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Patent Boxes Design, Patents Location and Local R&D

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Abstract[1]

Patent boxes have been heavily debated for their role in corporate tax competition. This paper uses firm-level data for the period 2000-2012 for the top 2,000 corporate research and development investors worldwide to consider the determinants of patent registration across a large sample of countries. Importantly, we disentangle the effects of corporate income taxation from the tax advantage of patent boxes and exploit a new and original dataset on patent box features such as the conditionality on performing research in the country or their coverage. We find that patent boxes have a considerable effect on attracting patents, mostly because of their favourable tax treatment. Patents with high earnings potential are particularly sensitive. Patent boxes with a large coverage also have stronger effects on the location of patents. We also analyse the impact of patent boxes and their tax advantages on local R&D activities and find that R&D development conditions tend to attenuate the dominant fiscal effect of patent boxes.

Key words: Corporate taxation, patent boxes, location, patents, R&D, nexus approach
JEL classification: F21, F23, H25, H73, O31, O34

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1. Introduction

A growing number of developed economies have recently implemented patent box regimes. Patent boxes (also called IP boxes) are output-related tax incentives that apply reduced rates to income earned from exploiting intellectual property (CPB, 2015). It is called a box in reference to the box to be ticked on the tax form to benefit from the regime. In other words, a patent box is a special tax regime that grants preferential tax treatment to corporate revenues from intellectual property (IP).

The use of such schemes has raised suspicion about yet another tax competition device. In July 2013, German finance minister Wolfgang Schäuble publicly criticised patent box regimes as *'going against the European spirit'*, suggesting that they should simply be banned.[2] Such concerns appear justified by anecdotal evidence. For instance, Pfizer's widely discussed and failed attempt to takeover Astra Zeneca appeared to be essentially tax motivated.[3] The company resulting from this merger would have been incorporated in the UK taking advantage of a reduced corporate tax rate of 10% (instead of a standard rate of 21%) over future profits generated from patents. Similarly, the UK company GlaxoSmithKline has recently centralised all its vaccine-related IP in Belgium mainly for fiscal reasons while carrying its physical capital investment at home.[4] In another notable case, the hotel reservation company Booking.com was expected to reduce its tax rate by around 4 percentage points thanks to the Dutch patent box regime.[5] These examples seem to suggest that the decisions on patent registration by firms may have little to do with developing research and innovation but a lot to do with tax planning, echoing Minister Schäuble's worries that patent boxes are simply there *'to attract companies'*. Such concerns were also voiced in the context of the Organisation for Economic Cooperation and Development (OECD) Base Erosion and Profit Shifting (BEPS) discussions and in the EU code of conduct on business taxation.[6] The need to align taxation with 'substantial' research activity being developed by companies is now indeed seen as a key factor to ensure that such preferential regimes reach their goal of fostering innovation and economic growth.[7]

In this paper, we provide novel empirical evidence on the determinants of the geographical distribution of patent applications made by the 2,000 top corporate R&D worldwide investors. We focus on both tax and non-tax features of patent box regimes that might affect patent registration and local R&D activity. Our sample covers patents registered in 33 host countries[8] for 3 sectors of activity (the pharmaceutical industry, the car industry and the Information and Communications Technology, ICT) that have been particularly active in global patenting in the past decades, by parent companies located in

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[2] Breidthardt, A., 'Germany calls on EU to ban "patent box" tax breaks', Reuters, 9 July 2013, http://uk.reuters.com/article/2013/07/09/uk-europe-taxes-idUKBRE9680KY20130709
[3] Financial Times, 29 April, 2014
[4] See Financial Times, 12 March 2014 and "GSK renforce le rôle de la Belgique comme QG mondial", L'Echo, 7 April 2015.
[5] Breidthardt, A., 'Germany calls on EU to ban "patent box" tax breaks', Reuters, 9 July 2013, http://uk.reuters.com/article/2013/07/09/uk-europe-taxes-idUKBRE9680KY20130709
[6] OCDE (2014), pages 27-53 and Council of the European Union (2014).
[7] Van der Made (2014, 2015).
[8] The EU28 (except Bulgaria, Latvia and Malta), Canada, China, Japan, the Republic of Korea, Lichtenstein, Norway, Switzerland, and the USA

39 home countries[9] during the period 2000-2012. We disentangle the general effects of the corporate income tax (CIT) rate from tax and non-tax characteristics of patent boxes such as their coverage and eligibility conditions, and investigate whether or not these characteristics influence local research activity. Importantly, our firm-level data includes 12 countries with patent boxes, of which 10 have introduced a patent box within the period 2000-2012.

To the best of our knowledge, this is the first attempt to analyse the various specific designs of patent boxes and to test their impacts on patent location and local inventorship. Our results suggest that patent boxes have a strong effect on attracting high-value patents (those with high earnings potential), mainly owing to the favourable tax treatment they offer. Patents are also found to be more sensitive to the tax advantages offered by patent boxes when these have a large coverage in terms of the types of IP covered and when they grant their benefit to pre-existing patents, acquired patents and/or embedded royalties. Importantly, our results suggest that the tax advantages of patent boxes do not stimulate local innovative activities, given our finding that they fail to incentivize companies to develop local research. Nevertheless, our results show that the imposition of local R&D development conditions in the patent box regime has the potential to attenuate the fiscal effect of patent boxes.

There is to date little empirical evidence on the impacts of patent boxes on R&D and patent location[10], albeit the field is growing. A negative relationship between the level of the corporate income tax rate and the amounts of both a firm's intangible assets and its patents has been documented by Dischinger and Riedel (2011), Ernst and Spengel (2011), Karkinsky and Riedel (2012), Böhm et al. (2014), Ernst et al. (2014), Griffith et al. (2014) and Bösenberg and Egger (2017). For example, Karkinsky and Riedel (2012) estimate that a percentage point increase in the corporate tax rate reduces patent applications filed at the location by around 3.5%. Böhm et al. (2014) and Griffith et al (2014) show in addition that the quality of an intangible asset and the anti-avoidance framework (e.g. controlled foreign company rules) play a role in the location decisions. Böhm et al. (2014) and Ernst et al. (2014) suggest that low income tax rates particularly attract patents with high earnings potential. However, these papers use older data that do not cover the introduction of the many recent patent boxes and they often mainly analyse the effect of the (effective) CIT rate on the patent location choices. For instance, Griffith et al. (2014) use data extending till 2005 to simulate the impact of recent preferential tax regimes for patent income and conclude that they are likely to result in substantial revenue losses for all countries. More recently, Bradley et al. (2015) use more recent data extending from 1990 to 2012. Using OLS, for the log of total patents per country and year, they find that a one-percentage point reduction in the patent box tax rate increases patent applications by 3%. They however find no effect of patent box regimes

[9] The EU28 (except Bulgaria, Cyprus, Czech Republic, Estonia, Greece, Croatia, Lithuania, Latvia, Malta, Poland, Romania, Slovak Republic), Australia, Bermuda, Brazil, Canada, Cayman Island, China, Curacao, Hong Kong, India, Israel, Japan, Republic of Korea, Lichtenstein, Mexico, Norway, Russia, Saudi Arabia, Switzerland, Singapore, Taiwan, Thailand, Turkey, and the USA.

[10] In terms of macroeconomic effects, a recent study by Chen et al. (2016) finds some evidence that the implementation of a patent box in high-tax countries both reduces the outward profit-shifting and increases employment by multinationals in these countries.

on attracting foreign patents, indicating that the increase derives from domestic owners and inventors. Bösenberg and Egger (2017) equally extend their data till 2012 and find in contrast that whereas larger front-end R&D tax incentives (e.g. deductions and allowances for R&D costs) raise the propensity to file patents, back-end R&D tax incentives (e.g. patent boxes) have their biggest impact on patent trading.

The rising concerns surrounding patent boxes are part of a long-standing discussion on tax competition. This literature usually advocates for an increased global coordination of corporate tax policies. Countries around the world have always been eager to be attractive to foreign portfolio and physical investment, thus triggering a race to the bottom in corporate taxation, realising the theoretical predictions of Zodrow and Mieszkowski (1986) and Wilson (1986).[11] In the OECD, the average CIT rates fell from 48.5% in 1985 to 28.7% in 2007, while in the EU (EU-15) the fall was from 48.7% in 1985 to 28.8% in 2007. Recently, however, this race to the bottom seems to have levelled off. The EU-15 average moved from 27.5% in 2008 to 26.3% in 2015 and the OECD average changed from 27.6% to 26.4% over the same period.[12] At the same time, however, many EU Member States narrowed their corporate tax base with a view to stimulating and attracting investment.[13] Tax competition thus seems to have changed its nature, moving from a focus on statutory rates to one on tax bases.[14] Patent boxes are an important driver of these recent developments, with EU countries being especially active. Patent boxes first appeared in France and Ireland as early as the 1970s. Interestingly, Ireland is, to date, the only country that has abolished its patent box for budgetary reasons (2010), but has reintroduced such regime as from 2016.[15] Figure 1 shows that the number of patent boxes in the EU has grown from 2 in 1995 to 11 in 2015, with a clear acceleration in recent years. Bräutigam et al. (2017) argue that the reason for this acceleration is the Cadbury-Schweppes ruling of the European Court of Justice from 2006, which limits the applicability of Controlled Foreign Corporations (CFC) rules within the EU. The tax reduction offered by patent boxes varies across countries but the average advantage over the period has been as high as 75% reduction in the CIT rate (that is 17.9 percentage points).

Patent box schemes came under the scrutiny of the EU and OECD because of the apparent lack of linkage between the tax advantage offered and the presence of research or innovation activity. Discussions at both the OECD and the EU have led to an agreement on the requirement to establish a nexus between the income derived from IP and the expenditure incurred to develop this asset, for the income to qualify for the patent box preferential regime (OECD, 2014 and 2015b).[16] The existence of

[11] See Devereux et al. (2008) for an empirical analysis. Data on corporate tax rates can be found in, inter alia, European Commission (2017) and OECD (2015a).
[12] The EU-28 average moved from 22.7% in 2008 to 22.1% in 2015. The OECD data are for those that were members in 1985.
[13] See Garnier et al (2014) for a recent review on policy measures at EU level. See also Atkinson and Andes (2011) for a discussion of patent boxes into a US setting.
[14] The literature on the economic effects of harmful tax practices is summarized in Nicodeme (2009). Two strands are opposed with, on the one hand, authors that consider that these practices are parasitic and increase tax competition (e.g. Slemrod and Wilson, 2009) and, on the other hand, authors that argue that such practices increase economic efficiency by allowing states to offer preferential regimes to mobile activities (e.g. Keen, 2001).
[15] At a rate of 6.25%, that is half of the standard 12.5% corporate income tax rate.
[16] In the EU, an agreement on a modified nexus approach requires that Member States with patent boxes that do not meet this condition close them to new entrants by 30 June 2016 and abolish them by the 30 June 2021 (van der Made, 2015).

development conditions in some patent boxes may shed light on the potential effect of the nexus condition developed by the OECD and the EU, notably with regard to its effect on patent location, tax revenues and local R&D. Our finding that the tax-sensitivity of patent location is reduced when such specific conditionality is imposed would suggest that the nexus approach could (at least partly) inhibit the still dominant tax competition dimension of patent boxes.

