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Abstract

This paper analyzes externalities of patent box regimes in Europe. Tax reductions in foreign affiliates of a firm that also provide a profit shifting opportunity reduce the user cost of capital and thereby increase domestic investment. We test this mechanism for the case of research activity. By combining information on patents, firm ownership data and specific characteristics of patent box regimes, we show that patent box regimes without nexus requirements for tax-efficient reallocation of patent profits induce positive spillovers within multinational groups. The implementation of a patent box in a country one of the foreign affiliates of a firm resides, increases domestic research activity by about 74 percent or 2 percent per implied tax rate differential. Furthermore, our findings suggest that patent boxes generate negative spillovers on average patent quality. This has important implications for international tax policy and the evaluation of patent box regimes.

JEL Classification: F23, H25, O31
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1 Introduction

Many governments have recognized the importance of technological progress and corporate innovation for domestic productivity growth. Fostering research and development (R&D) activity of firms is therefore one of the key objectives when designing tax systems. In recent years, patent box regimes have become a very relevant instrument in this policy field. Patent boxes allow firms to exempt a large share of profits related to intangible assets (mainly patents)[1] from taxation and thus reduce the effective tax rate for these profits. They differ substantially in their design, in particular with regard to the type of patents that are taxed at the low patent box rates. In a global economy with strong international links, such policies may generate substantial cross-border externalities. The goal of this paper is to identify these spillovers of patent boxes and relate them to specific characteristics of the individual regimes.

Even though most governments claim to implement patent boxes mainly to facilitate *domestic* R&D activity, the emergence of these regimes has raised several concerns. Not surprisingly, the cross-border externalities that we investigate in this paper are at the heart of many of these issues. First, it is not certain that patent boxes actually boost new R&D projects and thus increase the overall level of corporate innovation. In response to the implementation of a more favorable tax regime in one location, firms may merely relocate existing research activity. Such a beggar-thy-neighbor effect is well-known for input-related R&D tax incentives (Wilson, 2009). Second, the economic role of patent boxes is strongly debated. In the best case, these regimes eliminate a market failure by increasing the net return to R&D to a level that better reflects the positive externalities that arise due to knowledge spillovers. In the worst case, patent boxes distort the efficient allocation of R&D investment. Finally, patent box regimes decrease or increase tax revenue. If a patent transfer is used as a cross-border profit shifting vehicle, patent boxes reduce tax revenues in countries with higher effective tax burdens and potentially also in patent box countries because of the lower rate. However, if they spur innovation that raises future profits, tax revenue may actually increase in the long-run.

Determining the sign and size of cross-border externalities of patent boxes

[1] Some patent boxes also allow for the inclusion of trade marks or other intellectual property.

is thus important to characterize the role of such regimes in an international context. In our paper, we analyze these externalities using micro-level evidence from European firms. We link ownership information for a large number of firms to R&D activity. The latter is measured as the number of granted patent applications per firm and year.[2] As we are interested in cross-border effects of patent boxes, we focus on the research activity of firms that are located in countries without a patent box regime. Cross-border links are established via multinational companies with affiliates both in patent box countries and in countries without a patent box regime implemented. We then estimate the effect of a patent box implementation on the R&D activity of a firm that is located in a non-patent-box country and has an affiliate in the implementing country.

In our analysis, we differentiate between patent box regimes with and without nexus requirements. The former usually require at least part of the research activity to be carried out in the respective country for the resulting patents to be taxed at the lower patent box rate. In contrast, the latter also tax patents that have been generated elsewhere at the favorable rate. This is usually done by including acquired patents in the patent box which provides firms with a simple profit shifting opportunity. Corporations can conduct R&D at the location of their choice and then transfer the resulting patent to a patent box location without nexus requirements and benefit from the lower tax rates there. Patent box regimes without nexus requirements thus lower the user cost of capital for R&D activity of firms in other countries that have an inter-corporate link to it. This mechanism is very similar to the role of tax havens in Hong & Smart (2010). In fact, this similarity is not surprising as countries that implement patent boxes without nexus requirement effectively become tax havens for a particular asset. We thus expect these regimes to generate positive cross-border externalities on R&D activity. For patent boxes *with* some nexus requirement, such an effect should not be observed since the profit shifting opportunity that also reduces the tax burden in other countries is limited.

