.41
GDP per capita	46113.14	22124.58	88174.158	66049.578
Net of tax	.732	.656	.875	.219
2010				
Number of Patents by Population	201.859	6.526	743.019	736.493
GDP per capita	46741.304	22498.691	87693.79	65195.099
Net of tax	.733	.656	.875	.219
2011				
Number of Patents by Population	206.009	7.731	763.138	755.407

GDP per capita	47071.845	22149.631	87413.177	65263.546
Net of tax	.735	.639	.875	.236
2012				
Number of Patents by Population	206.675	8.298	742.961	734.662
GDP per capita	46732.952	21337.286	88604.575	67267.289
Net of tax	.735	.639	.875	.236
2013				
Number of Patents by Population	206.113	9.088	733.046	723.958
GDP per capita	46655.683	21256.76	88444.895	67188.135
Net of tax	.733	.62	.875	.255
2014				
Number of Patents by Population	201.075	10.525	692.169	681.644
GDP per capita	47287.618	21540.988	89175.5	67634.512
Net of tax	.738	.62	.875	.255
2015				
Number of Patents by Population	200.821	9.67	709.546	699.875
GDP per capita	48608.546	22018.009	90029.356	68011.346
Net of tax	.74	.62	.875	.255
2016				
Number of Patents by Population	199.523	7.789	717.414	709.625
GDP per capita	49259.355	22533.632	90195.964	67662.331
Net of tax	.746	.656	.875	.219
2017				
Number of Patents by Population	204.813	9.565	707.758	698.192
GDP per capita	50374.045	23052.986	91549.038	68496.052
Net of tax	.744	.556	.875	.319

Number of Patent Applications per Million Inhabitants Over Time

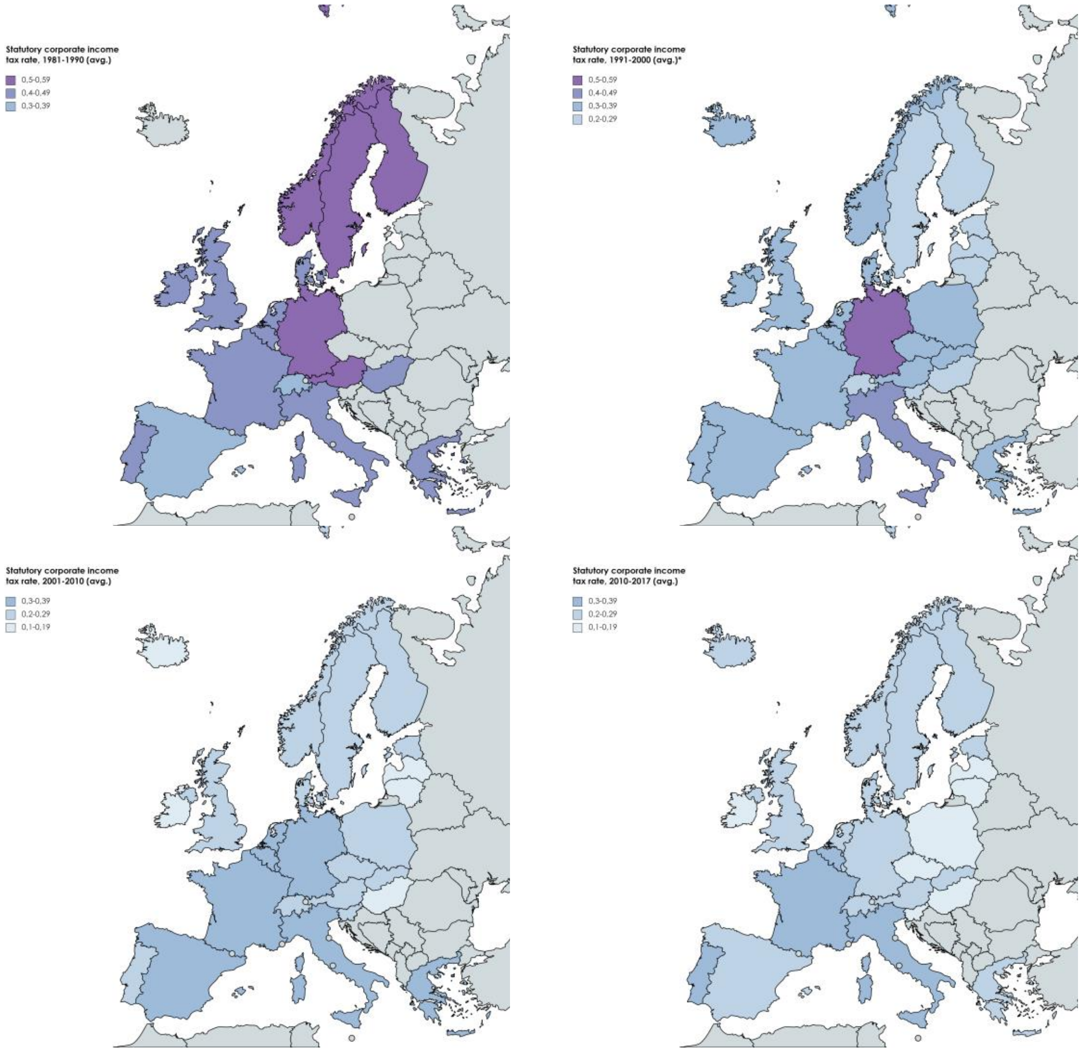
Figure 1



Notes: The four maps depict the average number of patent applications to the EPO per million inhabitants for the period 1981-2017 in decade-long increments, from left to right and top to bottom.
Maps created with mapchart.net

Statutory Corporate Income Tax Rate Over Time

Figure 2



Notes: The four maps depict the average statutory coroprate income tax rate for the period 1981-2017 in decade-long increments, from left to right and top to bottom.
*For the period of 1991-2000, for some countries only data on the year 2000 was available. In this case, that year's corporate income tax rate was used instead of an average.
Maps created with mapchart.net