STOCKHOLM SCHOOL OF ECONOMICS
Department of Economics
Bachelor's Thesis, Course 659
Spring 2013

THE SHORT-TERM EFFECT OF PATENT BOX REGIMES

A study of the actual impact of lowered tax rates on patent income

Per Hassbring[∞] Erik Edwall[♂]

Abstract:

In an effort to secure future economic growth, several European countries have adopted policies putting significantly lower tax rates on income derived from patented products–implementing so called Patent Box Regimes. A handful of recent studies show that firms actively relocate intellectual property to low-tax countries using foreign subsidiaries. In this paper, we provide evidence that there has been a short-term effect on where and to what extent patent applications are filed because of the implementation of these tax policies. Using data from 21 OECD countries from 2000-2010, we estimate the effect on the aggregate number of patent applications using pooled ordinary least squares, including country and year fixed effects to account for unobserved heterogeneity. We find that Patent Box countries on average have experienced a 20.6 percent increase in foreign inventor patenting. At the same time, domestic inventors' propensity to patent R&D activities has increased by 14.6 percent. Despite concerns of serial correlation and endogeneity, we conclude there is evidence of Patent Boxes having a positive effect on the number of patent applications to the European Patent Office.

JEL Classifications: F23, H3, O3
Key Words: patent box, corporate tax, intellectual property, multinational firms

Date submitted: May 15th, 2013
Date presented: June 3rd, 2013
Supervisor: Yoichi Sugita
Examiner: Örjan Sjöberg
Opponents: Jessica Guter, Jakob Nyström

∞ 22357@student.hhs.se
♂ 22293@student.hhs.se

Acknowledgement

We thank our supervisor Yoichi Sugita, Assistant Professor at the Department of Economics at the Stockholm School of Economics, for valuable guidance and support in all aspects of this paper. We would also like to give a special thanks to Jan Eklöf, Associate Professor at the Statistics Department at the Stockholm School of Economics, for invaluable guidance regarding our econometric approach.

We also express our gratitude to Lars Bager-Sjögren, Senior Economist at Swedish Agency for Growth Policy Analysis, for early guidance on the topic.

Table of Contents

List of Tables

List of Figures

Introduction

In an increasingly competitive global economy, countries are struggling to fight soaring unemployment levels and faltering growth rates. At the center of these developments are intellectual property rights, playing a key role in protecting valuable innovations that can potentially improve the future economic performance of countries. As the first academic study of its kind, this paper examines the actual short-term effects of Patent Box regimes, recent tax policy changes where a group of countries have introduced significantly lowered tax rates on income derived from patented products. In order to promote growth-spurring innovative activities, policymakers in several important economies around the world thus use tax incentives to increase domestic ownership of patents and other intellectual property (IP). Interestingly, the use of patent applications as a unique measure of innovation is largely subject to discussion (Lazarus, 2001), although one cannot ignore the fact that patents reflect the results of innovative processes. As policymakers engage in tax competition through Patent Boxes, they risk tax revenue losses while outcomes are uncertain. We reason that the first step of exploring these developments is to assess whether or not there have been an effect on patent applications.

Up until this point, lack of sufficient data has encumbered evaluation of the quantitative effects of the tax policies employed. However, recent papers have examined the impact of tax rates on the location of IP (Rachel Griffith, Helen Miller and Martin O'Connel, 2011; Tobias Böhm, Tom Karkinsky and Nadine Riedel, 2012), generating a coherent conclusion that "tax rate is an important determinant of location choice" (Griffith et al. 2011). In this paper we evaluate the Patent Box regimes and if their actual short-term effects on patenting have been as significant as earlier research suggests. While Griffith et al. (2011) estimate the future effects of Patent Boxes using historical data from 1985-2005, we instead center our attention on the years before and after the introductions of Patent Boxes with a data set covering the years 2000-2010. As the studied tax policies have been introduced 2005-2008, at least three years of application data is available after the introductions of the Patent Box regimes.

Through a review of relevant previous literature and drawing from an economic framework building on Nancy Gallini, Jonathan Putnam and Andrew Tepperman (2001), we expect positive effects of tax breaks on the number of patent applications to the European Patent Office (EPO) from an

average country. Altogether, firms are expected to utilize income shifting strategies and patent larger shares of their innovative activities. However, due to considerable heterogeneity in firms' decisions of where to locate patents, the aggregate effect can be deemed uncertain. We use data from the Worldwide Patent Statistical Database (PATSTAT) on the number of patent applications of different nationalities to evaluate the aggregate effects.

In an analysis of 21 OECD countries, we conclude there is indicative support for our hypotheses. Pooled ordinary least squares (OLS) estimations using fixed effects attributable to countries and years show that the Patent Box dummy variable has economically large and statistically significant effects. The number of patent applications and the propensity to patent amongst foreign and domestic firms are positively affected by the policy change. Our results suggest an increase in domestic inventor propensity to patent of 14.6 percent and in foreign inventor patenting by 20.6 percent. These results correspond to previous research on the relocation of mobile intangible assets as consequence of lowered corporate tax rates. Our findings add to the current state of knowledge by revealing the previously unexplored effect of Patent Boxes. However, as our estimates are likely subject to potential inconsistencies and biases, we reserve the results to be of an indicative nature.

Background

Patent Box Regimes

There are currently ten countries allowing corporate income from the sales of patented products, or other types of IP, to be taxed at a lower rate. The use of the word "box" simply refers to the box on the tax declaration form that should be ticked off if one wants to take advantage of the lower tax rate. The ten nations–Belgium, China, France, Hungary, Ireland, Luxembourg, the Netherlands, Spain, Switzerland and the UK–have adopted Patent Boxes at different points in time, Ireland being the first in 1973 while the UK implemented it as recently as April, 2013 (PricewaterhouseCoopers, 2012).

One of the Patent Box's main objectives is to incentivize the commercialization of research and development (R&D) activities into patents or other forms of qualified IP (Atkinson and Andes, 2011). Another objective is to provide a more attractive location for firms to locate their mobile intangible assets in. Intuitively, by easing the taxation of IP-qualified income a country will reduce the outflow of IP to tax havens, offsetting the expected loss in tax revenues (Griffith et al., 2011). Furthermore, it is difficult for individual firms to reap the full benefits from patents and IP because of the presence of knowledge spillovers to society, making it reasonable for policymakers to incentivize innovation[1]. One key aspect of the Patent Box therefore is to target the common R&D market failure by allowing for even higher individual returns on patents and other IP[2].

The UK Intellectual Property Office motivates its implementation of the Patent Box: "Patents [...] have a strong link to R&D and high-tech manufacturing and are used by innovative companies in a wide range of sectors [...] It will provide an incentive for these companies in the UK to develop new innovative patented products [...] This will encourage companies to locate the high-value jobs associated with the development, manufacture and exploitation of patents in the UK and maintain the UK's position as a world leader in patented technologies.".

---

[1] For a detailed discussion of market failures see "Do subsidies to commercial R&D reduce market failures? Microeconomic evaluation studies" by Tor Jacob Klette, Jarle Moen and Zvi Griliches.

[2] Prominent economists Paul Romer and Paul Krugman laid the foundation of the widely accepted notion that spillovers from economic knowledge across agents and firms is vital in generating increasing returns and ultimately economic growth (Audreutsch and Feldman, 1996).

Patent Box regimes differ across countries. Patents are considered to qualify as IP, though some countries have broadened the definition of what can be classified as IP-income. For example, Ireland, Luxembourg, Spain and Switzerland admit income from designs, copyrights and trademarks to be taxed at the lower patent box rate while China even allows commercial know-how, such as process innovation, to be taxed at the lower rate[3].

The various Patent Box regimes also operate different tax rates. For example, Ireland has a zero rate with a progressive income cap that eventually reaches the statutory tax rate of 10 percent. UK will gradually reach a 10 percent rate over four years from 2013-2017 (PricewaterhousCoopers, 2012). Switzerland applies a rate between zero and 12 percent depending on what is decided during the tax ruling process. France and Spain have the highest rates, but at 15 percent they are still significantly lower than the ordinary statutory corporate tax rates[4]. Belgium and Luxembourg differs in allowing for an 80 percent deduction on taxable profits, effectively resulting in effective tax rates of 6.8 and 5.9 percent respectively[5].

[3] Another aspect where the Patent Box regimes contrast each other involves the treatment of acquired IP. The majority of the countries allow acquired IP to qualify, meaning licensed IP from another firm that in turn generates income is taxed at the lower Patent Box rate as well. Only the Netherlands and Spain restrict their Patent Box more by excluding licensed IP-income from the lower tax rate. All countries except China approve R&D performed abroad, meaning there is generally no need to relocate R&D activities to be able to utilize a Patent Box.

[4] France has a statutory corporate tax rate of 34% and Spain has a statutory tax rate of 25% (PwC, 2013).

[5] More detailed information about Patent Boxes can be found in Table 1 (p. 17)

The EPO Application

An invention must fulfill three requirements to be eligible for an EPO application: "[…] it must be new, industrially applicable and involve an inventive step." (European Patent Office, 2013). Patents as a form of IP should not be confused with others such as copyrights, trademarks, utility models and design. The patent is applied for in those countries where the firm wishes to protect its invention from being imitated. The application procedure can mainly be done in two ways: a firm operating in several markets can proceed by applying to the EPO where one single application is sufficient in order to receive protection in the countries selected by the inventor. If the applicant instead chooses to apply for a patent in less than four countries, he or she is instead recommended to apply directly to national patent offices (EPO, 2013). In this paper we will narrow down the scope and solely focus on EPO applications.

Prior Research

In the following, we summarize the current state of knowledge in the relevant topics surrounding Patent Boxes. First, we summarize recent studies made on ways of incentivizing patenting through improving the legal environment. Second, we look at the research covering the location of IP rights with regard to tax rates. Third, we consider firm heterogeneity and what parameters affect the individual firm's choice of where to locate its IP rights. Lastly, we briefly review the research on fiscal incentives to increase R&D and subsequently innovation.