We test these hypotheses with a Poisson count model which relates the implementation of a patent box in a foreign affiliate to the number of domestically

[2]Focusing on granted applications allows to better capture actual research activity rather than strategic patent filing and is thus commonly used in the literature (e.g. Aghion *et al.*, 2013; Bena & Li, 2014; Seru, 2014; Stiebale, 2016).

developed patents of a firm while controlling for various location-, firm- and group-specific variables that might drive innovative activity. Our estimation results suggest that the implementation of a patent box *without* nexus requirements raises R&D activity by 73.67 percent in firms with a cross-border link to the implementing country. When relating this effect to the implied tax difference between firm and affiliate location, we find that a one percentage point difference in the tax rate resulting from a patent box introduction leads to an increase of R&D activity by 2.10 percent.

These positive externalities are robust to controlling for domestic tax-related input incentives such as super-deductions and credits. They also pertain when we adjust the patent count for heterogeneity in the patent quality. For patent boxes with nexus requirements, we find negative, and much smaller cross-border externalities. However, this finding is not robust once we include a set of relevant control variables. As an additional result, we find that both types of patent box regimes reduce the average patent quality in related firms abroad. This result can be explained by the sorting of patents according to their profitability which is similar to the sorting mechanism of firms with different levels of productivity in Melitz *et al.* (2004) and related findings for tax competition by Becker *et al.* (2012) and Haufler & Stähler (2013). Patent boxes with nexus requirement probably lead to the reallocation of the most profitable patents while those without nexus requirement allow the firm to realize more but also less profitable R&D projects.

Our analysis contributes to the large literature that relates tax policy to R&D activity. In particular, researchers have established a link between corporate taxation and investment in R&D (Mamuneas & Nadiri, 1996; Bloom *et al.*, 2002; Wilson, 2009), the location choice of intangible assets within multinational firms (Dischinger & Riedel, 2011; Karkinsky & Riedel, 2012; Griffith *et al.*, 2014) and the quality of patents (Ernst *et al.*, 2014). Only few papers analyze international spillovers of tax policy, but all of them relying on macro-level data of R&D activity. For example, Wilson (2009) uses aggregate R&D data from US states to show that large part of the R&D increasing effect of tax credits is due to a reallocation of research activity between states. In contrast, our paper uses micro-level data to establish positive cross-border externalities of output-related tax incentives as a novel effect of tax policy on R&D.

In addition, we also contribute to the growing literature on patent box regimes.

In this field, more normative analyses (e.g. Evers *et al.*, 2015) have recently been complemented by empirical studies (e.g. Bradley *et al.*, 2015). To the best of our knowledge, our paper is the first to empirically analyze cross-border externalities of patent boxes on real R&D activity.

Finally, our analysis is related to the literature on tax havens. As noted above, by implementing patent boxes, the respective countries effectively become tax havens for intangible assets. Thus, the criticism that is put forward against tax havens (e.g. Dharmapala, 2008; Slemrod & Wilson, 2009) may also apply to patent box countries. Depending on their design, they may divert firm profits away from the location of real activity and thus erode the tax base of high-tax locations. Alternatively one could apply the more positive view of Hong & Smart (2010) and Desai *et al.* (2006). They argue that low-tax jurisdictions may be beneficial because they enable governments to implicitly differentiate between mobile and immobile firms, even if they cannot distinguish between the two types or are not willing to do so because of political reasons. As a first-order effect, allowing mobile firms to shift profits to low-tax locations lowers the user cost of capital in high-tax locations and increases investment there. The simple notion underlying these arguments is that there are real responses of domestic firms to tax incentives abroad. Our empirical results suggest that such a mechanism exists with regard to R&D investments.

The remainder of this paper is structured as follows. Section 2 develops a simple theoretical framework for our analysis and characterizes existing patent boxes. We explain the empirical strategy in Section 3 and describe the data collection in Section 4. Results are presented in Section 5 while Section 6 concludes.

2 Externalities from Patent Boxes

2.1 Theoretical Framework

In this section, we set up a simple theoretical model to analyze the reaction of the R&D investment of a particular firm i to the introduction of a patent box in the country one of its foreign affiliates resides. Throughout the analysis, our focus will thus be on the number of successfully realized research projects, measured as granted patent applications, at the location of i rather than the overall research activity in all affiliates of the multinational company.

Each firm i can choose to realize projects from a given set of potential research undertakings indicated by $s = 1, ..., n_i$. The return to each project is given by $r_s = (1-t)\,\pi_s - c$ and is defined as the difference between the net profit, defined as revenue less deductible cost after taxes, $(1-t)\,\pi_s$, and some non-deductible fixed costs c. The latter may comprise costs that are hard to price and usually not considered as deductible expenses such as the cost of risk-taking, the cost of becoming acquainted with local patenting institutions or the cost to find and hire suitable researchers.