Theoretically, there are a number of reasons for suggesting that patent boxes do not necessarily serve the goal of boosting local R&D activity. First, unlike expense-based tax incentives for R&D, such schemes do not reward firms for the social benefits that they cannot appropriate. Instead, they award additional tax benefits to a successful innovation that already enjoys IP protection. Un-patentable research efforts with potentially higher social spillovers are less attractive and thus become indirectly discriminated against. Second, patent boxes also rank very low in terms of good tax incentive practices such as their coverage (determining the size of the tax base), their targeting and their organisational practices (CPB, 2015).[17]

In our regressions, we provide evidence that the presence of a patent box has a distinctive effect on patent location and that the tax advantage offered through patent boxes is effective in attracting patent registrations and high value patents in particular. Our results suggest that a distinction between countries that have a low tax rate under the general regime and countries that have a low rate because of a patent box is useful. In our regressions we test whether the tax advantage offered by patent boxes as a different effect than the standard CIT rate and we test whether its effect is affected by the characteristics of patent boxes. The remainder of the paper is organised as follows. Section 2 describes patent box regimes and their characteristics and details the nexus approach chosen by developed economies. Section 3 explains our patent data and section 4 discusses our empirical strategy. Next, section 5 describes our identification strategy. Section 6 presents our empirical results before concluding in section 7.

2. Patents, patent box design and local R&D

2.1. Who patents and why?

A patent is a ‘legal title that gives inventors the right, for a limited period (usually 20 years), to prevent others from making, using or selling their invention without their permission in the countries for which the patent has been granted’.[18] Before moving into the analysis on the location of patents, it is useful to understand why companies patent their inventions in the first place and why it is strategically important to locate patent for fiscal reason, in particular for large multinationals. The patent system is territorial, and a patent is valid for the geographical area for which it is granted. This has the effect of

[17] CPB (2015) reviews the economic literature on the determinants of R&D activity to benchmark the tax schemes. Patent boxes are found to have several non-recommended practices such as being related to output or having weak targeting.
[18] Definition according to the European Patent Office: http://www.epo.org/service-support/glossary.html.

dividing world markets into protected trade areas (Greenhalgh and Rogers, 2010).[19] Holders of a patent issued by a patent office have a given period of time (12 months) to file a patent application abroad and still claim priority for the existing application.

Large R&D-intensive firms tend to patent more, whereas process-oriented innovators patent less than product-oriented innovators (Peeters and van Pottelsberghe, 2006). Many sectors are not patent-active, and patenting firms represent a small part of the population of firms, e.g. only between 1.6% in Ireland and 8.8% in Germany (OECD, 2013). Hall et al. (2013) find that even among firms that conduct R&D in the UK, only 4% patent. The share of patenting firms is much lower than one might expect given that around 20% of firms that invest in R&D report product innovations. Findings are similar for the USA as only 5.5% of US manufacturing firms own a patent (Balasubramanian and Sivadasan, 2011). Regressing by sector is hence justified by the heterogeneity of the determinants of patent registration across sectors. This derives from sectorial differences in the economic, tax and patenting perspectives. Computers, electronics, machinery, chemicals and pharmaceuticals are the sectors with the highest patenting activities (OECD, 2013). ICT, pharma and car sectors are the most patent- and R&D-intensive companies in our sample. Empirical evidence suggests that for many sectors patents are an ineffective way to appropriate returns, and secrecy (e.g. the Coca-Cola formula is a closely held trade secret, hence not patented) and lead times are used extensively (Arundel, 2001; Hanel 2008; Hall et al., 2013). This does not necessarily mean that different means of appropriation are substitutes, as for non-patentable inventions such as software in Europe. Hall et al. (2014) review the vast economic literature with a focus on the trade-offs between using patents (and hence disclosing) versus secrecy. They conclude that the most robust finding is heterogeneity in the use of patents across industries. The nature of innovation and degree of competition are key factors that will shape a firm's propensity to use secrecy rather than patents. Companies that regard patents as important appropriation means and that are more likely to opt for patents are the larger firms, those that already have patents and R&D-performing firms, which typically jointly form our sample. However, Hall et al.'s review highlights that the theoretical literature concentrates on the binary choice between patents and secrecy, while the available survey data suggests that patents and secrets are used as complements. Firms hence appear to combine formal (patents, copyrights, trademarks) and informal (secrecy, lead times) means of appropriation to protect different elements of their innovation (Hall et al., 2013, 2014). This is important for our work, as the evidence presented in this paper suggests that many patent boxes apply to IP, which is much broader than patents.

Furthermore, even for large, R&D-intensive firms coming from sectors where patents are used intensively, differences in strategy remain (Dernis et al., 2015). We are interested in these differences as we expect that responses to patent boxes will vary across sector. Griffith et al (2014) already show higher sensitivity to tax in certain broad

[19] This means, for instance, that a US company holding a US patent (granted by the United States Patent and Trademark Office, USTPO) would need to file for patent/register with the European Patent Office (EPO) or a national patent office to obtain a patent that also covers European countries.

categories of industries. Indeed, patent value, R&D intensity and organisational structure of MNEs will vary across sectors. Intensity in intangible assets will vary per industry and will be an important element in firm decision-making over how to organise tax planning activities. Beer and Loeperick (2015) show that intangible asset endowment of subsidiaries and the supply-chain complexity of multinationals explain aggregate profit-shifting trends. Their paper reveals noticeable differences in both intangible endowments of affiliates across different sectors as well as a major variance in the complexity of the MNE groups these affiliates belong to. According to their classification, pharmaceuticals and ICT are top or above the median in terms of intangible endowment, while motor vehicles have much smaller share of intangibles in total assets but the complexity of their supply chain is high.

Another difference relates to the motives for patenting, which can differ across sectors. For example, they may depend on whether an industry mainly produces ‘discrete’ or ‘complex’ products (Cohen et al, 2000). The most important objective behind patenting is to prevent third parties from exploiting the protected invention. However, strategic patenting seems increasingly important and may also provide signals to rivals, potential negotiation leverage and boost to reputation, but also incentives for R&D employees and the measurement of performance (Blind et al., 2006). Such strategic motives can affect the sensitivity of patents to taxation. For example, there is limited incentive to exploit a patent which is deployed for blocking a competitor. There is an interest to keep a patent at a location it was invented if it is used as a tool for motivating employees or measuring performance.

2.2. Patent Boxes: a European story

The European patent system, more specifically considered in this paper, is rather complex. The patent applicant have a choice between following the national procedure in each state for which (s)he seeks protection or taking the European route via the European Patent Office (EPO), which in a single procedure confers protection in all the designated contracting states. However, the EPO applicant will still need to validate the European patent in the designated states within a short time limit after the EPO grants the patent (usually 3 months). This could entail a substantial cost due to a number of requirements, such as payment of the fees and translations.[20] The patent can also be owned by someone outside Europe (home country) or developed by someone residing outside Europe (host country). It should be noted that patent protection is a separate issue from patent boxes (even though the former is a condition for benefiting from the latter). Even if a company registers its patent in a country, it cannot benefit from its

[20] Patenting in the EU is expected to become less complex and costly thanks to the introduction of the European patent with unitary effect, the so-called "unitary patent" (European Commission, 2011). Such patent will be yet another option for users besides already-existing national and "classical" European patents. It will enable a unitary effect in 25 EU states without the need for subsequent validation. However, the system is not yet in force. The unitary patent may be requested from the date of the entry into force of the Agreement on a Unified Patent Court. 25 EU Member States signed the agreement on 19 February 2013. It will need to be ratified by at least 13 states, including France, Germany and the United Kingdom to enter into force.

patent box when it is not tax resident because its IP income is not taxable income in this country. Registration of a patent does indeed not create a permanent establishment that would give rise to a taxable income in the country of registration (and hence to a tax rebate).

Patent boxes are very heterogeneous in their design. These differences are shown in more detail in Table 1 where we focus on five design characteristics that are expected to make the tax advantage more or less pronounced: (a) which IP rights qualify for the patent box (the coverage); (b) the treatment of existing patents; (c) the treatment of acquired patents; (d) the treatment of embedded royalties; and (e) the existence of development conditions.[21]

The name 'patent boxes' can be deceptive, as many patent boxes have a much larger coverage than just patentable rights, as summarised in Table 2. All patent boxes cover patents and often rights equivalent to patents such as supplementary protection certificates. Besides patents, patent boxes can also cover designs and, to a lesser extent, trademarks. In addition, they often consider copyrights, sometimes with a restriction to software, probably to compensate for the fact that software is not patentable in Europe unlike in the USA. Firms often combine different forms of IP, even for the same invention (Hall et al, 2014). This implies that the advantage conferred by patent boxes with a wide IP coverage could be more generous than intended by policymakers and would over-subsidise the same invention.

Second, the effects of a patent box on tax revenues depend on its provisions. Existing (i.e. prior) patents may in some cases also benefit from the lower tax rates of patent boxes, as in the systems put in place in Cyprus, France, Hungary, Malta, Spain, the UK, Ireland (up to 2010), Liechtenstein and the Nidwalden canton in Switzerland. This represents a windfall gain to firms with existing patents, as after-tax income from their existing patents in that jurisdiction increases with no further action required.

Third, the treatment of acquired patents differs across patent boxes. A majority of patent boxes allow patents acquired from related or third parties, whereas only a small number of countries allow the use of acquired patents on condition that the acquirer further develops these patents.

Fourth, patent boxes also vary in the treatment of embedded royalties. The three 'narrowest' patent boxes in terms of coverage (in the UK, Belgium and The Netherlands) include only income from patents under their IP tax rules (as shown in Table 1). However, at the same time, these patent boxes also include the embedded royalties in the calculation of eligible income.[22] This means that the income from the sale of products that include patented items and the notional royalty from using patented industrial processes, fall under the patent box, implicitly increasing the coverage (and cost in terms of tax expenditures) of the IP boxes. For instance, Evers et al. (2015) find that the treatment of expenses relating to IP income is generally more decisive for the effective

[21] In our analysis, we do not include Israel and Turkey that offer some tax advantages with an IP-related component, but these tax schemes are much broader and apply in special economic zones only. Turkey and Israel are also not in our sample. Italy also introduced a patent box regime in 2015 that offers a 50% exemption since 2017 (30% and 40% in 2015 and 2016 respectively) but is outside our sample.

[22] Embedded royalties also exist in broader patent boxes such as in Luxembourg, Liechtenstein and Nidwalden canton in Switzerland.

tax burden than the nominal IP Box tax rate. The treatment of expenses can be so generous that IP Boxes provide negative effective tax rates. In these cases unprofitable investment projects are subsidised by the patent box regime. It is also important to note that other elements of the tax system need to be in place to make such schemes beneficial for tax-planning purposes, namely an extensive network of bilateral treaties, weak CFC legislation, flexible transfer pricing rules and flexibility of the tax administration (e.g. advance rulings). In addition, some countries offer standard corporate tax rates below the tax advantage offered by a patent box and could be more attractive for companies that prefer to book their full profits in such jurisdictions.

In the next section, we examine the fifth important characteristic of patents, the possible imposition of development conditions.

2.3. Patent Boxes and the link with local R&D.

Current patent boxes approach the question of the link with underlying research activity - thanks to which an IP right originated - in different ways. In half of the cases considered in this paper, the patent boxes do not require any development work by the taxpaying company in question. Patent boxes in The Netherlands, Belgium, the United Kingdom, Ireland (up to 2010), Spain, Portugal and China contain(ed) provisions specifying the link with the underlying research activity.[23] In the EU, this is usually done in the form of a development condition that requires at least part of the patent to be developed by the beneficiary corporate group within the Single Market. However, these conditions differ in their definition and strength. For instance, the Belgian patent box requires that the qualifying patent shall have been developed fully or partially by the taxpaying company in a Belgian R&D center that qualifies as a branch of activity. In the Netherlands, the patent box applies to intangible assets that the company has developed itself. It also covers intangible assets that are in large part the result of R&D work, conditional on the taxpaying company receiving a declaration from the Dutch Research Agency (Schellekens, 2013). This declaration in turn links the R&D activity with the use of the Dutch payroll deduction scheme for researchers. Under the UK patent box a company or group must have performed qualifying development in relation to the IP right in the UK, and the rules include provisions against full outsourcing (HMRC, 2010). Nevertheless, an additional 'active ownership condition' potentially limits the constraining aspect of the development condition. In such case, another company within a group could have fully developed the IP right, while the company that pays tax in the UK actively manages the IP portfolio.