Strength of Patent Rights and the Propensity to Patent

In a paper by Gallini et al. (2001)[6], the authors strive to determine if policy changes increasing the strength of patent rights have a positive effect on the *propensity to patent*, measured by patenting per unit of research and development (R&D). They find that the support for a causal relationship between the strengthening of patent rights and increased patenting is weak. However, they are able to find robust evidence of that it impacts an inventor's propensity to patent in another country. Using aggregate data from 17 countries during 1980-1995, they test their model examining the propensity to patent using two separate dependent variables, finding robust evidence of that the strength of patent rights incentivize foreign patenting. The variables used are defined as the number of patents applied for in a foreign country divided by two forms of the innovative effort in the inventors' country[7]. Subsequently, they apply the model to Canada's recent reform strengthening IP rights protection. They conclude that the model in general has a decent fit, however overpredicts the foreign propensity to patent in Canada. This is considered attributable to the heterogeneity in patenting decisions across different industries.

Tax Rates and the Location of Patent Rights

In a central piece of prior research, Griffith et al. (2011) estimate the impact of corporate tax rates on where firms choose to hold patents, drawing from classic work by Hall and Jorgenson (1967)[8]

---

[6] Their paper builds on literature supporting the notion that strength of IP rights impacts the propensity to patent (following prior work by Hall and Ziedonis, 2001; Hicks, Breitzman, Olivastro and Hamilton, 2001; Rafiquzzaman and Whewell, 1998; Rafiquzzaman, Mohammed, Whewell and Lori., 1998; Scherer and Weisburst, 1995; Arundel and Kabla, 1998 (All focusing on different geographical areas).

[7] The innovative effort of a country is proxied by R&D expenditure or the sum of applications from that country

[8] Hall and Jorgenson (1967) used the neoclassical theory of optimal capital accumulation to study the relationship between tax policy and investment expenditure.

and using a unique data set matching accounting data with patent application data. They also estimate the elasticities between countries regarding patent applications and predict the future outcome of Patent Boxes in Europe. Here, they find strong relationships between low tax countries and the migration of patents[9]. In a study of how multinational firms determine where to locate intangible assets, Lipsey (2008) argues that tax and legal strategies are the basis for the location of intangible assets. Böhm et al. (2012) add to these findings by concluding, "[…] low patent income tax rates are instrumental in attracting foreign patent holdings" (p. 2). They also find that patents with high earnings potential, or of high quality, are more likely to be relocated to lower tax jurisdictions[10]. Further empirical work by Dischinger and Riedel (2011) show that intangible assets owned by multinational firms often are placed in subsidiaries that face low corporate tax rates. Grubert and Mutti (2008) find similar evidence of this in the US, where the amount of R&D activities is correlated with corresponding earnings in low-tax countries, indicating that patents are being placed in offshore subsidiaries. Summarizing the above, we can conclude firms respond to tax rates and take action to benefit from low-tax environments.

Firm Location Choices and Heterogeneity

Across firms, the costs and benefits of investing or locating mobile intangible assets in certain geographical areas can vary substantially. This considerable heterogeneity in firm choices means tax rate will be far from the only factor considered when a firm chooses how and where to locate its IP-rights (Cohen, 2012). Although tax conditions may be favorable in some countries, other factors can indeed make it reasonable for firms to stay in higher tax countries. For example, some countries use so called Controlled Foreign Company (CFC) regimes, containing transfer pricing rules that make it harder for multinational enterprises (MNEs) to lower tax burdens by paying royalties to subsidiaries established in tax havens[11]. Also, the benefits that high tax rates often entail, such as developed infrastructure and high quality institutions, may lower the relative attractiveness of low tax jurisdictions. Moreover, firm characteristics such as size, organizational structure, tax strategies

[9] For example, the UK is expected to lose a significant amount of its EPO applications as a result of Patent Boxes in the Benelux countries (Griffith et al., 2011).
[10] A recent theoretical study by Becker and Fuest (2007) confirms this and explains how tax rates distorts the location of assets and functions so that those of the highest values are driven to lower tax locations.
[11] CFC prevents firms from avoiding taxed in their home-country by making it more difficult of shifting income towards lower taxed countries. Countries that have adopted CFC regimes immediately tax income originating from foreign subsidiaries if a set of criteria are fulfilled. For more info, see "The Impact of Corporate Taxes on R&D and Patent Holdings" by Böhm et al. 2012 (p. 5).

employed, headquarter location and industry can all play a pertinent role in the decision of where to locate patents (emphasized by Melitz, 2003; Bernard, Redding and Schott, 2007). For example, Graham and Tucker (2006) not surprisingly find that larger multinationals use low tax jurisdictions more intensively. Desai, Foley and Hines (2006) emphasize industry as an important factor that affects firm decisions in tax strategies. Thus, recent literature indicate that there is heterogeneity in firm choices. This has to be considered when estimating a model that seeks to determine the short-term aggregate effect of Patent Boxes.

Fiscal Incentives and Innovation

Policymakers have long tried to stimulate innovation via tax incentives on R&D. Previous research by Bloom, Griffith and Van Reenen (2002) and others find that tax changes have an effect on level of R&D (Bloom et al., 2002)[12]. However, there are often other supplementary policy goals with such fiscal incentives. A desirable outcome is increased commercialization of R&D, for example through patenting. There are a handful of papers addressing the effects of R&D tax incentives on output in terms of innovation, growth and productivity. For example, Czarnitzki et al. (2011) use data from 1997-99 on Canadian manufacturing firms and assess if fiscal R&D incentives increase the number of newly introduced products of various level of innovation, finding some positive relationships. Cappelen et al. (2012) added to this topic through studying the effects of a Norwegian R&D tax credit scheme for small and medium sized enterprises' innovation activities and patenting. Using micro data covering firms included in the tax reforms during 2001-2004, they find that the tax credit scheme contributed to the development of new-to-the-firm products and new processes. Despite this, they find no evidence of an increase in the probability of introducing a new-to-the-market products or applying for patents. Prior findings tend to be varying depending on the country studied and the econometric methods used[13]. Nevertheless, it is likely there is additional innovation output after implementing some sort of tax incentive.

---

[12] Bloom, Griffith and Van Reenen (2002) estimate an econometric model using a cross-country panel data set on tax changes and R&D spending in nine OECD countries. With an instrumental variable approach they investigated the elasticity of R&D with regard to its user cost and argued that tax changes do have an effect on level of R&D, however not substantial.

[13] Cappelen et al. (2007) and Colombo et al. (2011) do for example investigate effects of R&D tax incentives on productivity. No significant effects were found. Falk et al. (2009) test if R&D tax incentives has effects on innovation success. They find evidence that fiscal R&D incentives do increase some innovative dimensions of firms.

Concluding Remarks

Summing up the different aspects of the prior research discussed above, we can conclude that policy changes regarding the strengthening of IP rights protection in certain countries are found to increase foreign propensity to patent there. Furthermore, the relationship between location of patents and tax rates is strong, indicating that firms locate mobile intangible assets such as patents in low-tax countries. Still, other recent literature shows there are other aspects affecting a firm's choice of where to locate IP, for example certain benefits of higher tax economies, home-country CFC regulations and organizational structures of firms. These aspects potentially mitigate the attractiveness of a Patent Box. We reason that these conclusions are relevant to our paper as they provide us with an understanding of how firms react on the aggregate. Griffith et al. (2011) predicts the implementation of Patent Boxes in European countries should have a significant effect on the allocation of patent applications. As no previous research has examined the real impacts of these recent policy changes, we think it is of great relevance to assess if there is evidence of a short-term effect of Patent Boxes.

Theory

In the following sections we build an economic framework for patenting using an interpretation of Gallini et al.'s (2001) economic framework on the propensity to patent, defined as patent applications per unit of R&D[14]. We are thus able to illustrate theoretically why it is economically viable to expect an impact on patenting as a result of tax changes. To facilitate the formulation of our hypotheses, we model simplification of the R&D process containing the main parameters affecting investment in R&D and patent location decisions.

An Economic Framework

In Gallini et al. (2001), the authors examine if inventors from a country *i* patents a greater proportion of their inventions in a destination country *j* after a policy change strengthening IP rights protection in country *j* is introduced. They formalize a model explaining why inventors apply for patents in a certain destination country *j*. Parameters from both the source country *i*, where the invention is created, and the destination country *j*, where the invention is patented, are used to explain this theoretically. By doing so they manage to isolate a set of country specific features intuitively explaining patenting activity.

We argue that the same economic framework can help us explain why an inventor is prone to apply for a patent *via* a specific foreign country *j*, using a subsidiary, in order to reap the benefits of a favorable tax environment in that country. There is an important difference between our theoretical approach and theirs'; we consider patent applications to the EPO via a country *j* that originates from an inventor in source country *i*. Our interpretation will therefore primarily focus on if foreign firms to a larger extent apply for patents via a foreign country as a result of lower tax rates on patent income. In addition to this, we apply the theoretical framework from the perspective of a domestic inventor in country *j* and explain how Patent Boxes affect domestic firms' propensity to patent to the EPO. Thereby, we investigate if a greater proportion of country *j*'s R&D expenditure will be patented.

[14] Gallini et al. (2001) further based their analysis on Eaton and Kortum (1996) and Kortum and Lerner (1998).

The framework is based on two main decisions that are made simultaneously; The *patenting location decision* and the *investment decision*. In the patenting location decision it is assumed that the investment is made and the research has already been conducted. The inventor therefore chooses how many of the inventions to patent via country *j* and country *i*, implicitly assuming that the inventions will be patented. In the investment decision, the level of investment in research projects directed towards patentable inventions is determined. Below, we focus on these two decisions separately and complete the framework.