The firm realizes any project that yields a positive return $r_s > 0$. We define the net profit of the cut-off project as $\tilde{\pi} = \frac{c}{1-t}$ such that the firm realizes all projects with a net profit of $\pi_s > \tilde{\pi}$ and disregards projects with $\pi_s \leq \tilde{\pi}$. We can sort the net profits of all available projects along the interval $(\underline{\pi}_i, \bar{\pi}_i)$ and define the corresponding cumulative distribution function F. We assume that each realized research project generates one patent and denote the overall patent count for firm i by P_i which is given by

$$P_i \quad = \quad n_i\,(1 - F\,(\tilde{\pi}))\,. \tag{1}$$

Equation (1) defines the number of patents as a decreasing function of the fixed cost c and the applicable profit tax rate t.[3]

So far, the setting applies to a domestic company with no international links. We now turn to a multinational company. More precisely, we assume that firm i is located in country h and has an affiliate in country p. The two locations differ in the fixed cost and may apply different tax rates. We thus denote the return for a research project s in location l by

$$r_{s,l} = (1 - t_l)\,\pi_s - c_l, \;\; l \in \{h, p\}\,. \tag{2}$$

To simplify the derivation, we assume that firm i incurs a higher fixed cost if it relocates its research activity to country p (i.e. $c_p > c_h$). Besides the specific charac-

[3]This can be easily verified by taking the first derivative of P_j with respect to t and c: $\frac{\partial P_j}{\partial c} = -n_j f\,(\tilde{\pi})\,\frac{1}{1-t} < 0$, $\frac{\partial P_j}{\partial t} = -n_j f\,(\tilde{\pi})\,\frac{c}{(1-t)^2} < 0$

teristics of the fixed costs described above, this reflects potential reallocation cost that the firm would have to bear. Reallocation cost include the reestablishment of new organizational R&D structures in p and effort for convincing researchers to move.

There are two decisions to be made by the firm. First, it must decide *whether or not* to realize a research project. This is done along the rationale described above by evaluating whether it generates a positive return, $r_{s,l} > 0$. Second, the firm must decide *where* to realize the research project (i.e. in h or p). This is done by comparing the location-specific returns and choosing $l \in \{h, p\}$ such that $r_{s,l} = \max(r_{s,h}, r_{s,p})$.

Note that in our analysis, we focus on the number of patents generated by the firm in its original location h. We begin with the hypothetical situation where there are no tax differences between the two locations such that $t_h = t_p$. In this scenario, the firm locates research in h since $c_p > c_h$ implies that $r_{s,h} > r_{s,p}$. All projects with net profit $\pi_s > \tilde{\pi} = \frac{c_h}{1-t_h}$ are realized and the number of generated patents is given by equation (1).

Now, assume that a patent box is implemented in location p. This reduces the effective tax rate there such that $t_h > t_p$. The impact of the patent box on the number of research projects realized in h depends on its nexus requirements. For illustrative purposes, we demonstrate the effects of two extreme options: *full nexus* and *no nexus* requirements at all. In the first case, the firm must carry out all the research in p to be able to opt for the favorable tax regime. Under the second option, the firm can locate research activity in h but still benefit from the low tax rate in p. A typical example for this would be the case where a patent box also allows for the inclusion of acquired patents. The firm can then generate the patent in h and subsequently transfer it to its affiliate in p where patent profit is generated via license fees from the firm in h.

Consider first a patent box in p *without nexus* requirements. In such a scenario, the firm always allocates the patent rights to the low-tax affiliate in p so that its profits are taxed there, resulting in $t_l = t_p$. However, it keeps research activity in h because of the fix cost advantage. The return of conducting research in h is given by $r_{s,h} = (1 - t_p)\,\pi_s - c_h$ and we can define the profit of the cut-off project as $\tilde{\pi}' = \frac{c_h}{1-t_p}$ such that all projects with $\pi_s > \tilde{\pi}'$ are realized in h. Note that in this extreme case, no research is carried out in p because of the higher fixed cost there.[4] The number of patents in h is then given by

$$P_i' = n_i \left(1 - F\left(\tilde{\pi}'\right)\right). \tag{3}$$

Because of $\tilde{\pi}' < \tilde{\pi}$ we have $P_i' > P_i$. A patent box without nexus requirement in p increases research activity in h. The underlying mechanism is very similar to the concept of the user cost of capital applied in investment theory. If the patent box requires no change of location of the actual research process, the lower profit tax effectively increases the return from the patent which decreases the user cost of capital and makes R&D investment more attractive.