Generally, development conditions often contain qualitative terms such as ‘substantial’ or ‘significant’ work that are open to interpretation and have to be assessed on a case-by-case basis.[24] It is also worth mentioning that in the specific case of the EU, its Member States cannot restrict the benefits of R&D tax incentives to activities performed in their

[23] China has a preferential rate for new high-technology enterprises, which need to meet a number of requirements to qualify to profit from the rate (e.g. level of R&D expenses).
[24] In our sample, only China applies the territorial restrictions so that most of the related R&D must be done in China.

territory as this would infringe upon the freedom of establishment and prevent companies from conducting their R&D elsewhere in the EU.[25]

3. Patent data

This paper uses the patent applications to the European Patent Office (EPO)[26] of world corporate R&D investors from 39 home countries[27] in 33 different host countries[28] over the period 2000-2012. The analysis is based on the top 2,000 worldwide corporate R&D investors as reported by the EU Industrial R&D Scoreboard (European Commission, 2013), which ranks the companies that invested the largest amounts of R&D in 2012.[29] Altogether, these companies accounted for about 90% of global business R&D spending.[30]

The Scoreboard data are drawn from the latest available company accounts reported in the ORBIS database as provided by Bureau Van Dijk Electronic Publishing. ORBIS contains ownership, balance-sheet accounting and financial information about firms located worldwide. The patents filed by these companies at the European Patent Office (EPO) are from the Patstat[31] database in the framework of a JRC-OECD joint project (see Dernis et al., 2015). This project has carried out a matching on a by-country basis using a series of string-matching algorithms contained in the Imalinker system (Idener Multi Algorithm Linker) developed for the OECD by IDENER, Seville (2013).[32] To ensure a high quality of the matching, threshold values for string matching have been set in order to minimize both false positives and false negatives. After the matching

[25] See Baxter and Fournier European Court of Justice cases, C-254/97 and C-39/04.

[26] We have chosen to use patents from EPO because this set of patents seems the best to study the impact of taxes on the location of the legal ownership of patents. Pooling patents from different offices may at first sight seem a good approach, but present a series of serious shortcoming. First, when using different patent offices, one shall be prudent with the concept of patent counts as the same invention (patent) can be filed in different patent offices to seek protection in different legislations/markets (see the Apple vs Samsung case). This is particularly true when considering large R&D investors operating on a global scale. In this case, using patents is possibly leading to multiple counting and the concept of INPADOC families should be preferred (the INPADOC family concept connect all the documents directly or indirectly linked to one specific priority patent document). Second, patent boxes impose some restrictions on the authority granting the IP right limiting it to patent registered at EPO or national patent offices. Third, there are also ownership requirements and it is reasonable to expect that third parties would only accept to pay for the use of IP rights that are effectively protected in the territory where they are used. The focus on EPO patents seems the most aligned with the MNEs patenting strategies as these companies would apply for a patent at EPO and then validate it in the designated states. The EPO 2012 annual report show a record number of patent filings at 257,700 and 65,700 patent grants. 24.6% of filings originated from the US, followed by Japan (20.1%) and Germany (13.3%). With 2,289 applications, Samsung topped Siemens (2,193) and BASF (1,713). There seems however to be no reliable data source to identify patents that are filed both at the EPO and at national patent offices.

[27] Home countries: Australia, Austria, Belgium, Bermuda, Brazil, Canada, Cayman Island, China, Curacao, Denmark, Finland, France, Germany, Hong Kong, Hungary, India, Israel, Italy, Ireland, Japan, Republic of Korea, Lichtenstein, Luxembourg, Mexico, Netherlands, Norway, Portugal, Russia, Saudi Arabia, Slovenia, Spain, Switzerland, Singapore, Sweden, Taiwan, Thailand, Turkey, United Kingdom, and the USA.

[28] Host countries: Austria, Belgium, Canada, China, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, The Republic of Korea, Lichtenstein, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, and the USA.

[29] This has implications for the interpretation of our results as we de facto exclude companies not engaging in R&D activity. Hence, our results shall be interpreted as the various effects of patent boxes on patent location of companies engaging in R&D activities rather than their effect on companies starting research ex-nihilo.

[30] The EU Industrial R&D Investment Scoreboard sample is assembled by the Joint Research Centre of the European Commission. For more information on the sample of firms included in the R&D Scoreboard, see http://iri.jrc.ec.europa.eu/scoreboard.html. and European Commission (2014).

[31] PATSTAT is the European Patent Office's Worldwide Patent Statistical Database, which contains data about 70 million applications from more than 80 countries. See more details at http://www.epo.org.

[32] Overall, in 2012 the top R&D investors controlled more than 500,000 subsidiaries (defined as firms more than 50% owned by the parent), including 'branches', which account for about 34% of all subsidiaries. Patent applications have been aggregated at the group level. A more extensive description of the approach used to perform the matching between Orbis and PATSTAT can be found in Dernis et al. (2015). For a description of Imalinker, see http://www.idener.es/?portfolio=imalinker.

procedure, results for 10% of companies were inspected manually. In particular, matches for the 2.5% of companies with the highest (and lowest) patent/R&D ratios were manually adjusted. Moreover, another 5% of companies were randomly checked; random checks confirmed the goodness of matching. Overall, 97% of the top-performing companies could be matched to at least one patent applicant.

The characteristics of innovations vary across sectors and so does the influence of taxation on the patent location choices, as discussed in section 2.1. Therefore, to account for this heterogeneity we adopt a sectorial approach to our regressions. Our regressions in section 6 confirm this heterogeneity. We identify three sectors of interest: the car industry (ICB code 3350), the ICT industry (ICB code 9500) and the pharmaceutical industry (ICB code 4570), together with their subsectors. Focussing on these three sectors allows covering 60% of total patents and those sectors are also the top R&D investors in the 2012 scoreboard.

Patent applications pertain to different technological fields.[33] Globally, in our full sample, chemistry counts for close to a quarter of all applications, very closely followed by electrical engineering; about a fifth of all applications are related to mechanical engineering and instruments. The remainder, 'other fields' counts for the remaining 9% of patent applications. Their distribution, however, differs widely across sectors. As shown in Table A1 of the Appendix, each sector focuses mainly on one specific technology field, but not exclusively. In the car industry, 64% of the 88,826 patent applications are related to mechanical engineering technology. In the ICT sector, electrical engineering accounts for 81% of all applications and in the pharmaceutical sector, chemistry has the lion's share with 79.5%. These differences justify a sectorial approach.[34]

An important characteristic of the patent box data is that it is highly skewed. Companies in many instances do not register their patent just in a given year and country. In addition, when they do register, they usually do it for one single patent only. However, a few companies sometimes register a very large number of patents in a given year and in a given country. Figure 2 shows the very skewed distribution of patents across companies considered in our empirical analysis. The large multinationals included in our sample have a patenting behaviour that differs from other companies with a large number of patent registrations. We find a positive and significant correlation between company size (measured by total employment) and patent registrations. Hence, the nature of our data on patent application is likely to have a bearing on the econometric strategy used for estimating the impact of taxation and patent boxes on patent registrations. These issues are discussed in the next section dealing with our econometric approach.

[33] The Industry Classification Benchmark (ICB) is a classification widely used by stock exchanges such as the NASDAQ and the NYSE.

[34] Moreover, to ensure consistency, our econometric estimations are run considering only the patents registered under the most frequent technology by sector.

4. Empirical strategy

We follow the structural model proposed by Griffith et al. (2014) and consider the payoff $\pi_{i,j,t}$ of a firm i from registering a patent in a specific location j at time t as being determined by industry and country-specific characteristics such that:

$$\pi_{i,j,t} = f\left(ETR_{j,t}, X_{j,t}, \varepsilon_{i,j,t}\right) \qquad (1)$$

where the company *i* will register its patent in country *j* if its expected payoff is higher than the expected payoff in any other alternative location *k*, that is $\pi_{j,t} > \pi_{k,t}$. This probability is a function *f* of the effective tax rate (*ETR*) in country j at time t – i.e. which is defined as:

$$ETR_{j,t} = CIT_{j,t} - tax\ advantage_{j,t} \qquad (2)$$

The ETR therefore accounts for the possible tax rebate granted via the patent box to income-related patents. The variable $X_{j,t}$ stands for country-specific and time-specific characteristics that can influence patent registration and which are described in the sequel. We also assume that payoffs are uncorrelated such that the error term $\varepsilon_{i,j,t}$ follows a normal distribution with zero mean and unitary standard deviation $N(0,1)$. Griffith et al. (2014) suggest however that the expected payoffs of registering patents in two different locations can be correlated, hence invalidating the previous assumption such that: $cov(\pi_{i,t}, \pi_{k,t}) \neq 0$. The possibility for a non-zero correlation in expected patents payoffs is dealt with by Griffith et al. (2014) by estimating a mixed logit model where the effects of taxation are assumed to vary across ideas, which the authors define as industry/firm size categories. Using such a mixed logit approach allows estimating the degree of heterogeneity in the effect of a specific variable, including the tax rate, along the industry/firm size dimensions. It can be used when patent registrations made by a given company *i* occur only once in a given year and a given country. To compare our results with those of Griffith et al. (2014) and the rest of the literature, we run some regressions with a logit model.

However, we have seen from our sample data that some companies often register more than one patent in a given country and year. Hence, it could be preferable to take advantage of this additional information and to use the total number of patents registered as dependent variable instead of zero-one dummy to estimate the probability of registering a patent (Hausman et al., 1984). The model to be estimated becomes:

$$n_{i,j,t} = \lambda\ ETR_{j,t} + \beta\ X_{j,t} + \phi_t + \varphi_j + \varepsilon_{i,j,t} \qquad (3)$$

Where the dependent variable is the number n of patents registered by a company *i* in a given country *j* in year *t*. ϕ_t and φ_j are respectively time and country fixed effects.

In this model, the parameters λ and β could in principle be estimated via a standard OLS as in Bradley et al. (2015).[35] It is however known that OLS models assumptions do not hold in cases where the dependent variable is discrete outcome, as in our case. As put by Karkinsky and Riedel (2012), the "OLS approach however does not account for the fact that the patent variable is restricted to positive values".

An alternative solution is then to use a Poisson model. However, the problem of over-dispersion arises in that case. This problem typically characterises patent registration data from large companies as in some industries only a handful of them generate a very large number of patents. To overcome these problems, a negative binomial model provides a better alternative than the Poisson model. This is also the preferred option of Karkinsky and Riedel (2012).

The negative binomial model preserves the conditional mean assumption of the Poisson model but it allows for a larger variation of outcomes than a Poisson and one can specify a so-called over-dispersion parameter that represents an objective proxy of the cause of this over-dispersion (Long and Freese 2014). In our negative binomial model and in line with the observation of our data sample, we assume that the latent heterogeneity inducing an over-dispersion in patent registrations is the firm size (represented by the number of employees).[36] We incorporate this parameter as exposure variable in the marginal negative binomial distribution and the model can be easily estimated using maximum likelihood (Greene, 2008).