The Patenting Location Decision

The patenting location decision is based on the expected return of the patent. This return is alternated by country specific parameters. More explicitly, the return from patenting via country *i* and country *j* can differ[15]. The firm therefore bases its decision on comparing the value of patenting via destination country *j*, $v_j(s_j, x_j, z_{ij})$, with the value of patenting via source country *i*, $v_i(s_i, x_i)$. Here, *s* denotes the strength of IP rights protection, *x* captures the economic environment and *z* denotes the characteristics of the relationship between the source and the destination country[16]. Costs specifically attributable to the EPO for a given patent application are assumed to be equal regardless of the origins of the applicants. c_{net} is then recognized as the additional administrative cost of relocating the patent application via a foreign country, for example the cost of establishing and administering a foreign subsidiary. The rationale behind this assumption is that it is less costly to apply for a patent via the source country *i* than it is to apply via country *j*. If we characterize each invention having a value, or quality denoted by *q*, the firm will patent an invention via country *j* if:

$$q(v_j(s_j, x_j, z_{ij}) - v_i(s_i, x_i)) > c_{net} \qquad (1)$$

Considering this equation, we can derive the quality level of a patent that makes the inventor from country *i* indifferent between patenting via country *j* and via country *i*:

$$q_{ij}^* = c_{net} / (v_j(s_j, x_j, z_{ij}) - v_i(s_i, x_i)) \qquad (2)$$

---

[15] Gallini et al.'s (2001) work differ from ours regarding their comparison of how much the firm earns per unit of quality *q*, by patenting directly in country *j*, $v_p(s_j, x_j, z_{ij})$, with how much the firm earns if an invention is *not* patented in country *j*, $v_n(s_j, x_j, z_{ij})$.

[16] Builds on the same assumption as Gallini et al.(2001), that N_i is drawn from a distribution $f(q)$ that has a cumulative distribution of $F(q)$ and support $(0,Q)$, that yields a technology of uncertain quality, *q*.

Using equation (2), we can derive the probability that the invention is of sufficiently high quality to be eligible for patenting via country *j*. This probability is denoted ϱ_{ij}^* and is formalized by $\varrho_{ij}^* = Pr(q > q_{ij}^*)$. Utilizing a cumulative distribution function for an invention with a value of q_{ij}^* or less and substituting in the right hand side of equation (2), the probability can be expanded to the following form:

$$\varrho_{ij}^* = 1 - F(c_{net} / (v_j(s_j, x_j, z_{ij}) - v_i(s_i, x_i))) = \varrho(s_i, s_j, c_{net}, x_i, x_j, z_{ij}) \qquad (4)$$

The Investment Decision

In the investment decision, the profit-maximizing number of research projects, N_i^*, can be determined using the same parameters as in the patenting location decision. The investment decision however depends on the patenting location decision, referring to the expected value of patenting an invention of quality *q* via country *j* or country *i*[17]. This means that when $q > q_{ij}^*$, the expected value of patenting via destination country *j* is higher, and vice versa. The inventor thereby maximizes his total expected profits for all patented inventions by choosing the optimal location for each patent. The solution to the profit-maximizing number of patentable research projects N_i^* is therefore formalized as:

$$N_i^* = N(s_i, s_j, c_{net}, x_i, x_j, z_{ij}) \qquad (3)$$

Completing the Model

Using the two decisions describing via which country to patent and how much to invest in projects directed towards patentable inventions the expected number of patent applications filed via country *j* from country *i*, $E(P_{ij})$, can be formalized as:

$$E(P_{ij}) = N_i^* \varrho_{ij}^* = N(s_i, s_j, c_{net}, x_i, x_j, z_{ij}) \varrho(s_i, s_j, c_{net}, x_i, x_j, z_{ij}) \qquad (5)$$

Equation (5) emphasizes two key mechanisms through which a Patent Box regime in destination country *j* may impact the total number of patent applications to the EPO. Gallini et al. (2001) hypothesize about the first effect saying: "Stronger protection in destination country *j* may increase researcher's incentives to develop more patentable inventions if a higher return from patenting is anticipated *(the innovative effect)*." Continuing to the second: "Researchers may have greater incentives

[17] See Gallini et al. (2001) for thorough analysis of maximizing expected profit over N_i.

to patent rather than keep inventions secret for a given number of patentable inventions in source country *i* (*the patent propensity effect*)." (Gallini et al., 2001, section 8-8, p. 445). In the sections below, we explain the implications of our economic framework and state hypotheses derived from it.

Foreign and Domestic Patenting

As tax rates on patent income decrease when a Patent Box regime is implemented, the economic environment of a country (x_j) becomes more attractive for a firm considering applying to the EPO. Simply put, for a given patent quality level, the return from patenting via the Patent Box country will be higher. Ceteris paribus, the expected number of applicants from source country *i* filing via country *j* increase as an effect of the policy change. Below, this theory is related to the fundamental impacts on main actors such as multinational and domestic firms engaged in patenting activities.

Income Shifting Firms Incentivized

Patents and other IP are indeed mobile assets. Tax incentives can therefore lead to income shifting via subsidiaries, more explicitly by paying royalties to foreign entities holding patents. We reason firms capable of income shifting will be able to make use of a Patent Box in a foreign country. Studies by Becker and Fuest (2007) as well as Haufler and Stähler (2012) support the income shifting pattern and add to it by showing that the highest valued IPs are driven towards low-tax countries. This, in connection to our theoretical model, implies that a country's economic environment, affected by tax rates, can be deemed instrumental in attracting foreign ownership of patents.

An important factor directly affecting firms' decisions of where to locate patents are their home-countries' controlled foreign company rules, or CFC rules. These regulations are meant to hinder domestically based firms from earning passive income from abroad through paying royalties to offshore subsidiaries, taxing income in low-tax jurisdictions. A number of countries in our data use various forms of CFCs over the period studied, consequently making firms originating from those countries less inclined to respond to lowered tax rates in foreign countries. We control for this mitigating effect in the empirical analysis through characterizing it as constant over time, maintaining the overall view that a given firm will have clear tax-related incentives to apply for patents to the EPO via a Patent Box country.

Domestic Inventors' Propensity to Patent

As Patent Boxes has become popular instruments to attract IP rights around the world, an increasing number of innovative firms find themselves in favorable situations regarding home-

country tax rates. Firms large enough to market their products or services in several countries in Europe may well be interested in applying for patents to the EPO on a share of their inventions. When considering whether to incur the cost of patenting to the EPO or not, domestic firms facing lower tax on patent income will have stronger incentives to apply for patents as the potential value of their inventions increases. Hence, their propensity to patent might increase, here defined as the number of applications to the EPO divided by R&D expenditure[18]. One must furthermore acknowledge that not all domestic firms have reasons to apply at the EPO level and thus limit their applications to national patent offices. These firms are not accounted for in our analysis, even though they can be expected to similarly have stronger incentives to patent domestically under a Patent Box regime.

[18] Proxied by Business Enterprise R&D expenditure in million US dollars.

Summary and Hypothesis

Following the economic framework and subsequent discussion of impacts on firms, we derive our hypotheses from the perspective of a firm deciding how large the patented fraction of R&D expenditures should be and via which country to patent. Intuitively, the Patent Box is expected to have a positive effect on patenting activity via a given country that has adopted a Patent Box regime. First, foreign inventors are expected to apply for patents more intensively via subsidiaries in countries that have Patent Box regimes. Second, a given inventor is incentivized to increase the share of total patent filings abroad in those countries that have adopted a Patent Box regime. Third, firms headquartered in Patent Box countries are expected to apply for patents on a larger fraction of their
R&D activities as their economic evaluation of patentable projects improve when tax rates are lower. We therefore hypothesize the following:

Hypothesis I. The Patent Box has had a positive, aggregate short-term effect on the number of foreign inventor applications to the EPO via a given country in the sample.

Hypothesis II: A sample country's short-term propensity to patent in a foreign sample country, defined as the number of applications filed via a specific foreign country in the sample divided by the country's sum of applications via the sample countries, has increased if the destination country has adopted a Patent Box regime.

Hypothesis III: The Patent Box has had a positive, aggregate short-term effect on the number of domestic inventor applications and on an average domestic inventor's propensity to patent to the EPO.

Method and Data Presentation

The introduction of Patent Boxes in a group of countries has provided us with a natural experiment (Wooldridge, 2009, p. 453) and an opportunity to examine the effect on new applications to the EPO as a consequence of the exogenous event of a Patent Box implementation[19]. We thus consider the treatment group to be those countries, that have implemented a Patent Box, while the control group consists of countries that have not done so. Examining the validity of the stated hypotheses, an empirical approach on a dataset containing 231 cross-sectional observations from 21 OECD countries during 2000-2010 is used to draw conclusions of the causal effect of implementing a Patent Box. Pooled OLS estimations are used to examine the Patent Box policy change. To control for time-invariant unobserved effects related to each country, we include fixed effects in the form of dummy variables. Moreover, shocks experienced by all countries in a given period are controlled for through year fixed effect in time period dummy variables. In order to isolate the effect of the Patent Box, other time-varying controls affecting patenting are accounted for. The methods employed will be covered more in-depth in the following sections.

Patent Boxes

As mentioned, Patent Boxes and their structures differ across countries, sometimes considerably. However, for the purpose of evaluating the short-term aggregate effects on patent applications of recently lowered tax rates on patent income, we consider five regimes to be equal. Only countries that have introduced Patent Box regimes during the studied period will be evaluated, while traditional low tax countries like Ireland and Switzerland, having used alternative forms of Patent Boxes during many years, will not be considered as Patent Box countries[20]. Details of the Patent Boxes can be found in Table 1.

[19] The exogeneity of the Patent Box is further discussed in section 6.3.

[20] China and Hungary are removed because the absence of sufficient data, Ireland and Switzerland are not included since they are viewed as traditional tax havens.