Consider now the situation where p introduces a patent box with *full nexus* requirements. The firm will only realize projects in h with a net profit of $\pi_s > \tilde{\pi} = \frac{c_h}{1-t_h}$. However, not all of these projects are necessarily realized in h but the research activity may also be carried out in p. In particular, the firm will locate the most profitable research projects to p because for these projects the tax savings from relocation are the largest. Formally, we define the cut-off profit for relocating profits by $\tilde{\pi}'' = \frac{c_p - c_h}{t_h - t_p}$ such that all projects with $\pi_s < \tilde{\pi}''$ are located in h whereas all other realized projects are located in p. The number of research projects realized in h is then given by

$$P_i'' = \max\left(n_i\left(F\left(\tilde{\pi}''\right) - F\left(\tilde{\pi}\right)\right), 0\right) \tag{4}$$

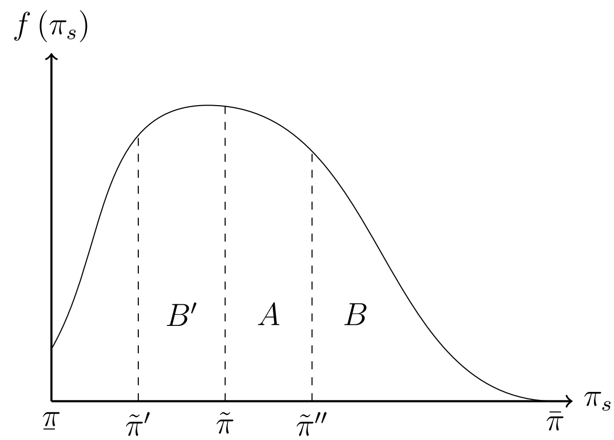
Since $F\left(\tilde{\pi}''\right) \leq 1$, we must have $P_i'' \leq P_i$. If the patent box in p requires full nexus, it provides an incentive for the firm to relocate those projects from h to p whose profits are sufficiently large such that the resulting tax savings fully compensate the increase in the fixed cost. Consequently, the number of patents in h decreases with the introduction of such a patent box.[5]

Let us assume for illustrative purposes that $\tilde{\pi}' < \tilde{\pi} < \tilde{\pi}''$. This allows us to graphically display the effect of a patent box introduction. Figure 1 plots the

[4] This is also a result of our focus on R&D activity in h. To make the model more realistic, one would have to assume that the affiliate in p also faces a set of potential R&D projects. Such a set up, however, would complicate our model while not adding any new insights with regard to the cross-border externalities of tax policy in p on R&D activity of firm j in h.

[5] Note that this does not necessarily imply that overall research activity of the multinational company decreases. If the tax benefits in p are large enough, the total number of patents may even increase. This occurs, however, only because the increase in research activity in p more than compensates for the decrease in h. Research activity in h always decreases.

Figure 1: Profit distribution and realized R&D projects



density function of the profits of available research projects. Without a patent box in location p, the firm realizes all projects with profit above the threshold $\tilde{\pi}$ and the share of realized projects is given by area $A + B$. Introducing a patent box without nexus makes research more profitable also in h and the firm now realizes all projects with profit greater than $\tilde{\pi}' < \tilde{\pi}$. The share of realized projects increases by the area B' such that the overall share of projects is given by the area $A + B + B'$. In contrast, a patent box with full nexus requirements induces the firm to realize those projects with profits above $\tilde{\pi}''$ in p. This corresponds to a share B of available projects. The share of projects realized in h is thus reduced to area A.

Finally, we observe that the average profit of realized patents in h decreases with the implementation of a patent box. This can be easily seen when comparing the average profits of the different fractions of research projects in Figure 1. A formal analysis of this result is presented in Appendix A.1. The sign of the effect is independent of the nexus requirement of the patent box, but it follows different intuitions in each case. A patent box *without nexus* requirements lowers average patent profits because it allows R&D projects with lower profitability to be realized. Patent boxes *with nexus* requirement reduce the average profit in h because R&D activity for the most profitable projects is relocated to p. The latter mechanism is related to the one described for international trade by Melitz *et al.* (2004) who show that only the most productive firms relocate internationally. Furthermore, Haufler & Stähler (2013) show in a tax competition model, that more profitable projects sort into low-tax jurisdictions. Empirical evidence by Becker *et al.* (2012) suggests that this effect contributes significantly to the overall tax base location effect of corporate taxes. In our firm-level analysis below, we show that a similar mechanism is particularly relevant for corporate R&D activity.

Deviating from the two polar cases of *full* and *no nexus* requirements leads to intermediate cases that offer less clear-cut predictions. In particular, when the patent box of in a country requires some but not all of the R&D activity to be generated in this country to be able to opt for the lower tax rate, both the increasing and decreasing effect on R&D activity in h are present. The overall impact depends then on which of these effects dominates. The negative effect on the average profitability of R&D realized in h should, however, prevail.