We next also consider an alternative mixed negative binomial model in order to account for unobserved heterogeneity and to estimate fixed and random effects on the effective tax variable, which reflects the fact that firms do not behave similarly to fiscal conditions. This mixed model allows us checking whether our main results hold when using a specification including random effects comparable to Griffith et al. (2014).

Next, as in Griffith et al. (2014) we must consider the influence of additional non-tax factors on the location choice for patents registration. These controls are embodied in the set of variables X of equation (3). We first control for the size of the market measured by the log of GDP (in Euros) of the country of potential application by the variable *GDP level*. We also control for the innovation potential of the country, captured by private business R&D expenditures in percentage of GDP, *Business R&D/GDP*. We moreover include a control for the degree of IP protection in the potential countries of location of patents, with the index variable *IP protection*. For this variable, we take a widely used index developed by Ginarte and Park (1997) and subsequently updated by Park (2008). Finally, we also control for research activities related to the patents considered in our data. The *Real Research Activity* variable measures whether or not any of the inventors of a given patent reside in the country where the patent is registered according to the Patstat database. Since we use a count model, the *Real Research Activity* is measured by the number of patents where at least one of the inventors resides in the country where the patent was registered, as a percentage of the total number of patents registered in that country by a given firm. All four controls variables also used by Griffith et al (2014), are

[35] Although these authors use the log of the total number of patent applications per (owner or inventor) country and per year.
[36] See also Cohen et al. (2000) for evidence of this relationship.

expected to exert a positive effect on patent applications. It should be noted that our equation includes only alternative choices-level control variables as usually done in this kind of model. The only company-level control variable is the size of the company (measured by its level of employment) which is however only used to correct for over-dispersion in patent registration as discussed earlier. As our explanatory variables are defined at company-level basis and that patent registration under the EPO is exclusive (despite the fact that patents can later be registered in multiple countries), it is likely that our residuals are correlated across parent companies, thus biasing our estimated standard errors. In order to correct for this, we cluster our observations at the level of the parent company, following Moulton (1990).

5. Identification strategy

Before discussing the estimation results, we should note that our identification strategy hinges on the assumption that governments' decisions to set-up a patent box regime or to change the characteristics of existing one are exogenous to the conditions of R&D activities in their country. However, despite the fact that these tax policy decisions are unlikely to be frequent (which lends some support to the exogeneity assumption), we cannot fully rule out the possibility for these changes to be endogenous. Indeed, the presence of patent boxes or of some of their features (such as the existence of a development condition) may be chosen by governments because of existing business R&D activities. The causation can go in both directions of attracting patents or retaining existing ones.

Our approach looks at annual microeconomic decisions of multinationals to register patents through different subsidiaries potentially located in 33 countries as a response to macroeconomic decisions on patent boxes and tax rates set by governments. These latter are however not immediately adjusted on the basis of current firms' decisions. Our data on patent boxes indeed suggest that - at least for the period considered - patent box regimes seldom change once in force in a given country (with a few exceptions such as the recent change in tax rebate in the Spanish scheme). However, in order to test more thoroughly whether our identification strategy is valid we have run a set of logistic regressions at the country level to check whether local business R&D activities had a bearing on the presence of patent boxes and features. In particular, we have estimated regressions where the presence of a patent box (and the presence of development conditions) represented by a dummy variable is used as dependent variables and the Business R&D expenditures (BERD) as share of GDP was used as explanatory variable. In addition, we have also used as dependent variable a dummy variable indicating the presence of development conditions (conditional of course on the existence of a patent box regime). We also include time and country fixed effects.

The results of these regressions are shown in Table A2 of the appendix. In these regressions, we define different lag structures for the effect of BERD including lags and leads. The coefficients attached to BERD never come out as statistically significant, except only in the regression with the development condition as dependent variable. Even in this case, the lag and lead of BERD are only significant at 10%. These results lend some support to the exogeneity of patent boxes to the BERD activity. One must admit however that our identification strategy is limited in absence of a valid instrumental variable controlling for the fact that patent boxes might be introduced in anticipation of rising R&D.

6. Econometric Results

Table 3 provides the summary statistics on the dependent and exogenous variables for the estimation samples used to run our base regressions. The average value of the patent count is more than 10 times lower than its standard deviation in all sectors, illustrating the skewness of the dependent variable. The control variables display almost identical means and standard deviations across sectors as these statistics are country-specific. The level of IP protection, GDP and business R&D also display low variability compared with the tax advantage and the patent box dummy variables, reflecting the fact that over the period considered countries have increasingly used patent boxes, thereby reducing their effective CIT rate to attract patenting activities. Table 3 also provides information on the degree of foreign ownership of the companies in the three sectors. All companies in the sample are multinationals, i.e. they have at least one affiliate located in a different country. The three sectors are however not homogeneous regarding their foreign presence. The car industry is clearly over-represented as companies covered in our sample have on average 537.2 foreign affiliates in the 33 host countries considered, against 94.2 in the ICT sector and 14.6 in the pharmaceutical industry. Companies in the ICT sector are much more heterogeneous in relation to their foreign presence, with a large ratio of their standard deviation to the average number of foreign affiliates of 2.6 against 1.4 for the car industry and 0.6 for the pharmaceutical sector. ICT companies are also those that register fewer patents abroad (9.2% of the total patents registered in this sector), while the pharmaceutical sector register a quarter of its patents (26.3%) in a different country against 14.3% in the car industry. Therefore there is no clear correlation between the extent of foreign presence and the registration of patents abroad in the sample of sectors considered here.

6.1. Patent boxes and the fiscal advantage of patent box regimes

We first run our basic regression separately for the three sectors of interest using two different specifications: we use a logit like in Griffith et al. (2014) and a negative binomial model. The results of these estimations are reported in Table 4. All regressions contain our variable of interest (the Effective Tax Rate), country and time fixed effects, and our four control variables (*GDP level*, *Business R&D/GDP*, *IP protection and Real Research Activity*). As expected, the level of *IP protection* and *Real Research Activity* have both a large, positive and significant effect on patent location. Interestingly, the level of *business R&D* to GDP seems to have no strong effect on patent location and is only significant for the ICT sectors in the logit regression and for the pharmaceutical sector in the negative binomial specification respectively. Finally, the log of *GDP* has contrasted effects. It appears to exert a strong and significant positive effect for the pharmaceutical sector in both specifications. The effect is negative for the car industry, although only significant for the negative binomial model. This may be due to the absence of US leadership in this sector and a high geographical concentration of patents in a few countries, despite the presence of country dummies. [37]

The *effective tax rate* (ETR) provides contrasting results depending on the sector and specification considered. It is negative and significant at the 1% or 5% levels in the pharmaceutical and car industries but statistically insignificant for the ICT sector. All in all, the results in Table 4 suggest that a lower effective tax rate tends to attract patent registrations, a result in line with Griffith et al. (2014).

We can compare our results with previous results in the literature. We first compare our results with those of Griffith et al. (2014) who use a logit model as in our first set of regressions (columns 1 to 3) and find negative semi-elasticities between 0.5 and 3.9 depending on the selected countries.[38] Using the same specification, our results show significant and negative semi-elasticities of 1.8 and 1.9 for the pharmaceutical and cars sectors respectively (all taken at mean values of the regressors). The semi-elasticity for the ICT sector is estimated at 0.6 but fails to be statistically significant. Next, using the negative binomial model (columns 4 to 6) our semi-elasticities for the Pharmaceutical sector and the Car sector are both negative and equal to 4.2 and 5.6 respectively. In contrast, the semi-elasticity for the ICT industry would be positive (1.0) but it is not statistically significant. In a previous study, Karkinsky and Riedel (2012) find semi-elasticities of about 3 for the negative binomial model.[39] Importantly, our results suggest that the negative binomial model specification is preferable to a logit specification according to the LR test reported at the bottom of Table 4. They also point that over-dispersion is an issue to consider given the high statistical significance of the Alpha parameter. Hence, we use the negative binomial model from there on.

The finding that higher effective tax rates lower the number of patents registered in a given country makes us expect that the tax advantage offered through a patent box should exert a positive influence on patent registration. To test this, Table 5 reports negative binomial model regressions with a separate impact of the statutory corporate tax rate (CIT) from the tax advantage related to the patent box together. The regressions also include a dummy variable indicating whether a patent box is in place in a given country/year. The tax advantage offered by the patent box regime comes as suspected with a positive effect in all regressions, which is significant at the 1% level in the Pharmaceutical and Car industries and at the 10% level in the ICT sector. Calculating the marginal effects, we find that for each percentage point increase in the tax advantage

[37] In our sample, the top three patent locations for the car industry (DE, JP, US) represent 83.0% of cases, compared to 69.7% in the pharmaceutical sector and 66.7% in the ICT sector.

[38] Please note that Griffith et al. (2014) estimated a mixed effect logit while here we use a simple logit specification in order to be able to compare the results with other papers as well. The elasticities obtained using a mixed logit did not differ significantly from the ones reported here. We estimated a mixed effect model for the negative binomial model which is our preferred specification.

[39] Using OLS, Bradley et al. (2015) find a semi-elasticity of the tax rate on the number of patents of about 3. In their OLS estimates, Karkinsky and Riedel (2012) find semi-elasticities ranging between 2.3 and 7.7.

offered by the patent box, the number of patents in the concerned country will rise by as much as 11.8%, 8.6% and 17.0% for the pharmaceutical, ICT and car industries respectively. These results therefore confirm that the tax advantage of patent box regimes explain their positive and significant impact on patent registration. Our regressions also tend to confirm large difference in coefficients across sectors. They can be explained by the interplay of the tax and strategic factors. We find ICT to be on average the least sensitive sector to the tax advantage offered through patent boxes. This can be due to the 'complex' nature of the industry (Cohen, 2000), but also to the fact that R&D and product cycles in this sector can be much shorter. Bilir (2014) indeed finds that firms with short life-cycle technologies are insensitive to the strength of IP rights at a location, because offshore imitation is less likely to succeed before obsolescence. There may be less interest in tax gains from patents which protect short-lived technology if a complex tax planning need to be organised first. On the other hand, R&D cycles in new drugs and cars can be rather long and they are more of a 'discrete industry' (Cohen, 2000). In addition, motor vehicles and chemicals (subsector of pharma) also seem to have more complex supply chains. This suggests higher sensitivity to tax (Beer and Loeperick, 2015).[40]

Our estimations can also be used to analyse the extent to which the *size* of the tax advantage offered through patent box regimes matter for attracting patent registration. This question is particularly relevant from a fiscal perspective given that government may aim at minimizing the tax revenues losses from patent boxes while maximising their expected positive impact on patenting activities. The effect of a patent box regime depends on the tax rebate offered – itself often a percentage of the CIT rate – and on the conditions under which this tax rebate applies, i.e. the patent box dummy. In addition, a company may choose to set up a subsidiary in a given country primarily to reduce its overall tax bill by shifting patent registration there, but it might also consider the level of the CIT rate applying to revenues other than patents. To account for the full effect of patent box regimes we need to consider all components together.