Table 1: Detailed Summary of Patent Boxes

Country	Regular Corporate Tax Rate	Effective Corp. Tax Rate on Qualifying IP	Types of IP that Qualify	Acquired IP Qualifies?	R&D Performed Abroad Qualifies?	Year Enacted
Belgium	20%	6.8%	Patents and supplementary protection certificates	Yes, under conditions	Yes	2008
France	34%	15%	Patents and supplementary protection certificates	Yes, under conditions	Yes	2005
Luxembourg	17%	5.9%	Software, copyrights, patents, trademarks, designs or models	Yes	Yes	2008
The Netherlands	25%	10%/5% (from 2009)	Patents or IP from qualifying and approved R&D	No	Yes, but not for R&D certificate	2007
Spain	25%	15%	Most IP	No	Yes	2008 (2007 qualifies)

Source: PwC (http://businessroundtable.org/uploads/studies-reports/downloads/BRT_14_country_international_tax_comparison_20100510.pdf)

Data and Variables Description

The data set has been collected from EPO Worldwide Patent Statistical Database, OECD StatExtracts and the Economic Freedom database. Summary statistics and variable definitions are presented in Tables 2-3 below.

Table 2: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Total Applications	231	6559	10363	84	49398
Domestic Inventor Applications	231	5637	9376	50	42922
Domestic Inventor Propensity	231	0.30	0.18	0.04	0.85
Foriegn Inventor Applicants	231	896	1214	2	6443
Foreign Inventor Propensity	5082	1087	2103	15	13387
Patent Box Dummy	231	0.87	0.28	0	1
IP Rights Protection	231	8.14	0.89	5.57	9.62
BERD	231	24438	53045	315	293897
GDP/Capita	231	35211	10594	21093	84672
FDI	3710	1972	7304	15	13387

Note: Applications are counts of EPO filings from each country. IP Rights Protection is an index ranging between 1-10. GDP/Capita and FDI denoted in million US dollars.

Table 3: Variable Definitions

Variable	Variable Name	Definition	Source
APPLNS_TOTAL	Total Applications	Total nr. of applications to the EPO from a country during a year	EPO Worldwide Patent Statistical Database (PATSTAT) rev. Oct 2012
APPLNS_DOM_INVT	Domestic Inventor Applications	Nr. of applications filed from a country by a domestic inventor	EPO PATSTAT rev. Oct 2012 & OECD StatExtracts (rev. March 2013)
PROP_DOM	Domestic Inventor Propensity	Nr. of domestic inventor applications divided by Business Enterprise R&D expenditure	EPO Worldwide Patent Statistical Database (PATSTAT) rev. Oct 2012
APPLNS_FOR_INVT	Foreign Inventor Applications	Nr. of applications filed from a country by an inventor of another nationality	EPO Worldwide Patent Statistical Database (PATSTAT) rev. Oct 2012
PROP_DEST	Foreign Inventor Propensity	Nr. of applications via a particular country divided by the sum of applications filed via all sample countries	EPO Worldwide Patent Statistical Database (PATSTAT) rev. Oct 2012
PBOX	Patent Box Dummy	Binary variable assuming the value of unity if Patent Box is implemented, zero otherwise	PricewaterhouseCoopers International Tax Comparison Report May 2010
IP_RIGHTS	IP Rights Protection	Index of the quality of Legal and Intellectual Property Rights protection	2012 Economic Freedom Dataset
BERD	Business Enterprise R&D Expenditure	Gross Business Enterprise R&D Expenditure in million US $, current prices, current PPPs.	OECD StatExtracts (rev. March 2013)
GDPCAP	GDP per Capita	Gross domestic product per Capita (expenditure approach) in US $, current prices, current PPPs.	OECD StatExtracts
FDI_DEST	FDI in destination country	Foreign direct investment by partner country	OECD StatExtracts

The reason we have chosen to study a selection of OECD countries is their dominant position as the world's main patent holders and applicants. The lion's share of the world's MNEs originates from these countries and it is where the majority of global R&D investments are made each year[21].

Patent application data, containing the number of applications to the EPO, is obtained from the Worldwide Patent Statistical Database (PATSTAT) October 2012 edition[22]. Patent applications are used instead of granted patents because of the often considerable time lag between the filing of an application and the granting of a patent in each country. This improves the timeliness of our data[23]. The total number of new applications to the EPO is initially separated into foreign and domestic applications and later into cross-application counts from all countries via every other separate country. We define the origin of the inventor and applicant as the country of residence of the *first* individual or firm specified in the application[24], corresponding to EPO definitions. For example, if the first inventor specified lives in the US and the first applicant lives in the Netherlands, the application is regarded as a foreign application to the EPO from the Netherlands. Likewise, if both the first individual or firm specified as an inventor and applicant on the application originates from the Netherlands, the application is counted as a domestic inventor application from the Netherlands to the EPO. The lax definition has its limitations since an application may not in fact be of a certain nationality just because the first individual or firm specified is of that particular nationality. It is however more inclusive than using the alternative strict definition requiring that all inventors specified must originate from a certain country[25]. The implication of using a strict definition would result in potentially not counting applications that should in fact be classified as either foreign or domestic. Therefore, assuming that the country of residence of the first individual is a better measure of the origin of a given application, we choose to use the lax definition. We also disregard the possibility of country of residence not corresponding to a person's real nationality. Descriptive statistics on EPO applications are shown in Figure 1-3 below.

---

[21] Greece, Cyprus, Iceland, Hungary, Chile, Estonia, Korea, Mexico, Poland, Portugal, Slovak Republic, Slovenia, Turkey are left out because of lack of sufficient data and highly moderate patenting activity.
[22] The raw data is in turn extracted from EPO's master bibliographic database DOCDB, known as the EPO Patent Information Resource.
[23] Following previous research this is an approach based on Griffith et al. (2011) (p. 11).
[24] Drawing from the "lax" definition from Böhm et al. (2012) (p. 7).
[25] A strict definition of a foreign patent requires all applicants on the application are located in a different country than all the inventors named on the patent in order for the patent to be defined as a foreign one according to Böhm et al (2012) (p. 7).