2.2 Patent Boxes in Practice

Before testing our hypotheses developed above, it is useful to relate our theoretical model to the patent boxes that exist in practice. Evers *et al.* (2015) provide a comprehensive overview of the various regimes that have been established since 2000, which has recently been updated by Alstadsæter *et al.* (2015). In Table 1 we summarize key elements of existing patent box regimes in Europe. In general, firms enjoy substantial reductions in effective tax payments when opting for these regimes but significant differences between individual regimes remain. Patent boxes differ in the treatment of expenses as well as in the types of intangible assets they may be applied to beyond patents (e.g. trademarks, brands).The extent of the tax exemption varies significantly across locations. While the tax rate on profits from patents is reduced by 35 percentage points in Cyprus, firms only enjoy a 50 percent exemption in Portugal which implies a decrease in the statutory tax rate of 11.25 percentage points.

As pointed out above, the extent of nexus requirements of patent boxes is relevant for the sign of their cross-border externalities. In this regard, existing patent boxes also vary substantially. Some regimes include acquired patents (France, Hungary, Malta, Cyprus, Turkey). As this allows firms to conduct the actual development of the patent elsewhere and then transfer the resulting patent right to the patent box location, these regimes correspond to the patent boxes without nexus requirements described above.

Table 1: Patent box regimes in European countries

Country	Year of implementation	Corporate income tax rate (2015)	Patent box tax rate (2015)	Nexus Requirement
France	2000	34.0	16.8	No
Hungary	2003	19.0	9.5	No
Netherlands	2007	25.0	5.0	Yes
Spain	2008	30.0	12.0	Yes
Belgium	2008	34.0	6.8	Yes
Luxembourg	2008	29.2	5.8	Yes
Malta	2010	35.0	0.0	No
Cyprus	2012	10.0	2.5	No
United Kingdom	2013	20.0	12.0	Yes
Portugal	2014	22.5	11.3	Yes
Italy	2015	31.4	22.0	Yes
Turkey	2015	20.0	10.0	No
Ireland	2016	12.5	6.3	Yes

Other patent boxes require that at least part of the research activity must be conducted at the location of benefit, such that firms need to allocate their research activity to the patent box location in order to fully benefit from the tax exemption. This approach is taken by patent box regimes in Belgium, the Netherlands, Spain, Italy, Ireland and Portugal. Other regimes, such as those in Luxembourg and the United Kingdom, allow for inclusion of patents developed abroad but strongly limit the extend to which these patents are included in the patent box to avoid any profit shifting incentives.[6] None of these patent boxes imposes a full nexus

[6]From 2016 onward these regimes are expected to be adjusted to the Modified Nexus Ap-

requirement as supposed in our theoretical model. Rather, they constitute an intermediate case in which firms are generally incentivized to relocate their R&D activity to these countries but some profit shifting opportunities remain.

3 Empirical Strategy

The goal of this paper is to assess the impact of foreign tax reductions for patent profits on domestic R&D activity. This is achieved by estimating the effect of the introduction of a patent box regime in countries firms do not reside therein but have foreign affiliates that do. Following Blundell *et al.* (1995) and Stiebale (2016), R&D activity of a firm is measured by its newly registered annual patent output.[7] More formally, we model the number of new granted patent applications P_{ijct} of firm i member of multinational group j located in country c in period t as a function of the availability of international patent boxes to a foreign affiliate and several control variables:

$$E\left(P_{ijct}\right) = exp\left(\mathbf{x}'_{\mathbf{ijct}}\beta\right)$$
$$\text{with } \mathbf{x}'_{\mathbf{ijct}}\beta = \alpha \cdot BOX_{jt} + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z_{jt}} + \boldsymbol{\delta C_{ct}} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i} + u_{it}$$

where BOX_{jt} is a binary variable that is equal to 1 if a patent box is implemented in the country of residence of at least one of the foreign affiliates of firm i and zero otherwise. $\boldsymbol{X_{it}}$, $\boldsymbol{Z_{jt}}$ and $\boldsymbol{C_{ct}}$ are firm, group and location characteristics. $\boldsymbol{\phi_t}$and $\boldsymbol{\phi_i}$ capture time- and country-specific effects.

The macroeconomic and institutional variables include productivity measured as the log of GDP per capita, GDP growth, general research activity measured as R&D expenditure as a percentage of GDP, the corporate income tax rate and the user cost of capital for R&D. The latter is a composite measure that includes input-related tax incentives such as tax credits and super-deductions for R&D

proach adopted by the EU and the OECD. This approach allows only for a certain share of intellectual property income to be included in the patent box which must correspond to the share of research conducted by the firm itself.