To investigate the global effect of patent boxes and their tax advantage on patents location, it is important to recall that in non-linear models - such as in the negative binomial used here - marginal effects are sensitive to the baseline values chosen for all independent variables. However, the baseline value of a control for a specific category of observations (e.g. all observations with a patent box) differs from the baseline value for the entire sample (e.g. all observations with or without a patent box). In our sample, the average tax advantage given by patent boxes is about 17 percentage points but this average drops to 2.7 percentage points when we consider the whole sample, including observations without a patent box, for which this advantage is therefore zero. This average value of 2.7 percentage points for the full sample is even well below the lowest observed tax advantage in our sample (bar the zeros), that is 8.8 percentage points. A specific concern about the estimation of marginal effects of interaction effects in non-linear model lies in the fact that the marginal effect cannot be directly determined by the first derivative of the expected value of the dependent variable with respect to the

[40] Their research on the link between supply chain and tax sensitivity is described in section 2.1.

interaction term. The marginal effect should be instead calculated as the cross partial derivative of the dependent variable with respect to each interacted variable separately in order to interpret it correctly. A very practical solution is to calculate the incidence ratio. The marginal effect of the interaction term between the tax rebate and the patent box dummy variable can be interpreted directly as a measure of the differential impact of the tax rebate due to the presence of a patent box regime. Calculating the incidence ratio, one can infer the marginal effects of multiplicative terms directly.[41] Figure 3 shows the predicted percentage change in the number of patents at levels of corporate tax rebate conditional on the existence of a patent box regime. Given the non-linearity of the model, this effect varies with the level of tax rebate but we see that the effect of patent boxes is economically significant.

Back to our regressions, we see in columns (1)-(3) of Table 5 that the coefficient of the patent box dummy variable is negative and significant. This variable captures all patent-box related features which are not represented by the tax advantage for a given level of the tax advantage which is set at the average sample value. Our previous discussion shows that this sample value is arguably very low since the sample average includes countries with and without patent boxes and in the latter the tax advantage is zero. Therefore, strictly speaking, the negative coefficient on the patent box dummy could reflect the fact that, for a given tax advantage, i.e., given at its average sample value, other patent box features such as the compliance to conditions that must be met in order to grant the tax rebate exert a negative impact on patent registration.

As a robustness check, we also estimate our model by analysing whether or not firms could respond heterogeneously to the tax advantage offered by patent boxes. As Griffith et al. (2014) point out, there is little reason to consider that patents payoffs are uncorrelated across countries, such that $Cov(\pi_{j,t}, \pi_{k,t}) \neq 0$. They suggest using a mixed model with random coefficients in order to control for the possible correlation in location choices. Such an approach is particularly relevant when large multinational companies - as the ones considered in our data - develop a high number of patents and arbitrate across different locations. In such cases, patents payoffs are more likely to be correlated. We hence estimate such mixed models using our negative binomial model, estimating the random coefficient on the tax advantage offered through patent boxes. Our results are reported in the last three columns of Table 5. We find significant random effects on this variable for the ICT sector (significant at 1%) and the Car industry (at 5%) but no significant random effects for the Pharmaceutical sector. Griffith et al. (2014) find large and significant random effects for the effect of the corporate tax rate on patent registration. This difference with our results might be due to the fact that we run

[41] In particular the marginal effects of an interaction term provided by the statistical software will be the marginal effect of the interaction term calculated at the average sample value for both elements of the interaction on the expected value of the number of patents $\frac{\partial \mathrm{E}(\#\mathrm{patents})}{\partial(\mathrm{dj,t}*\mathrm{T})}$ where dj,t stands for the patent box dummy variable and T is the tax advantage in the patent box regime. In reality, the average tax advantage conditional on having a patent box is higher than for the total sample (which includes the cases for which there is no patent box). Hence, the marginal effect is not calculated at the right reference point. We are instead interested in the marginal effect of the patent box on the marginal effect of the tax advantage on the expected number of patents, that is $\partial\left(\frac{\partial \mathrm{E}(\#\mathrm{patents})}{\partial \mathrm{T}}\right) \Big/ \partial \mathrm{dj,t}$. We are particularly thankful to Marteen Buis for very helpful discussion on this point.

our estimation by sector of activity that are less broadly defined than the ones considered by the aforementioned authors. In addition, we measure the impact of the tax advantage and not the impact of the corporate tax rate and we control for the existence of a patent box, which is not considered in Griffith et al. (2014). While heterogeneity still matters in our case as shown by the significance of the random effects in 2 out of 3 sectors, our different specification and the fact that we observe actual tax rebate under a patent box regime can explain our differences in results. In the extensions of our empirical analysis presented in the following sections, we use the negative binomial model without the random term, which is computationally less demanding, since the model with the random effect does not appear to modify our results significantly.[42]

We have finally run a number of robustness check of our results reported in Table 4 in order to check whether our estimates could be biased by the fact that we do not control for the fact that countries compete to attract patent registration and that the number of patents registered in one countries might be negatively affected by the number of patents registered in third countries. As the previous discussion shows this competition is done globally and the geographical mobility of patents is relatively weightless, i.e. companies can decide to move such intangible assets from one country to another one at very low cost, unlike tangible assets. In addition, our results could also be biased if large companies, in particular companies with large number of registered patents, are able to influence the tax policy of countries, notably small countries that strive to attract foreign investment and R&D activities. We have tested these assumptions by first running additional regressions controlling for the occurrence of new patent boxes in the sample of countries considered.[43] We have included a dummy variable equal to 1 when a new patent box regime was created in at least one of the countries in a given year. Our results indicate that this variable exerts a negative and highly significant effect on patent registration, thus suggesting that countries are effectively competing to attract foreign patents in their own constituency. The results of all our main variables of interest remained virtually unchanged. Second, we also removed the top 5% patent registering companies from the sample in order to check whether not including these large companies could potentially alter our results. As before, our results remained broadly in line with the ones reported in Table 5; in some cases we even observe an increased significance of the coefficients. Likewise, if we in addition exclude small countries (which we define as the bottom 20% countries in terms of GDP size) from our sample, the results remain in line with the one reported in Table 5.

6.2. Patent value

Innovation outcome distributions are highly skewed with major innovations capturing the lion's share of value creation (Scherer and Harhoff, 2000). Patent value can serve as a

[42] As additional robustness check we also verified whether the effect of patent boxes could come with a lag given that the effect of patent box may take time before becoming tangible in order for firms to adapt to such policy change. The results of these regressions showed no significant differences with the results reported here.

[43] Results of these additional regressions are available from the authors upon request.

proxy for innovations with high earning potential, the holy grail of innovation policy. The role played by ideas and patent value is therefore quite fundamental in the analysis of patent boxes. The motives for different patent registration choices are likely to be correlated within ideas, and so is the potential influence of tax determinants, since firms are likely to decide on the geographical registration of their patent portfolio strategically, depending on the market potential of new ideas embedded in patents. Griffith et al. (2014) use a group variable based on the simultaneity between industry and the network of inventors of patents registered by a single firm to identify idea membership. Such a measure could nevertheless be regarded as somewhat restrictive, since it excludes patents registered by different firms but relating to the same idea or invention, as well as patents relating to the same idea or invention but registered at different times. There are also two reasons for using an alternative measure of patent value. First, competing firms are also likely to compete for similar ideas. Second, firms may attempt to protect ideas or to generate revenues from a given idea by registering patents at successive times. To account for these possibilities, we use instead an indicator variable based on the information provided by the International Patent Documentation, i.e. the so-called INPADOC family group, produced by the European Patent Office. The INPADOC family groups indicate if a given patent registration corresponds to the same priority and invention. Using information based on INPADOC membership is likely to provide an accurate measure of the value of the patent given that it is not exclusive in terms of the time of registration and firm ownership of the patent. We defined high-value patents as those belonging to the top quartile by sector in terms of INPADOC family size. In line with our approach, patent's family size is also a preferred value measure of Böhm et al (2014). In Figure 4, we report the weighted average of the statutory and effective tax rates (i.e. including the patent box rebate whenever in place), using as weight the total number of patents registered. As one can see, high-value patents tend to be located in countries with lower corporate taxation and with a larger gap between the standard CIT rate and the effective tax rate. This descriptive evidence thus suggests that firms have exploited the tax advantage offered by patent boxes especially for high-value patents.

To confirm these results, we have run regressions separately for high-value patents, defined as patents belonging to the top quartile in terms of patent family size as defined above, and compared the results with the regressions covering the remaining patents. The results of these additional regressions are reported in Table 6. The effects of both the statutory CIT rate and the tax advantage in the patent box regime are different between the two groups of regression. The negative coefficients obtained for the statutory CIT rate are larger in absolute terms for high-value patents, and the tax advantage coefficients are always larger. Since these additional regressions are run over different sample sizes, we have tested the significance of the difference in the coefficients estimated using a Wald test. The results of these tests are reported in the last row of Table 6 showing that the null hypothesis of equal coefficients can be rejected. These results therefore suggest that high-value patents tend to be significantly more sensitive to taxes.

6.3. Patent box characteristics

Next, we are interested in whether or not the specific characteristics of patent boxes have an effect on patent location and whether these effects vary across sectors. Given the high multicollinearity in some of the patent box characteristics[44], not all these characteristics were included in the regression. To test the effects of characteristics, we have identified five dimensions of patent boxes and we add dummy variables reflecting these specific features of the patents as described in Tables 1 and 2. These regressions are run conditionally to the existence of the patent box regime, i.e. they are run for countries/years in which a patent box regime was in place. In doing, so we can interpret our estimates in terms of marginal effect of a given patent box characteristic for a baseline average effect of the patent box. The coefficients estimated for the patent box characteristics, the tax advantage and the interaction between these two variables are reported for the three sectors in Table 7.[45]

The first set of characteristics considered are dummy variables respectively for whether or not acquired patents, embedded royalties and existing patents (i.e. patents prior to the creation of the patent box) qualify for the tax advantages of patent boxes, see columns (1)-(3) of Table 7. We focus on the coefficient obtained on the tax advantage interacted with the specific patent box characteristic without making any inference on the separate dummy variables since, as discussed earlier, such discussion is best made for other than average values of the control variables. We find the tax advantage in the acquired patents characteristics to be positive and significant for the ICT and Car sectors but insignificant for the Pharmaceutical industry.[46] A similar finding is shown for the embedded royalties characteristic. For the existing patents condition, the results are contrasted. The interaction between this condition and the tax advantage turns out to be insignificant for the pharmaceutical and ICT sectors and negative and significant for the Car industry. The result on the existing patents condition for the car industry might reflect the dominant role played by large car producers with high patenting activity, such as Germany and Japan, where strategic market considerations might prevail over tax advantage when deciding about the location of a patent registration. The results for the acquired and existing patents characteristics can also be explained by the fact that patents are not developed in isolation but are usually part of a patent portfolio strategy by firms. Acquired patents can raise the value of other (including) future patents in a portfolio. To achieve this multinationals build up higher-value and better-matching patent portfolio (see Bösenberg and Egger, 2017).

Next, column (4) of Table 7, we look at the effect of having patent boxes offering a tax advantage to a larger range of rights than just patents (see Table 2 for details). In all three sectors, the coefficient is positive and significant, indicating that the broader the tax base concerned by the patent box the more attractive the country to patent

[44] An unreported correlation matrix shows a degree of correlation between the various characteristics.
[45] In order to save space the results for all other control variables are omitted. The full results are available from the authors upon request.
[46] Note that as we observe patent applications we cannot see changes in legal ownership of patents in our data.

registration. Finally, in Column 5 of the Table 7, we consider the role played by development conditions whereby countries grant tax rebate conditional on R&D activities being developed within the country. Controlling for the development conditions dummy variable makes the tax advantage to be insignificant in the car sector, but it makes it negative and significant for the Pharmaceutical and ICT sectors. The effect of development condition thus appears to be rather heterogeneous across sectors. It indicates that the imposition of development conditions can potentially decrease the tax sensitivity of patents registration.