Figure 1: Domestic Inventor Propensity to Patent

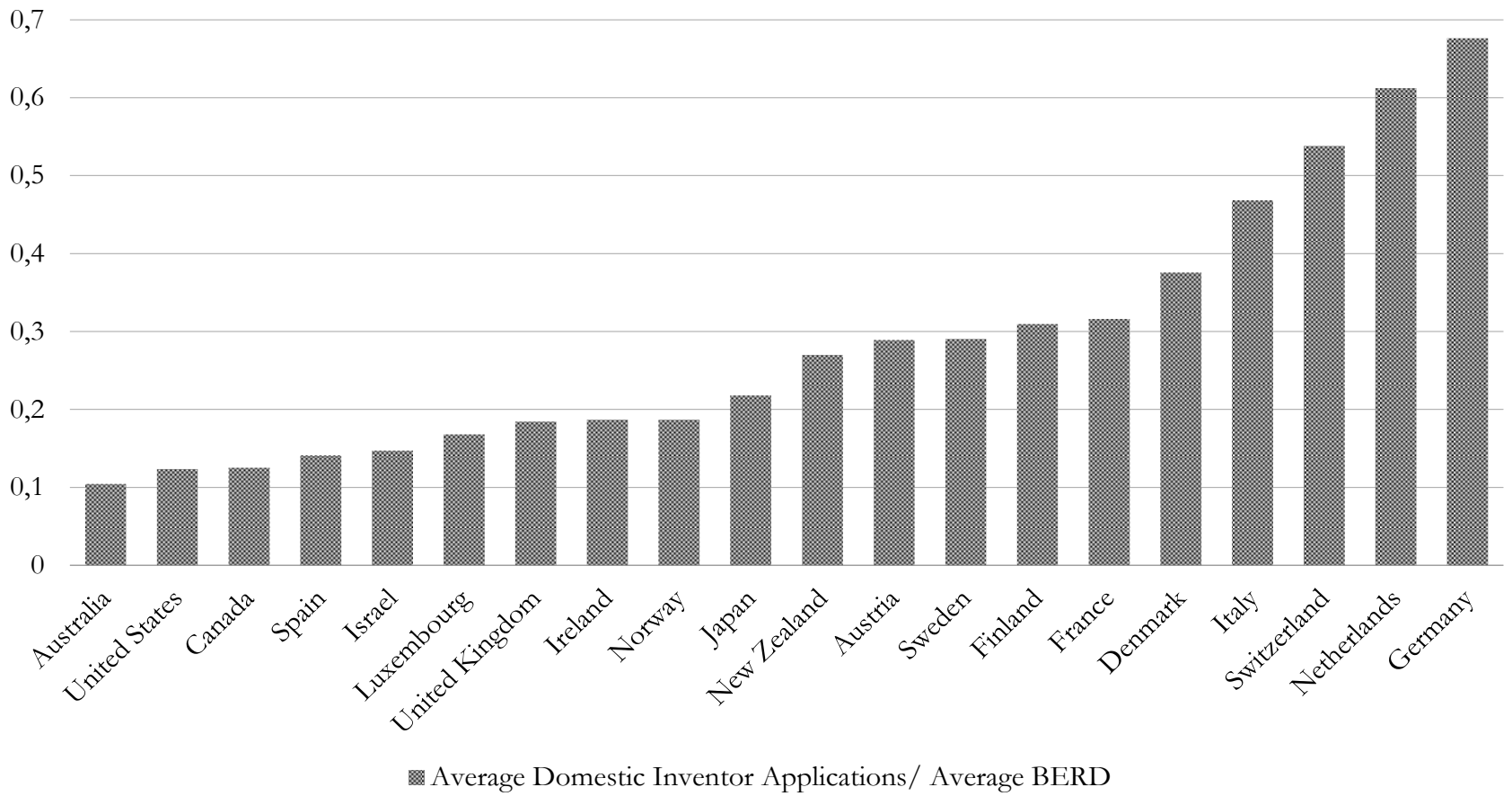


Figure 2: Share of Foreign Inventor Applications to the EPO

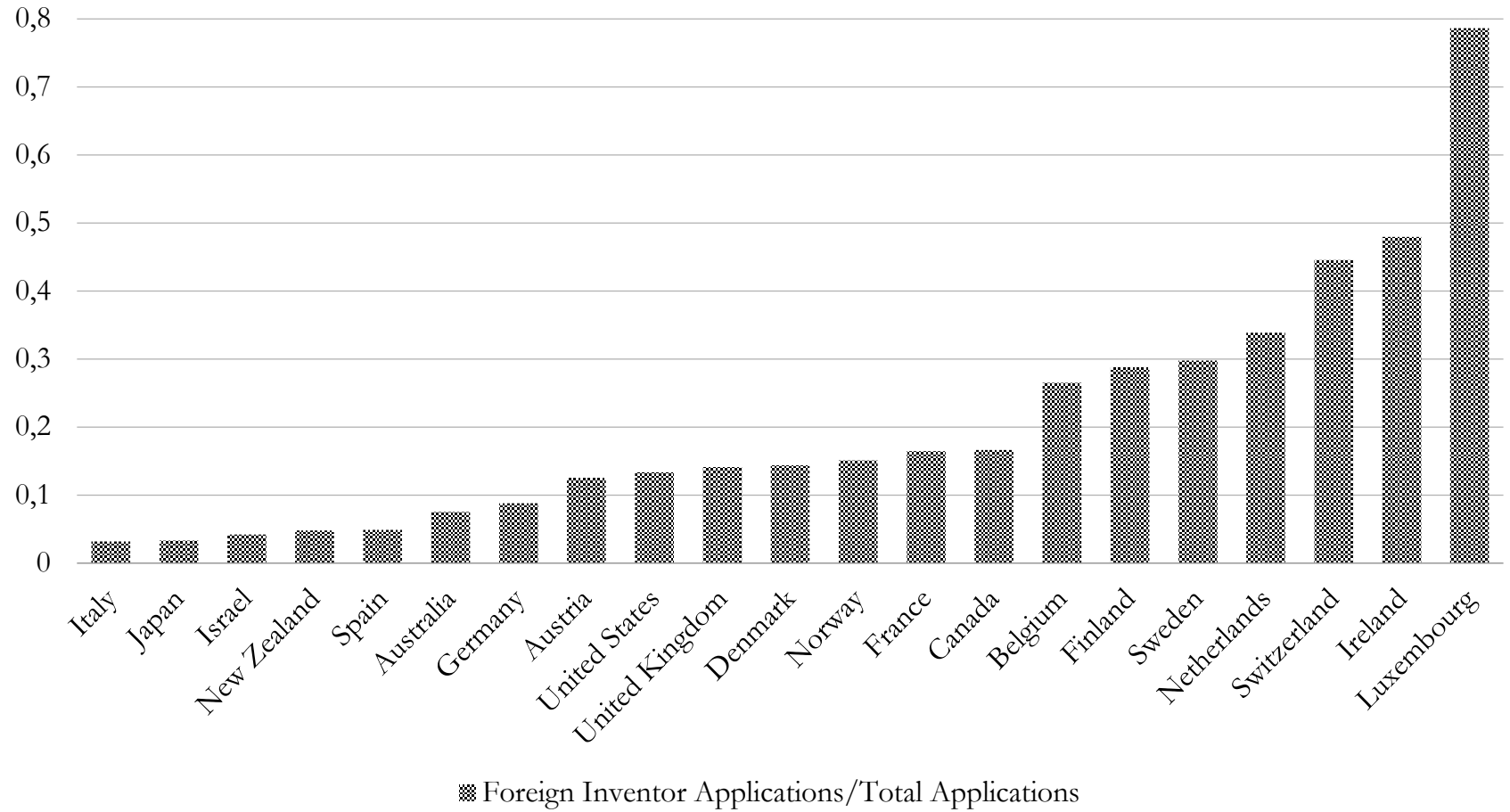
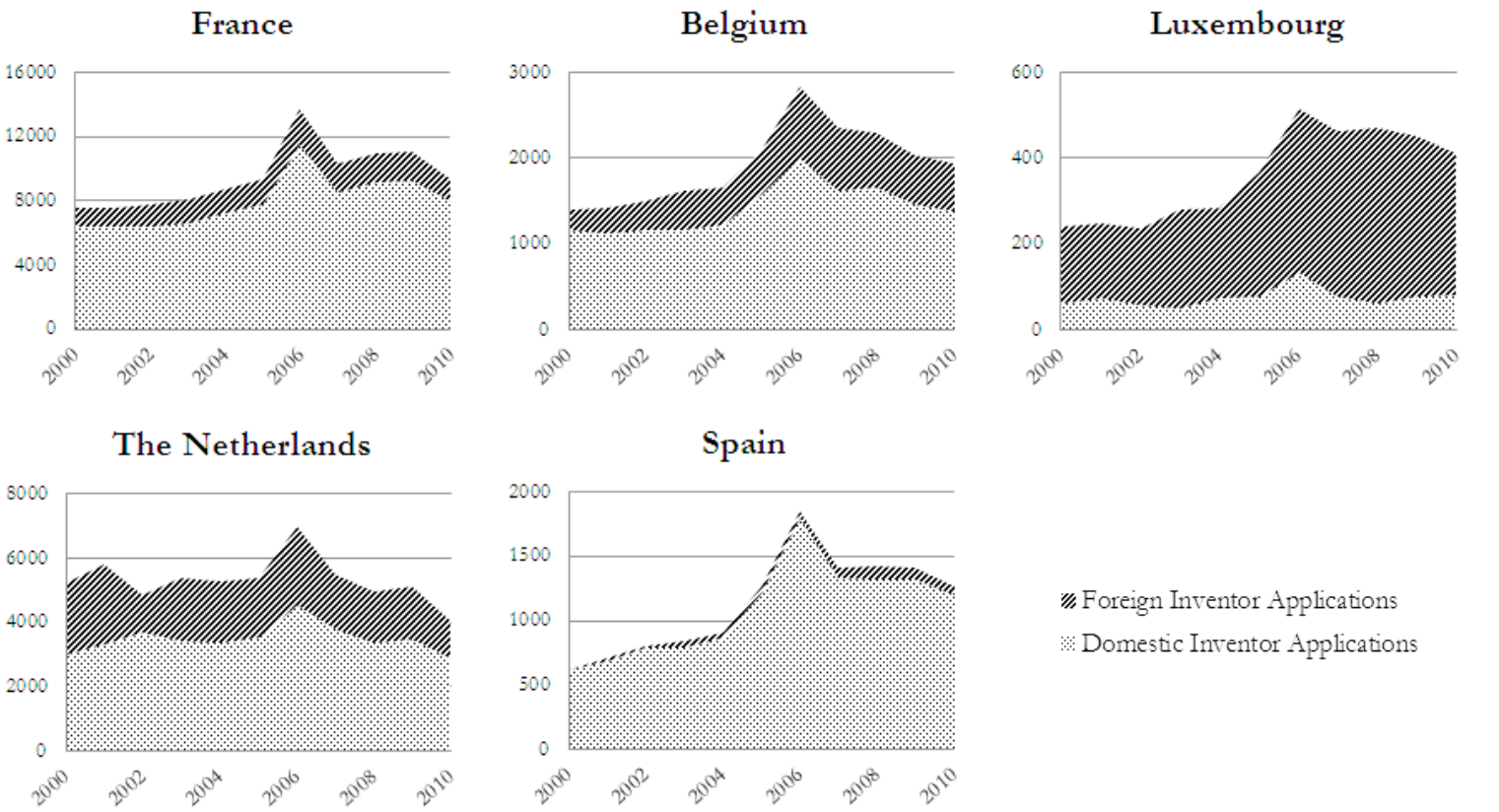


Figure 3: Domestic and Foreign Inventor Applications Per Year



Data on the strength of property rights protection is collected from Fraser Institute's database Economic Freedom of the World Data[26]. It is measured as an index of Legal System and Property Rights updated on a yearly basis. The data covers the years 2000-2010 and is used as a proxy for the strength of IP rights protection in a country.

Total Business Enterprise R&D expenditure (BERD) is taken from OECD StatExtracts and is defined as total R&D expenditure in business enterprises measured in million PPP[27] US dollars, current prices. Data coverage is high however not complete, as there is a small number of missing values. These are corrected for by estimating missing values according to their linear trends. Gross domestic production per capita data is also obtained from OECD StatExtracts in US Dollars current prices, current PPPs.

Foreign Direct Investment (FDI) data is gathered from OECD StatExtracts and captures the inward flows of capital by partner country, measured in units of millions of dollars, current PPPs, current prices. Here, there are some data complications due to a large number of missing observation, however not systematic to the missing values mentioned above. It is not considered reasonable to correct for that in this case.

The Dependent Variables

When evaluating the aggregate effect of introducing a Patent Box, five different dependent variables will be used in the model specifications. First, the total number of applications filed via a country to the EPO is used to investigate the aggregate effect on patenting from an average country. Second, the number of applications from domestic inventors via the home-country to the EPO is studied, examining the effect on the patenting activity in the country employing the policy change. Third, the propensity to patent from a domestic inventor's perspective is examined if inventors are more likely to patent their patentable invention when a Patent Box is implemented. Lastly, the number of foreign applications is separated into two different dependent variables. One measures the aggregate number of foreign inventor applications in a given country. The other measures the number of applications from every country via every other single country in our sample. This number is then divided by the total number of applications in those countries, resulting in a measure of the

[26] Authors: James Gwartney, Robert Lawson, and Joshua Hall Title: 2012 Economic Freedom Dataset, published in Economic Freedom of the World: 2012 Annual Report - Publisher: Fraser Institute - Year: 2012 URL: http://www.freetheworld.com/datasets_efw.html.