[7]We account for the time lag between generating an innovation and acceptance of the patent application by using the date of first patenting application instead of the patent publication date. The time between the application and the approval of a patent can be up to multiple years.

activity. We control for several items that have been suggested to affect R&D activity on the firm level (see Stiebale, 2016), such as the number of affiliates, the age of a firm as well as the firm size, measured in total assets, the working capital and the capital intensity of the firm. Finally, we include firm- and time-fixed effects to capture cross-sectional differences in the level of R&D output, as well as general time trends.

The number of patents is primarily measured as the simple count of annual granted patents per firm. To capture the intensity of domestic R&D activity, we also conduct our analysis using the quality-weighted number of new patents. Frequently cited patents registered at multiple patent offices and classified to contribute to many patenting classes are not only more valuable (see Harhoff *et al.*, 1999), but indicate also a higher R&D input (Hagedoorn & Cloodt, 2003). We construct patent quality using the composite quality indicator proposed by Lanjouw & Schankerman (2004) which is commonly used in this strand of literature (see, e.g., Hall *et al.* (2007); Ernst *et al.* (2014)). The composite quality indicator is derived by employing a multiple-indicator model relying on the number of forward citations, the patent family size and the number of patent classifications resulting in a relative measure for patent quality. The procedure to derive the composite quality indicator is described in detail in Appendix A.2. For the quality-weighted number of new patents, we weight each patent by its relative quality and aggregate it on an annual basis.

We also estimate the effect of a foreign patent box implementation on the average quality of new patents of a firm. The latter is computed by dividing the quality-weighted patent count by the number of patents, $q_{ijct} = \frac{P^{qual.}_{ijct}}{P_{ijct}}$. To account for general quality shifts within the same industry as well as level differences across industries and countries, we then scale this measure by its 2-digit SIC industry, country and year specific mean $\bar{q}_{sct}$ and obtain $\tilde{q}_{ijct} = \frac{q_{ijct}}{\bar{q}_{sct}}$. We relate the logarithm of this relative measure to foreign patent box implementations in a simple fixed effects regression using a specification that is similar to the one employed in the Poisson model above:

$$\log\left(\tilde{q}_{ijct}\right) \;=\; \iota + \alpha \cdot BOX_{jt} + \boldsymbol{\beta X_{it}} + \boldsymbol{\gamma Z_{jt}} + \boldsymbol{\delta C_{ct}} + \boldsymbol{\phi_t} + \boldsymbol{\phi_i} + u_{it} \qquad (5)$$

Note that we are only able to compute the average quality of patents for firm-year observations where the firm successfully applied for a patent. In order to not distort our estimation by potentially confounding effects of the patenting decision of a firm, we restrict this regression to firms that generate patents before and after a patent box was implemented in a country one of their foreign affiliates resides.[8]

A potential source of endogeneity is the structure of the multinational group. In principal, the multinational group that comprises firms with a high level of research activity has an incentive to set up a new affiliate in a country as soon as a new patent box regime is introduced there. To overcome this potential issue of reverse causality, only multinational groups without changes in their structure are considered. As a consequence, BOX_{jt} is an exogenous shock to the firm's tax incentives insofar as it is purely driven by exogenous policy changes in the residence countries of its affiliates. Identification thus hinges on the variation in the timing of the introduction of national patent box regimes.

Finally, we restrict the sample to firms located in non-patent box countries. This is done for two reasons. First, external effects of patent boxes should generally not be observed at locations where a patent box is already implemented since in this case, the foreign tax regime does not provide an additional incentive. Second, as the focus of this study are spillover effects of patent boxes, patent box locations must be excluded to avoid any distorting effects of the implementation of domestic patent boxes that may or may not coincide with the implementation of patent boxes abroad. After the exclusion of patent box locations for our sample period 2000-2012 there remain 23 locations which are listed in Table 2.

4 Data

The analysis is based on a rich panel dataset built by combining multiple data sources on patent data, firm information and patent box characteristics for the period 2000-2012. Patent data is taken from the PATSTAT database operated by the European Patent Office (EPO). PATSTAT is a comprehensive data source covering patent data for over 80 countries in a harmonized way (Jacob, 2013). For the econometric analysis we count the number of granted patents per firm for each year.