6.4. Effects of patent boxes on research activity

We now consider the interaction between patent box regimes and local R&D activities as this is an often advocated justification for granting preferential tax treatment. We define a measure of local R&D activity based on information for the total number of inventors (of patents) registered by each multinationals in each country and year. This is measured at company level to allow us linking the presence of patent boxes with patent registrations and local innovative activity with precision. We are interested in testing two arguments put forward in the patent box policy debate: (i) to what extent the tax rebate granted by a patent box is effectively promoting local inventorship in the foreign affiliate of the multinationals, and (ii) how effective are development conditions included in some patent box regimes in ensuring that the tax rebate is effectively fostering R&D in the country where the patent is being registered. A first option for measuring the impact of patent boxes on local R&D activities by foreign affiliates could be to simply consider the change in the total number of inventors associated to patents registered by a multinational in a given country. However in doing so we could possibly capture cases where the innovative activity of a given multinational is globally increasing (or decreasing) and wrongly attribute the change in foreign affiliate R&D activities to the existence of a patent box regime. In our estimations we therefore use a control variable represented by the growth in R&D activities in the home country. A second option is to build a dependent variable that distinguishes the changes in R&D activities both at the multinational group level and in the host countries where patents are registered. To validate the argument of fostering local research activities, our dependent variable should therefore capture a positive change in local R&D in the country of the patent measured as an increase in the number of inventors in the country of registration (i.e. the host country) and a decreasing or stable number of inventors in the multinational group globally. This indicator can be transformed into a dummy variable taking the value 1 if those two conditions hold (i.e. increase in the number of host country researchers and a decrease or stabilisation in the total number of researchers within the corporate group). Indeed, although we do not observe whether the inventors actually move from one country to another, we can reasonably assume that such simultaneous rise and fall in the number of inventors in two different parts of the (company) group indicates an inventor shift. This binary variable is used as dependent variable to assess its determinants through logistic regressions. These regressions are performed at the company-level. As control variables, we use the same as the previous specifications with two exceptions. First, we need to remove the Real Research Activity variable used in previous regressions as this variable could be endogenous in this specification. Secondly, we include a binary variable indicating the presence of development conditions in the patent box regime. As before all our regressions are performed by clustering observation at the level of parent companies.

The estimations reported in Table 8 provide the results of running OLS regressions where the dependent variable is the annual change in the (log) number of inventors (columns 1-3) and logistic regressions for the probability of performing an inventor shift (columns 4-6). Our results suggest that the tax advantage linked to the patent box is negatively correlated with both the annual growth in the number of inventors and the probability of moving inventors to the patent box country. These results could indicate that countries offering generous tax rebates through the patent box have also more difficulty in fostering local R&D even with a patent box. However, little can be said regarding a possible causality link between the size of the patent box tax advantage and the local R&D activity. The result obtained for the dummy variable indicating the presence of a development condition seems to be more straightforward. This variable displays a positive and significant effect (at 1%) in all specifications. Countries including a specific local development condition therefore have a higher probability of fostering local R&D activities or in experiencing an inventor shift and are perhaps more likely to promote local R&D activities in their favour, as reflected by the positive and significant coefficient attached to the development condition variable. This result also holds independently of controlling for the change in R&D activities at the multinational group level as shown by the results on the regressions on local inventors growth.

7. Conclusions

This paper analyses how the implementation of patent boxes affects the patent-filing strategies of top corporate R&D investors across countries. For this, we use a recent and rich firm-level dataset for the 2000-2012 period on the top 2,000 corporate R&D investors from 39 countries, considering their ownership structure, and analyse the determinants of patent registration across a large sample of 33 host countries.

For the first time, we disentangle the effect of three key characteristics of patent boxes: the corporate income taxation; the tax advantage of registering patents in a patent box country; and other characteristics of the patent boxes that define both their coverage (i.e. the tax base) and non-fiscal characteristics such as local R&D development conditionality.

Patent boxes exert a strong effect on attracting patents, mostly due to the specific favourable tax treatment that they bring about. However, this effect varies across sectors and with the specific characteristics of the patents. High-value patents are shown to be more influenced in their location choices by the tax advantage offered by patent boxes than patents of lower value. The possibility to grant the patent box tax regime to patents that have been acquired, existed previously or contain embedded royalties seems to make patent location even more sensitive to the tax advantages offered by patent boxes. The same can be said of patent boxes broadening their coverage to other rights such as trademarks, design and models, copyrights or domain names. Our results also suggest that in the majority of cases, the existence of a patent box regime incentivises multinationals to shift the location of their patents without spurring local R&D activities or without favouring a shift of inventors. This suggests that the effects of patent boxes are mainly of a tax nature.

An interesting development of patent boxes concerns the possibility of imposing development conditions for the patent to qualify for the advantageous tax regime. This is the case in several countries. These conditions provide a proxy for the possible effect of conditionality clause agreed at the EU and OECD, i.e. the so-called nexus approach. Our results show that such specific condition appears to dampen the dominant effects of the tax advantage of the patent box regime on patent locations while encouraging local inventorship.

Patent boxes are a relatively recent development among the tools offered to companies to boost R&D activities. They have been criticised for offering additional tax advantages to income already profiting from an IP protection and having potentially little effect on the level of R&D. Their development has raised concerns over the fact that they could exert a significant effect on patent location without any change in the real research activity, targeting only the tax benefits. Our results confirm these fears, with the tax attractiveness of patent boxes being greater the broader their coverage. Recent debates on the potentially harmful consequences of patent boxes have addressed the possibility of linking the advantages of patent to the requirement of a real research activity by the taxpayer that receives tax benefits. Our results suggest that it has the potential to decrease the still dominant tax effects of patent boxes on patent location and to raise the level of local inventorship. The nexus approach therefore offers some potential to mitigate the role of patent boxes as new tax competition tools.

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Table 1: Patent box characteristics (2000-2014)

	NL	BE	LU	FR	PT	CN	UK	ES	HU	MT	CH (NW)	CY	LI	IE
Top Corporate income tax rate in % (2014)	25	33.99	39.2	38	31.5	25	21	30	20.6	35	14.5	12.5	12.5	12.5
Effective tax rate on patent income within the patent box (calculated on top CIT rate with surcharges)	5	6.798	5.84	15.5 (16.245 2010-2015)	15.75	15	10	12	10.3	0	8.8	2.5	2.5	0
Year of introduction (changed)	2007 (2010)	2007	2008	1971	2014	2007	2013 (h)	2008 (2013)	2003 (2012)	2010	2011	2012	2011	1973 (2008)
Only patents and rights associated with patents	Y*	Y*		Y*			Y							
Applicable to existing IP				Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
Applicable to acquired IP		(b)	Y	(e)		Y	(i)		Y	Y	Y	Y	Y	Y
Authority granting the IP right	Y	(c)	Y	(c)	(c)	(c)	(j)	Y	Y	Y	Y	Y	Y	Y
Development condition	Y	Y			Y	Y	Y	Y						Y
Capital gains included	Y		Y	Y		Y	Y	(l)	(n)		Y	Y	Y	
Income from the sales of innovative products (embedded royalties)	Y	Y	Y			Y	Y			n.a.			Y	
R&D can be performed abroad (or within a group)	(a)	(d)	Y	Y	(f)	(g)	(k)	(m)	Y	Y	Y	Y	Y	(o)
Cap									Y					Y

Y: Yes; * See specificity in table 2. (a) Covers patents developed within a group when managed and coordinated in the NL; (b) If fully or partially improved; (c) Has to be registered at the national IP office; (d) If in a qualified R&D centre; (e) must be held for at least two years. Anti-avoidance rules for intragroup exploitation of IP rights; (f) double tax relief limited to 50%; (g) at least 60% done in China; (h) Phased in till 2017; (i) if further developed and actively managed; (j) if granted by EPO or UKIO; (k) if active ownership and self-developed; (l) if between unrelated parties; (m) if self-developed; (n) exempted if held for at least one year or used to buy other IP; (o) limited to EEA since 2008.

Sources: various sources such as Deloitte, EY, KPMG, PWC, International Bureau of Fiscal Documentation, and National websites sources, Acca (2013), European Commission (2014), Evers et al. (2015), Cao (2011).

Table 2: Coverage of patent boxes by country in 2014

Coverage	NL	BE	LU	FR	PT	CN	UK	ES	HU	MT	CH (NW)	CY	LI
Patents and associated patent rights	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Trademarks			Y						Y	Y	Y	Y	Y
Designs and models	(a)				Y	Y		Y	Y		Y	Y	Y
Copyrights	(a) (c)		(c)			(c)			Y	(d)	Y	Y	Y
Domain names			Y								Y		Y
Know-How	(a)	(b)		(b)				Y	Y		Y		Y

Y: Yes ; (a) Only if R&D declaration; (b) Know-how closely associated with patents; (c) Only software; (d) Only artistic

Sources: European Commission

Table 3: Summary statistics – base model

	Car (#obs: 30,881)				ICT (#obs: 78,139)				Pharmaceuticals (#obs: 57,193)			
	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.
Patent count	0	869	1.829	20.305	0	1.249	1.6662	25.555	0	598	1.061	12.445
Effective corporate income tax	0	51.612	24.963	10.273	0	51.612	24.929	10.258	0	51.612	24.901	10.247
Statutory corporate income tax	12.5	51.612	27.808	7.387	12.5	51.612	27.763	7.385	12.5	51.612	27.734	7.381
Tax advantage in patent box	0	32.850	2.845	7.022	0	32.850	2.834	7.001	0	32.850	2.833	6.999
Patent Box dummy	0	1	0.156	0.363	0	1	0.156	0.363	0	1	0.157	0.363
Business R&D / GDP	0.010	4.088	1.239	0.699	0.010	4.088	1.236	0.698	0.010	4.088	1.231	0.696
IP protection	0	1	0.498	0.500	0	1	0.499	0.500	0	1	0.499	0.500
Real research activity	0	1	0.095	0.294	0	1	0.082	0.274	0	1	0.092	0.288
GDP level (log)	7.898	16.353	12.420	1.792	7.898	16.353	12.424	1.793	7.898	16.353	12.423	1.791
Number of foreign affiliates	1	2,187	537.2	734.9	1	1,074	94.2	247.1	1	41	14.6	8.4

Sources: Patstat for patent count; Patstat and OECD for Real research activity; OECD for Business R&D; OECD for GDP; The Taxes in Europe Database, the OECD tax database and the International Bureau of Fiscal Documentation database, as well as national ministries of finance websites, for the statutory rates and the patent characteristics; Ginarte and Park (1997), and Park (2008) for IP protection. Except for the number of foreign affiliates, the sample statistics are for the regressions in Tables 4 and 5.