[27] Purchasing Power Parity, used to determine the relative value of currencies so they can be compared with each other.

propensity to patent in a specific country. An illustrative example of such an observation is the separate number of applications filed by inventors from Belgium via France, divided by the sum of Belgian EPO applications via all other countries in the sample. This count and division is then repeated for each and every country in the sample.

The Independent Variables

The economic framework suggests there are source country characteristics (s_i, x_i) destination country characteristics (s_j, x_j, c_{net}) along with relation specific features (z_{ij}) that are fundamental for understanding the patenting process. When identifying relevant explanatory variables, we rely on previous research as well as the main parameters of our economic framework. The key explanatory variable is the Patent Box dummy, improving a country's economic environment x, assuming the value of unity when adopted and zero otherwise.

As Gallini et al. (2001) find, countries with stronger IP rights protection are eligible to receive a larger amount of patent applications from a given foreign inventor. It is assumed that strong protection can mitigate imitation and consequently avoid long and costly litigations. We therefore control for each country's strength of IP rights protection (s_{ji}) by introducing an index of Law and Intellectual Property Protection[28].

Investment in R&D is expected to increase a country's amount of patentable projects. We therefore control for the source country's innovative effort by including Business R&D expenditure (BERD)[29]. Next, there are two secondary destination specific characteristics potentially explaining patenting. First, a large GDP per capita can be characterized as signaling an attractive economic environment, a part of x_j, therefore interpreted as having a positive relationship with foreign inventor patenting. Finally, a measure of Foreign Direct Investment is included in the analysis of disaggregated data to capture specific relations between source and destination countries (z_{ij}). These variables are included for three reasons. First, they are regarded as elements characterized as omitted variables when not included. Second, they vary over time and third, they are elements in our model that are likely to have an effect on the amount of foreign applications filed via a given country.

[28] Obtained from the 2012 Economic Freedom Dataset, Authors: James Gwartney, Robert Lawson and Joshua Hall.
[29] Obtained from OECD StatExtracts Online Database.

Models and Results

In order to receive as consistent results as possible, the recommended methods for estimating panel data models with unobserved effects first have to be decided upon. Correlation between unobserved effects and the independent variables may alternate the choice of which estimator to choose (Wooldridge, 2009, p. 456)[30]. In our context, it is intuitively likely that the Patent Box dummy variable is correlated with unobserved effects through institutional features. A fixed effects approach is therefore used to account for inherent time-invariant differences attributable to countries and years[31].

In the following sections, we perform an empirical analysis based on the economic framework, the data collected and the variables presented in previous sections. Following our analysis of why a particular country is economically attractive for an inventor willing to apply for a patent to the EPO, we estimate the baseline fixed effects model:

$$log(y_{it}) = \beta_0 + \beta_1 PBOX_{it} + X_{it}\delta + a_i + u_{it} \quad (1)$$

For $t = 1, 2, \dots, 11$. Here $\log(y_{it})$ represents the logarithmic number of patent applications from country i to the EPO a given year between 2000-2010, although specified in various forms in our subsequent analysis. Allowing for a nonlinear relationship between the dependent and the explanatory variables with the use of logs is deemed suitable as we look for a percentage increase in patenting for the average country[32]. β_1 measures the effect of the Patent Box on the percentage change of the five defined dependent variables, once the policy change is implemented. X_{it} is short-hand for other explanatory variables. The variable a_i is the time-invariant unobserved effects and u_{it} is the idiosyncratic error term. The regressions are estimated using pooled OLS, with robust

[30] This choice is in our case between using fixed or random effects estimators.
[31] Conducting the Hausman test strongly supports this notion. Additionally, "FE is almost always much more convincing than RE for policy analysis using aggregated data" according to Wooldridge (2009) (p. 493).
[32] Using natural logs leads to coefficients with appealing interpretations. In our case, the estimates are less sensitive to outlying observations. The use of logs is also appropriate since the dependent variable is consistently positive along with that the Classical Linear Model assumptions is often better satisfied when the dependent variable is logarithmic than when using the level of y_{it} (Wooldridge, 2009, p. 191).

standard errors to account for heteroskedasticity[33]. Below, the results from our estimated fixed effects regressions are presented.

The Effect on Total Patenting

Table 4 shows that a Patent Box policy increases the number of patents filed via a particular country to the EPO by an inventor of any nationality. Model 1 shows the simple relationship between the total number of patent applications via a particular country with the Patent Box policy change. When adding fixed effects (Model 2), the coefficient drops by a half, implying unobserved effects and omitted variables captured in the error term is making the OLS estimators suffer from positive bias[34]. As we introduce the control variable IP Rights Protection (Model 3), the coefficient of the Patent Box dummy decreases, still significant on a 5 percent level. Adding BERD increases the magnitude and significance of the Patent Box dummy's coefficient, indicating it suffers from negative bias in Model 3. This implies BERD is negatively correlated with the other regressors. As expected, the IP Rights Protection has a positive coefficient, although not statistically significant. The estimate in Model 4 shows a statistically significant average increase of 14.5 percent in total patenting activity via a given country when introducing a Patent Box. This economically large effect indicates we have reason to suspect an element of upward bias is present. Based on the small number of explanatory variables, we are concerned that the bias is caused by omitted variables that positively affect patenting and are positively correlated with the introduction of Patent Boxes.

[33] Heteroskedasticity in itself does not cause bias or inconsistency in the OLS estimators, but the usual standard errors and test statistics are no longer valid. The Breusch-Pagan test of heteroskedasticity rejects the null hypothesis of homoscedasticity in each of our regressions, suggesting that robust standard errors should be used.
[34] Similar to Griffith et al.'s (2010) findings on page 19-20 regarding tax rate.

Table 4: Pooled OLS Estimates of the Effect of Patent Boxes on Total Applications to the EPO

Dependent variable: Log of Total Applications	Model 1	Model 2	Model 3	Model 4
Patent Box Dummy	0.257	0.130***	0.119**	0.145***
	(0.270)	(0.049)	(0.048)	(0.043)
IP Rights Protection			0.059*	0.026
			(0.031)	(0.031)
Log(BERD)				0.329***
				(0.097)
Country & Year Dummies	No	Yes	Yes	Yes
Constant	7.742***	6.374***	5.909***	3.408***
	(0.103)	(0.116)	(0.316)	(0.766)
Observations	231	231	231	231
R^2	0.002	0.992	0.992	0.993

Note: Pooled OLS estimation for 2000-2010. Total applications to the EPO measured as count by country the of residence of EPO applicants. Patent Box Dummy assumes the value of unity if adopted, and zero otherwise. Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Increased Propensity to Patent

Table 5 juxtaposes the results of introducing a Patent Box regime and its significance on the total number of domestic applications as well as the propensity to patent. As a clarifying remark, the domestic propensity to patent is given by the domestic inventor applications filed from source country *i* in year *t*, divided by country *i*'s Business Enterprise Research and Development expenditure in million dollars ($P_{it}/BERD_{it}$) in year *t*. This dependent variable is used to emphasize to what extent a country patents its innovative efforts. Our main focus is to examine in what way the domestic inventors respond to the introduction of a Patent Box. This is of importance since one of the policy's main objectives is to incentivize companies to remain in the home-country and increase the commercialization of R&D activities.

Model 1 and Model 2 shows the baseline regressions with no explanatory variables. Adding fixed effects to Model 3 and Model 4 indicates that the coefficient on *PBOX* is larger on the propensity to patent than on the number of domestic inventor applications. Including control variables in Model 5 shows that domestic R&D expenditure has a positive effect on the number of domestic patents filed to the EPO, as expected. IP Rights Protection on the other hand does not explain much of the domestic patenting activity indicating that home-country legal conditions do not affect patenting decisions, seeming reasonable from the perspective of a domestic inventor. Interestingly, in the case of propensity, the IP Rights Protection coefficient is negative and moderately significant in Model 6. This suggests that the strengthening of patents rights protection have a larger relative effect on BERD, which is the denominator in the dependent variable in this case, than on patenting activity. Comparing the Patent Box dummy coefficients on the two different dependent variables implies that the relative increase in patenting is stronger than in R&D, alternatively that the relative decrease is smaller than in R&D. In Model 5 and 6, the coefficients suggests a 9.8 percent increase in the number of domestic inventor applications and a 14.6 percent increase in the propensity to patent if a country has implemented a Patent Box regime.

Table 5: Pooled OLS Estimates of the Effect of Patent Boxes on Domestic Inventor Applications to the EPO

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Depedent variables:	Log(Dom. Invt. Applns.)	Log(Dom. Invt. Prop.)	Log(Dom. Invt. Applns.)	Log(Dom. Invt. Prop.)	Log(Dom. Invt. Applns.)	Log(Dom. Invt. Prop.)
Patent Box Dummy	0.046	0.012	0.077	0.136***	0.098**	0.146***
	(0.366)	(0.132)	(0.047)	(0.045)	(0.042)	(0.045)
Log(BERD)					0.363***	
					(0.101)	
IP Rights Protection					0.002	-0.058*
					(0.032)	(0.031)
Country & Year Dummies	No	No	Yes	Yes	Yes	Yes
Constant	7.483***	-1.387***	6.536***	-2.046***	3.399***	-1.501***
	(0.110)	(0.040)	(0.068)	(0.129)	(0.801)	(0.327)
Observations	231	231	231	231	231	231
R^2	0.000	0.000	0.99	0.93	0.99	0.93

Note: Pooled OLS estimation for 2000-2010. Domestic inventor applications to the EPO measured as count of applications from a given country where the applicant and inventor are of the same nationality. Patent Box Dummy assumes the value of unity if adopted, zero otherwise. Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Attracting Foreign Inventors

The estimated models in Table 6 indicate that Patent Box regimes attract foreign inventor patent applications. The transition from Model 1 to Model 2 again show the repeated pattern of decreasing coefficients of the Patent Box dummy when controlling for fixed effects. In Model 3, the control variable IP Rights Protection is included and indicates a positive effect on foreign inventor applications. On the other hand, it loses its significance when GDP per capita is included in Model 4, indicating that IP Rights is overestimated in Model 3. However, GDP per capita has a strong and significant relationship with foreign applications filed via the destination country indicating a one-to-one relationship in percentage increases. The key variable of interest, the Patent Box, Model 4 suggest an increase in foreign patenting via the average country by 20.6 percent. Relating this result to previous literature, we can expect a large fraction of this increase is due to foreign MNEs.