In our analysis we focus on domestically developed patents. In principal, the

[8]We also estimated equation 5 on the full sample and obtain virtually the same result.

country of residence of the firm applying for a patent does not necessarily constitute the place of development of the patent. As is common in the literature, we identify whether or not a patent was developed at the location of the firm by using address information of the inventors (Guellec & de la Potterie, 2001). A patent is classified as domestic if the majority of its inventors reside in the same

Table 2: New Patents, 2000-2012

	Number of firms in sample	Share of firms with affiliate in patent box location		Avg. new dom. patents per year	Avg. new dom. patents per year (qual. wt.)
		w nexus requirement	w/o nexus requirement		
AT	906	0.15	0.16	0.40	0.22
BG	109	0.00	0.00	0.15	0.06
CH	1,028	0.28	0.26	0.43	0.26
CZ	731	0.04	0.05	0.25	0.09
DE	10,261	0.11	0.12	0.38	0.20
DK	462	0.15	0.17	0.31	0.19
EE	42	0.00	0.00	0.22	0.09
FI	441	0.14	0.16	0.38	0.22
GB	3,324	0.17	0.20	0.30	0.19
GR	13	0.23	0.07	0.33	0.21
HR	18	0.11	0.05	0.13	0.07
IE	134	0.14	0.11	0.27	0.18
IS	8	0.00	0.13	0.15	0.11
IT	3,289	0.05	0.05	0.27	0.15
LT	19	0.05	0.11	0.14	0.06
LV	42	0.00	0.00	0.21	0.06
NO	462	0.08	0.12	0.26	0.16
PL	422	0.06	0.07	0.28	0.14
RO	145	0.01	0.01	0.22	0.08
SE	750	0.21	0.22	0.34	0.21
SI	144	0.03	0.03	0.27	0.11
SK	51	0.00	0.00	0.21	0.11
TR	399	0.02	0.03	0.24	0.08
Total	23,200	0.12	0.13	0.34	0.19

country as the firm which filed the application.[9] We remove outliers by trimming the sample at the 99 percentile of annual domestic patent output.

Table 2 displays descriptive statistics of the firm locations we include in our sample. Research activity is particularly strong in Switzerland, Austria and Germany with average annual domestically developed patents per firm of 0.43, 0.40 and 0.38 respectively.

We obtain PATSTAT patent data through Orbis which is a Bureau van Dijk database. This allows us to link patents of the applying firms to the comprehensive ownership information contained in the Bureau van Dijk's Amadeus database via unique identifiers. By exploiting the ownership structure, we are able to identify the ultimate owner for each firm in the sample. We construct multinational groups by assigning firms with a common ultimate owner to the same group. This approach is complemented by checking whether the firm existed throughout the whole observation period to exclude tax-driven affiliate establishment in patent box countries. Finally, we combine the ownership information with data on mergers and acquisitions (M&A) from Bureau van Dijk's Zephyr database to capture ownership changes within the observation period. We exclude all groups where the firm structure changed with respect to the patent box locations displayed in Table 1. That is, all groups are excluded where one of the affiliates in a location that has implemented a patent box regime has been established, acquired or sold during our sample period. In line with Stiebale (2016), we further restrict our sample to industries where patenting is actually relevant. We include firms active in the manufacturing sector, as well as, several knowledge-intensive service sectors such as information technology, telecommunications, transport, R&D, or business-related services.[10] Table 2 provides information on the geographical distribution of firm observations.

[9]For those patents with no inventor information provided by PATSTAT, it is assumed that the patent was developed domestically. As a robustness check, it is also assumed that all patents without inventor information provided are non-domestic ones. The results still hold true implying that these patents are not systematically different from those with inventor information.

[10]This excludes financial services. We identify relevant sectors via 2-digit NACE Rev. 2 codes and include firms with codes NACE 2 codes 10-32, 51-53, 58-63, 69-74 and 77-82.

Table 3: Summary Statistics

	Number of Observations	Mean	Standard Deviation	Min	Max
New patent appl.	271,251	0.338	0.864	0	7
New patent appl. (qual. adj.)	271,251	0.186	0.525	0	6.929
BOX	271,251	0.116	0.320	0	1
BOX_{Nexus}	271,251	0.060	0.238	0	1
Δt	261,950	1.788	6.383	0	31.4
Number of affiliates	271,251	190.203	705.738	0	15,747
Log Age	226,721	2.671	1.056	0	6.592
Log Total Assets	271,212	9.121	2.474	-8.151	17.342
Working Capital	271,213	-6.992	2041.411	-769	344,827
Log Capital Intensity	261,969	-2.760	2.267	-24.136	10.815
Corporate income tax rate	271,251	31.974	7.104	10	52
User cost of R&D capital	271,251	0.337	0.022	0.241	0.350
Real interest rate	261,786	0.056	0.020	-0.014	0.265
R&D expenditure (% of GDP)	259,629	2.079	0.731	0.323	3.913
GDP p.c.	269,553	35762.050	10,069.710	2,750.587	69,094.750
GDP Growth	269,553	1.437	2.668	-14.814	11.902