Table 4: Basic regressions: the impact of the effective corporate tax rate on patent registrations

	(1) Logit			(2) Negative Binomial		
	Pharma	ICT	Car	Pharma	ICT	Car
Effective Tax rate (ETR)	-0.018***	-0.006	-0.019**	-0.042***	0.010	-0.056***
	(0.006)	(0.005)	(0.009)	(0.011)	(0.029)	(0.020)
Business R&D / GDP	0.212	0.356***	-0.093	0.561**	-0.205	-0.247
	(0.153)	(0.134)	(0.234)	(0.267)	(0.755)	(0.476)
Intellectual property protection	2.258***	1.686***	1.817***	4.962***	4.772***	4.919***
	(0.106)	(0.088)	(0.112)	(0.196)	(0.381)	(0.412)
Real research activity	4.369***	4.076***	5.210***	9.571***	13.037***	10.602***
	(0.074)	(0.076)	(0.110)	(0.277)	(0.532)	(0.717)
GDP level (log)	0.886***	0.263	-0.246	2.074***	-0.277	-2.935***
	(0.323)	(0.294)	(0.374)	(0.726)	(0.992)	(1.016)
Country-fixed effects	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Time fixed-effects	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Observations	57,193	78,139	30,881	57,193	78,139	30,881
Wald test (Chi-square)	11,088	13,749	8,491	38,499	20,699	10,980
Prob > Chi-square	[0,000]	[0,000]	[0,000]	[0,000]	[0,000]	[0,000]
Alpha (overdispersion)	-	-	-	24.22	60.79	22.31
Alpha std. error	-	-	-	(0.928)	(2.330)	(1.333)

Note: We use the number of patents registered by one company in a specific country during a specific year as dependent variable (count of patents) for the Negative Binomial model. For the logit model, we use a dummy indicating the presence of (at least) one patent. Standard errors, clustered at company and year level, are reported in parentheses. The levels of significance are reported as *** p<0.01, ** p<0.05, * p<0.1. The model is estimated via a logit model in regressions (1) and via a negative binomial model in regressions (2). In this latter, we use as exposure variable the total number of employees of a company (including its subsidiaries). The unit of observation is parent company – country of the subsidiary company (-ies) – year. The Wald test informs about the joint significance of the parameter estimates, the null hypothesis being that all of the regression coefficients are simultaneously equal to zero. The alpha parameter informs about the degree of dispersion, if alpha is significantly greater than zero then the data are over dispersed and are better estimated using a negative binomial model than a poisson model.

Table 5: Estimating the effect of the tax advantage on patent registrations

	Negative Binomial			Mixed Negative Binomial		
	(1)	(2)	(3)	(4)	(5)	(6)
	Pharma	ICT	Car	Pharma	ICT	Car
Statutory corporate income tax (CIT)	-0.171***	-0.018	-0.070*	-0.130***	-0.069**	-0.057**
	(0.034)	(0.056)	(0.038)	(0.022)	(0.033)	(0.025)
Tax advantage in patent box	0.112***	0.083*	0.157***	0.085***	0.138***	0.227***
	(0.021)	(0.044)	(0.027)	(0.015)	(0.023)	(0.036)
Tax advantage in patent box (random effects)	-	-	-	0.000	0.012***	0.014**
	-	-	-	(0.000)	(0.004)	(0.006)
Patent box dummy	-2.000***	-2.495***	-2.794***	-1.652***	-3.081***	-3.856***
	(0.303)	(0.411)	(0.252)	(0.168)	(0.252)	(0.322)
Business R&D / GDP	0.674**	0.468	-0.307	0.197	0.469	0.009
	(0.285)	(0.653)	(0.446)	(0.263)	(0.316)	(0.404)
IP protection	4.895***	4.947***	5.048***	4.584***	4.774***	4.683***
	(0.179)	(0.383)	(0.378)	(0.168)	(0.195)	(0.303)
Real research activity	8.897***	11.543***	10.398***	7.429***	9.551***	10.424***
	(0.250)	(0.473)	(0.665)	(0.154)	(0.222)	(0.266)
GDP level (log)	1.928**	0.476	-2.425**	0.376	0.764	-0.705
	(0.751)	(0.941)	(1.014)	(0.507)	(0.593)	(0.888)
Country-fixed effects	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Time fixed-effects	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Observations	57,193	78,139	30,881	57,193	78,139	30,881
Chi-square	41,905	20,144	12,404	2,866	2,272	1,657
Prob > Chi-square	[0,000]	[0,000]	[0,000]	[0,000]	[0,000]	[0,000]
Alpha (overdispersion)	22.46	57.08	20.86	-	-	-
Alpha std. error	(0.878)	(2.369)	(1.244)	-	-	-

Note: We use the number of patents registered by one company in a specific country during a specific year as dependent variable (count of patents). Standard errors, clustered at company and year level for the negative binomial regressions, are reported in parentheses. The levels of significance are reported as *** p<0.01, ** p<0.05, * p<0.1. The model is estimated via a negative binomial model in regressions (1) to (3) and via a mixed negative binomial model in regressions (4) to (6). In this latter, we use as exposure variable the total number of employees of a company (including its subsidiaries). The unit of observation is parent company – country of the subsidiary company (-ies) – year. The Wald test informs about the joint significance of the parameter estimates, the null hypothesis being that all of the regression coefficients are simultaneously equal to zero. The alpha parameter informs about the degree of dispersion, if alpha is significantly greater than zero then the data are over dispersed and are better estimated using a negative binomial model than a poisson model.

Table 6: Estimating the effect of the tax advantage on patent registration: High vs. low value patents

Model estimated	Negative binomial – high value patents			Negative binomial – other patents		
	(1)	(2)	(3)	(4)	(5)	(6)
	Pharma	ICT	Car	Pharma	ICT	Car
Statutory corporate income tax	-0.256***	-0.090	-0.229***	-0.112***	0.032	-0.014
	(0.054)	(0.080)	(0.086)	(0.037)	(0.055)	(0.038)
Tax advantage in patent box	0.172***	0.075	0.224***	0.093***	0.068*	0.191***
	(0.044)	(0.071)	(0.037)	(0.023)	(0.039)	(0.047)
Patent box dummy	-2.912***	-2.397***	-3.216***	-1.591***	-2.070***	-2.969***
	(0.600)	(0.804)	(0.406)	(0.347)	(0.344)	(0.272)
Business R&D / GDP	-1.410**	-2.212	-1.695***	1.129***	1.611***	0.381
	(0.637)	(1.406)	(0.610)	(0.295)	(0.339)	(0.701)
IP protection	6.103***	4.230***	4.570***	4.321***	4.650***	5.608***
	(0.456)	(0.646)	(0.628)	(0.189)	(0.263)	(1.014)
Real research activity	8.472***	17.623***	7.963***	8.650***	9.775***	11.999***
	(0.431)	(1.525)	(0.621)	(0.260)	(0.365)	(0.756)
GDP level (log)	2.168	0.167	0.007	0.958	1.221	-0.122
	(1.332)	(1.132)	(1.873)	(0.936)	(0.744)	(1.312)
Country-fixed effects	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Time fixed-effects	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Observations	15,215	21,037	8,253	41,978	57,102	22,628
Chi-square	9,160	9,316	8,100	42,419	19,211	15,651
Prob > Chi-square	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Alpha (overdispersion)	26.71	82.14	18.04	19.27	44.44	20.31
Alpha std. error	(1.980)	(7.835)	(2.523)	(0.941)	(2.012)	(1.261)
Chi-square equality of coefficients between high value patents and other patents (tax advantage in patent box)	22.08	47.13	5.29	-	-	-
Prob > Chi-square	[0.000]	[0.000]	[0.071]	-	-	-

Note: We use the number of patents registered by one company in a specific country during a specific year as dependent variable (count of patents). High value patents are defined as patents that belong to the top quartile in terms of INPADOC family size. Standard errors, clustered at company and year level, are reported in parentheses. The levels of significance are reported as *** p<0.01, ** p<0.05, * p<0.1. The model is estimated via a negative binomial model. The unit of observation is parent company – country of the subsidiary company (-ies) – year. The Wald test informs about the joint significance of the parameter estimates, the null hypothesis being that all of the regression coefficients are simultaneously equal to zero. The alpha parameter informs about the degree of dispersion, if alpha is significantly greater than zero then the data are over dispersed and are better estimated using a negative binomial model than a poisson model.

Table 7: Estimating the effect of the tax advantage on patent registration: Patent box characteristics

Model estimated	Negative binomial				
	(1)	(2)	(3)	(4)	(5)
	Acquired patents	Embedded royalties	Existing patents	Coverage of patents	Development conditions
			Panel 1 - Pharma		
Patent box characteristic (dummy)	2.738***	-3.739*	2.910	-1.820***	3.336***
	(0.508)	(2.134)	(1.891)	(0.687)	(0.620)
Patent box characteristic (dummy) * Tax advantage in patent box	0.111	0.171	0.009	0.288***	-0.247***
	(0.070)	(0.169)	(0.146)	(0.060)	(0.064)
Tax advantage in patent box	-0.036	0.040	0.092	-0.097***	0.014
	(0.028)	(0.035)	(0.135)	(0.019)	(0.077)
			Panel 2 - ICT		
Patent box characteristic (dummy)	0.891*	-9.419**	-4.310	-9.188***	1.971***
	(0.490)	(3.880)	(3.323)	(1.469)	(0.694)
Patent box characteristic (dummy) * Tax advantage in patent box	0.403***	0.975***	0.355	0.866***	-0.282***
	(0.099)	(0.310)	(0.326)	(0.161)	(0.089)
Tax advantage in patent box	-0.037	-0.277***	-0.290	-0.108**	0.272***
	(0.056)	(0.062)	(0.239)	(0.050)	(0.098)
			Panel 3 - Car		
Patent box characteristic (dummy)	-6.064***	-16.138***	26.435***	-5.938***	-4.732***
	(0.970)	(3.481)	(5.937)	(1.449)	(1.634)
Patent box characteristic (dummy) * Tax advantage in patent box	0.708***	1.300***	-1.960***	0.782***	0.136
	(0.092)	(0.243)	(0.528)	(0.125)	(0.198)
Tax advantage in patent box	-0.337***	-0.384***	1.721***	-0.339***	-0.042
	(0.047)	(0.068)	(0.522)	(0.062)	(0.122)
Additional controls included in all specifications:	*Statutory corporate income tax, Business R&D / GDP, Intellectual property protection, Real research activity, GDP level (log), Country-fixed effects, Time fixed-effects.*				

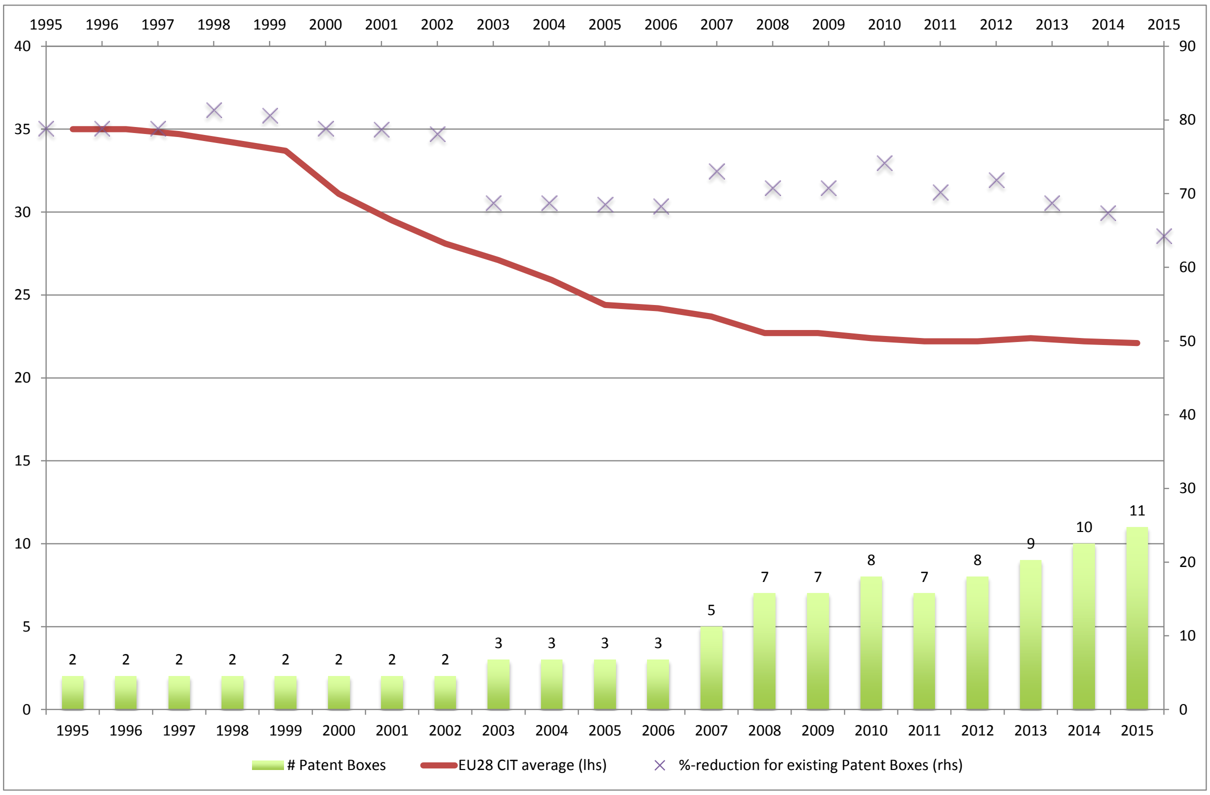
Note: We use the number of patents registered by one company in a specific country during a specific year as dependent variable (count of patents). Standard errors, clustered at company and year level, are reported in parentheses. The levels of significance are reported as *** p<0.01, ** p<0.05, * p<0.1. The model is estimated via a negative binomial model. The unit of observation is parent company – country of the subsidiary company (-ies) – year. Observations: 8,957 for Pharma, 12,226 for ICT, 4,832 Car. Chi-squares and overdispersion are high and significant in all the specifications.