As in previous sections with other explanatory variables, we suspect there is an upward bias in the key variable coefficient due to its economically quite large effect. Considering that the coefficient is not particularly sensitive to additional explanatory variables, although not as statistically significant in Model 4, we reason that the indication of a substantial positive effect is apparent. Corresponding to what Hypothesis I predicts, our results indicate that Patent Box regimes are attracting foreign inventor patenting.

Table 6: Pooled OLS Estimates of the Effect of Patent Boxes on Foreign Inventor Applications to the EPO

Depedent variable: Log of Foreign Invt. Applications	Model 1	Model 2	Model 3	Model 4
Patent Box Dummy	0.718**	0.241***	0.218**	0.206**
	(0.285)	(0.092)	(0.088)	(0.087)
IP Rights Protection			0.122**	0.081
			(0.057)	(0.060)
Log(GDP/capita)				1.085**
				(0.524)
Country & Year Dummies	No	Yes	Yes	Yes
Constant	5.714***	3.598***	2.535***	-8.234
	(0.116)	(0.180)	(0.553)	(5.287)
Observations	231	231	231	231
R^2	0.015	0.98	0.98	0.98

Note: Pooled OLS estimation for 2000-2010. Foreign inventor applications to the EPO measured as count of applications from a given country where first applicant and inventor are of different nationalities. Patent Box Dummy assumes the value of unity if adopted, zero otherwise. Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Disaggregated Data Indicates Income Shifting

In the disaggregated cross-applications data, counts of applications from every single country to the EPO via every other country in our study are analysed in a dataset consisting of 5082 observations[35]. Thus, we have facilitated a way of measuring each country's propensity to patent via another country, more explicitly by dividing the individual application counts by the sum of applications filed via the separate sample countries[36]. This share is then examined against the Patent Box policy along with an extended set of explanatory variables and fixed effects in an attempt to deepen our analysis of income shifting firms. Based on this, we estimate the following fixed effects model:

$$log(PROP\_DEST_{it}) = \delta_0 + \delta_1 PBOX\_DEST_{it} + X\delta_{it} + a_{it} + u_{it} \qquad (2)$$

For T = 1, 2, ..., 11. Because of the structure of our data, we must denote each dependent variable to refer to a *destination* or *source* country. Accounting for the parameters affecting the choice of locating patent applications and drawing from the work of Gallini et al. (2001), we use similar controls as in previous specifications and include a measure of FDI to specifically control for time-variant relationships between source and destination countries[37]. Experimenting further with additional controls, GDP per capita is added to capture secondary variables explaining patenting. Fixed effects are included as before, however this time also controlling for time-invariant relationships between countries. The results are presented in Table 4 below.

In Model 1, the coefficient on Patent Box is of little interpretable value, positive but statistically insignificant. Results are improved considerably in Model 2 as fixed effects are included, indicating a statistically significant increase of just above 11 percent in the propensity to patent via a destination country as a result implementing a Patent Box. Corresponding to previous reasoning, this suggests that fixed effects capture a large fraction of the variation[38]. As in earlier specifications of the aggregate data, we notice a decrease in the magnitude of the Patent Box coefficient as additional explanatory variables are added, indicating an omitted variable bias is present in the simple fixed effects model. Even so, Model 3 indicates a clearly positive effect of the Patent Box dummy of 5.8

[35] As many observations drop because of taking the logarithm of zero applications in another country, we have added a constant baseline of 100 to all counts.
[36] See section 5.2: The Dependent Variables for an elaborate explanation.
[37] This variable can potentially be correlated with the Patent Box dummy, however this is not the case when examining multicollinearity.
[38] Note the dramatic increase in R^2 as a result of adding fixed effects.

percent on the propensity to patent, yet at a somewhat lacking significance level (p-value = 7 percent). We reason the loss in significance may be due to omitted variables, but maintain the view of an indication of a clearly positive Patent Box effect.

Unfortunately, due to incomplete data, we lose a significant fraction of the observations in Model 3, due to the mentioned missing values in the FDI variable. We should also add that the FDI measure is far from perfect when describing relations between countries, as the dynamics of investments in foreign countries are not always signs of entirely beneficial circumstances[39]. The statistically significant coefficients on source country BERD and destination country GDP per capita both have negative influence on the propensity to patent. In the case of BERD, this may imply that an increase in expenditure on R&D increases the sum applications in the sample countries more than in a specific Patent Box country, thus offsetting the effect. The interpretation of the IP Rights Protection coefficient is as expected, showing a positive and strongly significant effect of approximately 6.8 percent. Given the loss of observations in Model 3 and difficulties in explaining the effects of the added explanatory variables, we conclude that the results of the estimates in the disaggregated data reinforce the indication of a positive coefficient on the Patent Box dummy variable.

[39] In Helpman, Melitz & Yeaple 2003 (p. 3), the authors discuss the tradeoff between trade and FDI.

Table 7: Pooled OLS Estimates of the Effect of Patent Boxes on Foreign Inventor Applications to the EPO

Depedent variable: Log of Foreign Inventor Propensity	Model 1	Model 2	Model 3
Patent Box in Destination Country	0.069	0.113***	0.059*
	(0.067)	(0.040)	(0.033)
IP Rights Protection Destination Country			0.068***
			(0.012)
FDI Destination Country			1.01e-05***
			(1.58e-06)
Log(GDP/Capita Destination Country)			-0.287***
			(0.045)
Log(BERD Source Country)			-0.130*
			(0.067)
Country & Year Dummies	No	Yes	Yes
Constant	-0.974***	0.0742	3.062***
	(0.0208)	(0.133)	(0.672)
Observations	5,082	5,082	3,710
R^2	0.000	0.75	0.85

Note: Pooled OLS estimation for 2000-2010. Foreign inventor applications to the EPO measured as a count of applications from an inventor country in every other single country. Patent Box Dummy assumes the value of unity if adopted, and zero otherwise. Robust standard errors in parentheses. Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Discussion

Beneath, issues and implications of the estimated models are discussed. We consider endogeneity problems and the assumptions required for our interpretations to be valid. The main aspects affecting the validity of our fixed effects approach is thereby addressed.

Few explanatory variables have been included when explaining the number of patent applicants to the EPO. Whether a country operates a Patent Box regime or not and the strength of the legal system and property rights protection is essentially considered as factors that makes intuitive economic sense, the latter also partially controlling for other government activities incentivizing R&D. In some specifications we include additional explanatory variables, however only to a limited extent, as it is complicated to establish their fundamental relationship with regard to patent applications. Examples of desirable explanatory variables on a country-level could be the amount of R&D tax credits or government support to innovative projects. Omitting time-varying variables affecting the number of patent applications imply we most likely have some variation over time in the idiosyncratic error term u_{it}, thus increasing the risk of an omitted variable bias in our estimators as the strict exogeneity assumption is then violated. We reason this concern is related to our suspicions of an upward bias in the economically large coefficients of the Patent Box dummy in previous results.

Another issue leading to similar implications is that policymakers potentially have implemented Patent Boxes in attempts to accommodate for low domestic patenting activity, corresponding to a self-selection problem. In connection to this, there may be further governmental measures introduced parallel to the Patent Box affecting patenting activity, such as funding of innovative efforts among companies, possibly leading to overestimation of the coefficients. Also, the costs of establishing and maintaining a business in a given country have been characterized as not varying over time, thereby assumed to be captured in the unobserved effects, a_i. One could argue that not including the costs, which are potentially varying, will increase concerns of serial correlation. The examples above could imply that systematically correlated effects are partially captured in economic and societal parameters in the composite error $v_{it} = a_{it} + u_{it}$ (Wooldridge, 2009, p. 253 and p. 457).

It is hard to test if there is serial correlation in u_{it}, especially after having performed the fixed effect estimations (Wooldridge, 2009, p. 487). The recommended approach is to overcome this problem via further econometric analysis using Feasible GLS (Wooldridge, 2009, p. 467). Correcting for

potential serial correlation is rather complicated and beyond the reach of our empirical work, as we only aspire to assess if there are indications of the Patent Box affecting the number of applications.

While the above raises some concerns of inconsistencies and biases in the OLS estimators, we end this section on a more positive note. When examining the residuals of the estimated regressions, we find they are close to normally distributed[40]. This supports the assumption of u_{it} being normally distributed, implying no serial correlation or endogeneity. Thus, we consider our findings only partially subject to biases and inconsistencies, with results valid for indicative interpretations.

[40] See distributions of residuals in Appendix.

Concluding Analysis

Reviewing the results of our empirical evaluation of the effect of the Patent Box regimes, we can confirm it has yielded some interesting but not entirely valid conclusions. Due to inherent heterogeneity in firms' location choices, the aggregate analysis of countries is complicated in terms of parameters driving patenting. In our approach, we therefore include the most instrumental ones and assume there is considerable heterogeneity captured in fixed effects, not varying over the time period. In the following, we focus on the main implications of our work and how it can assist us in answering the stated hypotheses.