Table 8: Impact of patent boxes on real research activity

Model estimated	Linear regression on local inventors growth			Logit on inventors shift		
	(1)	(2)	(3)	(4)	(5)	(6)
	Pharma	ICT	Car	Pharma	ICT	Car
Statutory corporate income tax	-0.008	0.004	-0.004	-0.045**	-0.023	-0.065***
	(0.010)	(0.012)	(0.009)	(0.020)	(0.027)	(0.023)
Tax advantage in patent box	-0.032**	-0.046***	-0.065**	-0.099***	-0.103***	-0.189***
	(0.012)	(0.016)	(0.026)	(0.015)	(0.016)	(0.044)
Development conditions are required in the patent box	0.651***	1.089***	1.232***	2.139***	2.006***	3.797***
	(0.153)	(0.242)	(0.422)	(0.256)	(0.257)	(0.659)
Business R&D / GDP	0.154	-0.023	0.228	0.316	0.295	-0.259
	(0.182)	(0.179)	(0.238)	(0.255)	(0.259)	(0.300)
Intellectual property protection	-0.684***	-0.471***	-0.473***	0.628***	-0.307*	-0.050
	(0.209)	(0.159)	(0.172)	(0.230)	(0.173)	(0.214)
GDP level (log)	-0.514	-0.667*	0.255	0.342	0.745	-0.205
	(0.413)	(0.371)	(0.544)	(0.566)	(0.525)	(0.794)
Inventor growth at the MNE level	0.365***	0.288***	0.250***			
	(0.059)	(0.050)	(0.077)			
Time fixed-effects	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Constant	0.957***	0.763***	0.867***	-1.609***	-1.502***	-0.951***
	(0.183)	(0.151)	(0.157)	(0.276)	(0.224)	(0.267)
Observations	3,327	3,727	2,029	3,327	3,727	2,029
R-squared ‖ Pseudo R2	0.062	0.078	0.067	0.044	0.041	0.053
F-test ‖ Chi-square	10.49	15.04	7.66	112.4	149.7	79.62
Prob > Chi-square (F-test)	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

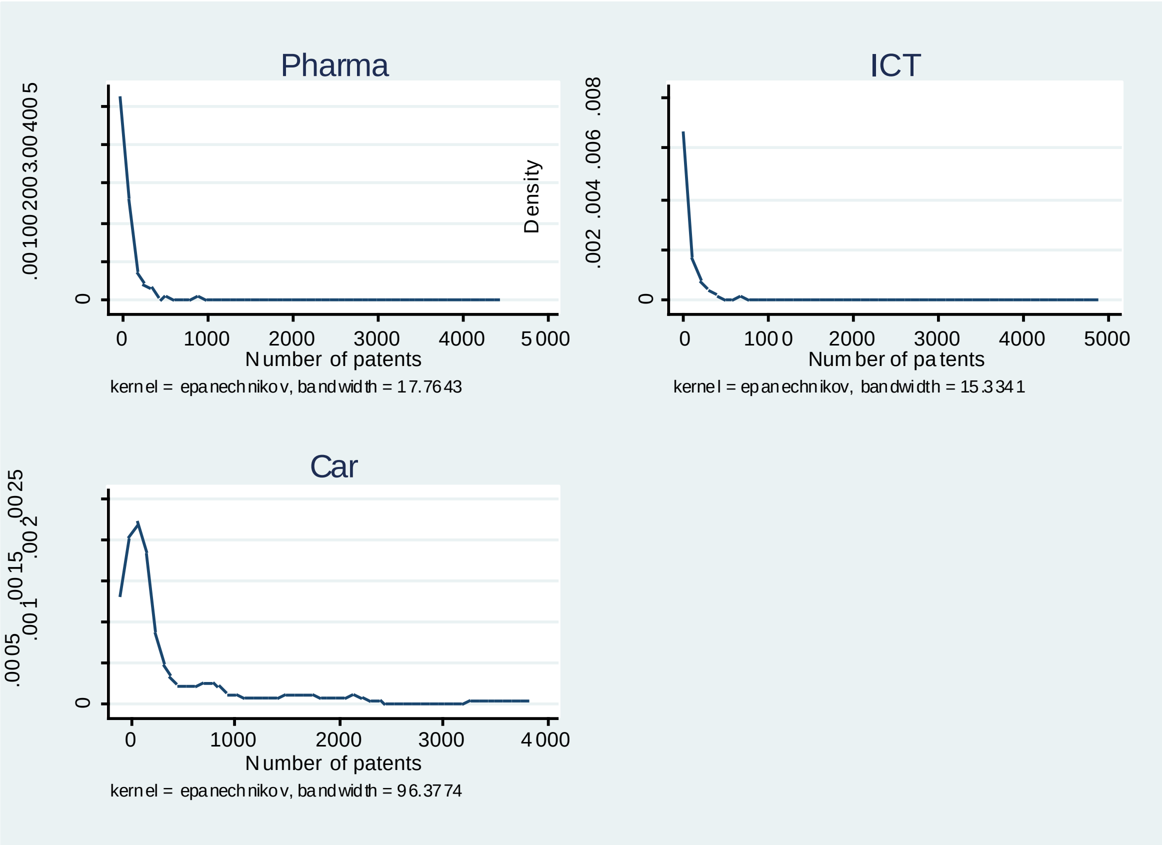
Note: In the logistic specification we use as dependent variable a binary variable taking the value 1 if the number of researchers of the company registered in the host country increases while the number of researchers of the company registered at the multinational group level decreases or is stable, and takes the value 0 otherwise. In the linear regression we use as dependent variable the growth rate of researchers of a company registered in the host country. We use observations with the presence of a patent box only. Standard errors, clustered at company and year level, are reported in parentheses. The levels of significance are reported as *** p<0.01, ** p<0.05, * p<0.1. The model is estimated via ordinary least squares in regressions (1) to (3) and via logistic regressions in (4) to (6).The models are estimated only for country/year with a patent box. The unit of observation is parent company – country of the subsidiary company (-ies) – year. The Wald (F-) test informs about the joint significance of the parameter estimates, the null hypothesis being that all of the regression coefficients are simultaneously equal to zero.

Figure 1: Average Corporate Tax Rate and Patent Boxes in the EU-28



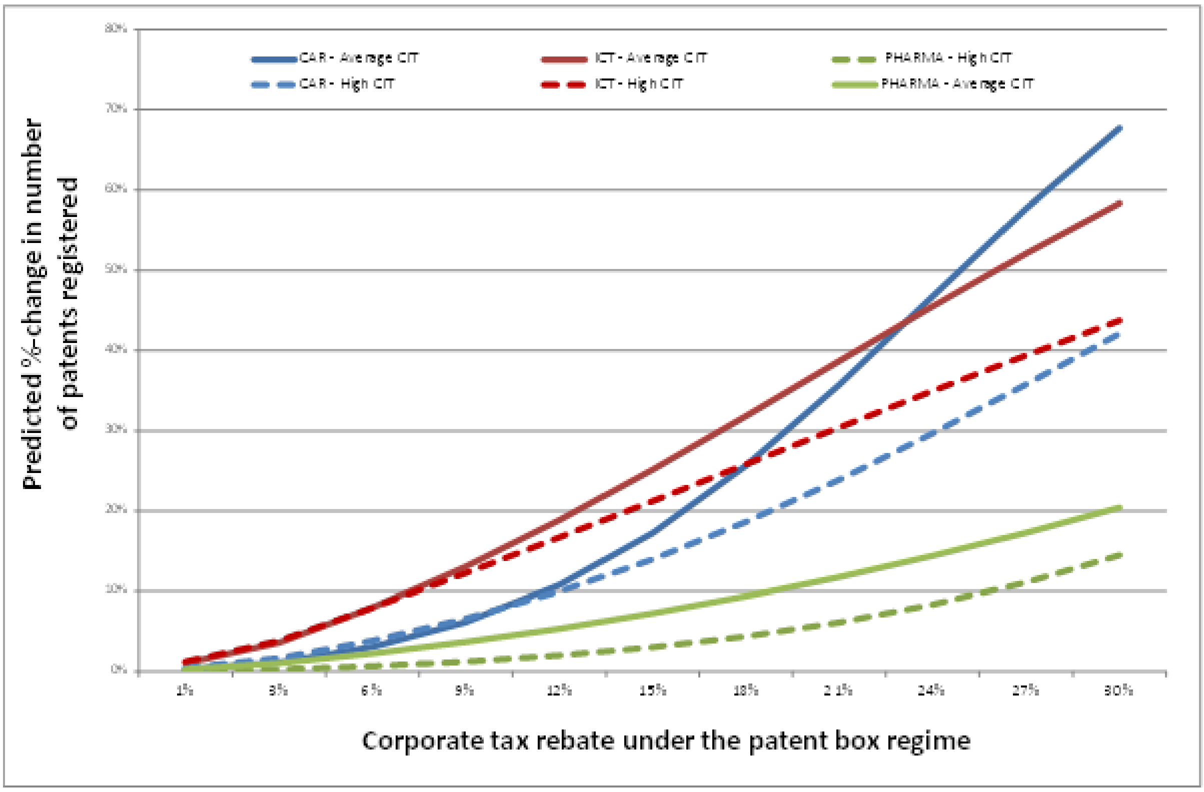
Sources: Taxes in Europe Database and own computations. The columns indicate the number of patent box regimes in the EU-28 and the crosses indicate the arithmetic average of the percentage reduction in corporate income taxes offered by the patent boxes. The straight line represents the arithmetic average statutory tax rate in the EU-28, including local taxes and surcharges.

Figure 2: Distribution of patents across companies



Note: *Kernel densities are calculated for companies included in the estimation sample with less than 5000 patents in order to improve visualization.*

Figure 3: Predicted percentage change in the number of patents at levels of corporate tax rebate conditional on the existence of a patent box regime



From regressions (1)-(3) in Table (5).

Figure 4: Average effective corporate tax paid on patent revenues: high- vs. low-value patents