The Patent Box regime is shown to have an economically large and statistically significant positive effect on both foreign and domestic inventor applications to the EPO. The explanatory power of our models is high across the board, indicating that fixed effects explain a large fraction of the variation, as is expected. The size of the coefficients indicate increases of 10-20 percent in patenting, varying conditional on the various dependent variables used in pooled OLS estimations. However, these results are subject to potential inconsistencies and biases, the main points of concern being endogeneity and serial correlation in the idiosyncratic error terms due to an unknown amount of time-varying omitted variables. In any case, the indication of a relatively substantial increase in foreign inventor patenting is reinforced in the subsequent analysis of the disaggregated data.

Relating to the hypotheses stated in section 4, we are able to position our arguments in favor of the theoretically expected effects of the Patent Box regimes. Data suggests that domestic inventors located in Patent Box countries are inclined to apply for patents to the EPO on a larger fraction of their R&D, satisfying Hypothesis III. The policy objective to promote commercialization of R&D is therefore affirmed in our analysis. Furthermore, there is strong indicative support for Hypothesis I, expecting that firms to a larger extent apply for patents via countries that have adopted Patent Boxes. The second policy objective of the Patent Boxes, namely providing a more attractive environment for IP holdings, is therefore proven to be fulfilled. There is weaker indicative support for Hypothesis II, where a smaller and less statistically significant effect on patenting activity in particular countries adopting Patent Boxes is shown. This could be explained by the fact that only the sample countries' patenting is included, while the aggregate data includes applications of all nationalities.

Our results correspond to what previous literature find regarding IP and location. In Griffith et al. (2011), the authors emphasize the importance of tax rates for locating IP, explicitly predicting substantial shifts in the geographical allocation of patent applications as a consequence of the Patent Box regimes[41]. Our results cannot be directly compared to theirs as they analyze if the shares of patent applications made by European countries will be redistributed due to the introductions of Patent Boxes and the inherent elasticities between countries. We also reason the differences in results are attributable to their much more disaggregated data set and the alternative econometric methods used[42]. Looking only at MNEs and the patenting intensive Engineering sector in a complex data set, they are able to disentangle more robust results to support the predicted effects of Patent Boxes.

In this paper, we have added to the current state of knowledge by estimating the actual short-term effects of five European Patent Box regimes, disentangling the effect on foreign and domestic inventors. We draw from previous literature on the topic and examine the propensity to patent R&D activities amongst domestic inventors as a result of a tax policy change. In a two-stage analysis of foreign inventor patenting activity, we are able to find indicative support for earlier findings on application locations in a shorter time-frame.

Summarizing the conclusions of issues inherent in explaining the variation in patenting activity and previous findings in the literature, we propose a more detailed approach in future research within this field. The need for further analysis of a broader set of explanatory variables and econometric approaches is apparent in our view. Furthermore, a cost-benefit analysis focusing on the tax revenue implications of the Patent Box and the emergence of global tax competition, is instrumental in evaluating the policy's attractiveness as an incentive for innovation. This will help policymakers around the world assess the effectiveness of tax incentives on innovative activities, a crucial topic in today's globally competitive economy.

[41] Böhm et al. (2012) reach similar conclusions regarding the importance of tax rates.
[42] Griffith et al. (2011) combine ownership structure and accounting data with patents data and can thereby look at patenting within more patenting intensive industries.

References

Arundel, A. & Kabla, I. 1998, "What percentage of innovations are patented? Empirical estimates for European firms", *Research policy,* vol. 27, no. 2, pp. 127-141.

Atkinson, R.D. & Andes, S. 2011, "Patent Boxes: Innovation in Tax Policy and Tax Policy for Innovation", *ITIF, October,* .

Audretsch, D.B. & Feldman, M.P. 1996, "R&D spillovers and the geography of innovation and production", *The American Economic Review,* vol. 86, no. 3, pp. 630-640.

Becker, J. & Fuest, C. 2007, "Quality versus quantity-the composition effect of corporate taxation on foreign direct investment", .

Bernard, A.B., Jensen, J.B., Redding, S.J. & Schott, P.K. 2007, "Firms in international trade".

Bernard, A.B., Redding, S.J. & Schott, P.K. 2007, "Comparative advantage and heterogeneous firms", *The Review of Economic Studies,* vol. 74, no. 1, pp. 31-66.

Bloom, N., Griffith, R. & Van Reenen, J. 2002, "Do R&D tax credits work? Evidence from a panel of countries 1979–1997", *Journal of Public Economics,* vol. 85, no. 1, pp. 1-31.

Boehm, T., Karkinsky, T. & Riedel, N. 2012, "The Impact of Corporate Taxes on R&D and Patent Holdings", NBER TAPES Conference, .

Cappelen, Å., Raknerud, A. & Rybalka, M. 2012, "The effects of R&D tax credits on patenting and innovations", *Research Policy,* vol. 41, no. 2, pp. 334-345.

Cohen, M. 2012, "Corporate Governance Law: Firm Heterogeneity and the Market for Corporate Domicile", *Available at SSRN 2116536,* .

Czarnitzki, D., Hanel, P. & Rosa, J.M. 2011, "Evaluating the impact of R&D tax credits on innovation: A microeconometric study on Canadian firms", *Research Policy,* vol. 40, no. 2, pp. 217-229.

Desai, M.A., Foley, C.F. & Hines Jr, J.R. 2006, "The demand for tax haven operations", *Journal of Public Economics,* vol. 90, no. 3, pp. 513-531.

Dischinger, M. & Riedel, N. 2011, "Corporate taxes and the location of intangible assets within multinational firms", *Journal of Public Economics,* vol. 95, no. 7, pp. 691-707.

Eaton, J. & Kortum, S. 1996, "Trade in ideas Patenting and productivity in the OECD", *Journal of International Economics,* vol. 40, no. 3, pp. 251-278.

European Patent Office, 2013, How to apply for a European patent. Available: http://www.epo.org/applying/basics.html [2013, 5/4].

European Patent Office, Guide for Applicants*, Part 1*.. Available: https://e-courses.epo.org/wbts/htgaep_en/index.html [2013, 5/4].

Gallini, N., Putnam, J. & Tepperman, A. 2001, "Intellectual property rights and the propensity to patent", *Prepared for the International Conference on Intellectual Property and Innovation in the Knowledge-Based Economy*.

Graham, J.R. & Tucker, A.L. 2006, "Tax shelters and corporate debt policy", *Journal of Financial Economics,* vol. 81, no. 3, pp. 563-594.

Griffith, R., Miller, H. & O'Connell, M. 2011, "Corporate taxes and the location of intellectual property", .

Hall, B.H. & Ziedonis, R.H. 2001, "The patent paradox revisited: an empirical study of patenting in the US semiconductor industry, 1979-1995", *RAND Journal of Economics,* , pp. 101-128.

Hall, R.E. & Jorgenson, D.W. 1967, "Tax policy and investment behavior", *The American Economic Review,* vol. 57, no. 3, pp. 391-414.

Hicks, D., Breitzman, T., Olivastro, D. & Hamilton, K. 2001, "The changing composition of innovative activity in the US—a portrait based on patent analysis", *Research policy,* vol. 30, no. 4, pp. 681-703.

Karkinsky, T. & Riedel, N. 2012, "Corporate taxation and the choice of patent location within multinational firms", *Journal of International Economics,* .

Klette, T.J., Møen, J. & Griliches, Z. 2000, "Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies", *Research Policy,* vol. 29, no. 4, pp. 471-495.

Köhler, C., Laredo, P. & Rammer, C. 2012, "The Impact and Effectiveness of Fiscal Incentives for R&D", .

Kortum, S. & Lerner, J. 1999, "What is behind the recent surge in patenting?", *Research policy,* vol. 28, no. 1, pp. 1-22.

Kortum, S. & Lerner, J. 1998, "Stronger protection or technological revolution: what is behind the recent surge in patenting?", *Carnegie-Rochester Conference Series on Public Policy*Elsevier, , pp. 247.

Lazarus, G. 2001, "On the role of patenting in innovation for the biotechnology industry in Canada", *Industry Canada International Conference on Intellectual Property and Innovation in the Knowledge-Based Economy, Toronto, May*.

Lazarus, G. 2001, "On the role of patenting in innovation for the biotechnology industry in Canada", *Industry Canada International Conference on Intellectual Property and Innovation in the Knowledge-Based Economy, Toronto, May*.

Lipsey, R.E. 2010, "Measuring the location of production in a world of intangible productive assets, FDI, and intrafirm trade", *Review of Income and Wealth,* vol. 56, no. s1, pp. S99-S110.

Mansfield, E. 1986, "The R&D tax credit and other technology policy issues", *The American Economic Review,* vol. 76, no. 2, pp. 190-194.

Melitz, M.J. 2003, "The impact of trade on intra-industry reallocations and aggregate industry productivity", *Econometrica,* vol. 71, no. 6, pp. 1695-1725.

Mutti, J. & Grubert, H. 2009, "The effect of taxes on royalties and the migration of intangible assets abroad" in *International trade in services and intangibles in the era of globalization* University of Chicago Press, , pp. 111-137.

PricewaterhouseCoopers 2010*,* "A Comparison of Key Aspects of the International Tax Systems of Major OECD and Developing Countries" [Homepage of PricewaterhouseCoopers LLP], [Online]. Available: http://businessroundtable.org/uploads/studies-reports/downloads/BRT_14_country_international_tax_comparison_20100510.pdf [2013, 4/15].

PricewaterhouseCoopers Ireland, Shanahan, Jim. 2011, "Is it time for your country to consider the "patent box"?".

PricewaterhouseCoopers LLP, D.M. 2012, *, The Patent Box makes the UK an attractive place to do business*. Available: http://www.pwc.co.uk/tax/issues/draft-finance-bill-2012-patent-box.jhtml.

UK Intellectual Property Office, 2013, *The Patent Box*. Available: http://www.ipo.gov.uk/types/patent/p-patentbox.htm [2013, 05/10].

Wooldridge, J.M. 2009, *Introductory Econometrics: A Modern Approach,* 4th ed., South-Western College Publishing, New York.

Appendix

Figures 1-5: Distribution of residuals from regressions.