We also obtain balance sheet items as well as firm age from Amadeus. Working capital is computed by scaling the difference between current assets and current liabilities with total assets, while the capital intensity is defined as the ratio of tangible fixed assets and sales.[11]

Macroeconomic control variables are obtained from the World Bank's World Development Indicators (WDI) and the OECD. Tax policy indicators are collected from the IBFD tax database. When computing the user cost of capital, we follow Bloom *et al.* (2002) and incorporate the input incentives, the applicable tax rate and the fixed depreciation rate into a measure for the user cost of a domestic R&D investment. In order to isolate the effect of tax policy on R&D activity, we calculate the user cost using a fixed interest rate of 5 percent.[12] Table 3 provides summary statistics for all variables used in the empirical analysis.

[11] Missing entries for the necessary variables are replaced by annual industry (2-digit US SIC code) means.

[12] See Appendix A.3 for a detailed description of the calculation of user cost of capital.

5 Results

5.1 R&D Quantity

Table 4 contains our estimation results. The parsimonious specification in column (1) relies solely on the *BOX* dummy that indicates the implementation of a patent box without nexus requirement a country one of the affiliates of a firm, and year-fixed as well as firm-fixed effects. Having an affiliate in a patent box country leads to a highly significant increase of domestic patenting activity of 60.9 log points. This translates into an increase of annual research activity by 83.85 percent. Evaluated at the sample mean, this indicates that a firm with an affiliate in an international patent box country registers one patent every one and a half years instead of every three years when compared to a similar firm without affiliates benefiting from a patent box regime. This points to a strong external effect of foreign tax incentives on domestic research activity. Our results suggest that a decline in the user cost of capital within a multinational group spills over to group members with no relevant tax policy change.[13]

In column (2) of Table 4, we include various characteristics of the firm-location that could affect R&D activity. R&D expenditure as a share of GDP and labor productivity measured as GDP per capita significantly increase patent output of firms. On the contrary, an increase in the corporate income tax rate is expected to induce a decline in innovative activity. The coefficient for the patent box implementation dummy remains significantly positive, albeit smaller than in the specification without controls. Hence, our estimated effect is not driven by coinciding tax policy changes or macroeconomic fluctuations.

We have noted above that patent boxes constitute an effective policy to attract foreign R&D investments and are thus a relevant instrument for international tax competition. One concern with regard to our analysis may be that those countries without a patent box have instead turned to input-related tax incentives in order to remain competitive R&D locations. If these alternative incentives are the main drivers of above observed increased domestic patenting activity, this would still hint to international spillover effects of patent boxes. Instead of a direct impact on the user cost of capital, the spillover would then be observable via policy

[13] If there are multiple affiliates of the multinational group in a country with no relevant tax policy change, all of them are affected similarly (see Table A.2 in the Appendix).

Table 4: Benchmark

	No. of new Patents					
	(1)	(2)	(3)	(4)	(5)	(6)
BOX	0.609***	0.552***	0.556***			
	(0.193)	(0.193)	(0.201)			
$BOX \times \Delta t$				0.022***	0.022***	0.021***
				(0.008)	(0.008)	(0.008)
R&D Exp.		0.155***	0.368***		0.172***	0.372***
		(0.060)	(0.066)		(0.062)	(0.067)
Log GDP p.c.		-0.953***	0.643**		-1.013***	0.662**
		(0.207)	(0.256)		(0.212)	(0.259)
CIT		-0.003	0.003		-0.004*	0.003
		(0.002)	(0.003)		(0.002)	(0.003)
GDP Growth		-0.012**	-0.002		-0.011**	-0.002
		(0.005)	(0.006)		(0.006)	(0.006)
User Cost of R&D		-1.984***	-1.157		-1.880***	-1.175
		(0.474)	(0.897)		(0.479)	(0.907)
Real interest rate		-0.883*	-0.420		-0.903*	-0.461
		(0.482)	(0.565)		(0.501)	(0.575)
No. of affiliates			0.000			0.000
			(0.001)			(0.001)
Log Age			0.098***			0.103***
			(0.022)			(0.023)
Log Total Assets			0.039***			0.038***
			(0.006)			(0.006)
Working Capital			0.000			0.000
			(0.000)			(0.000)
Log Capital Intensity			0.018***			0.018***
			(0.005)			(0.005)
N	271,251	248,889	194,139	259,624	238,133	190,974
No. of firms	23,200	21,880	17,706	22,082	20,819	17,250
Pseudo LL	-132,824	-122,243	-99,060	-126,815	-116,662	-96,718

Estimation of a Poisson fixed effects model. The dependent variable is the number of new patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

interactions in a fiscal competition game.

To account for this, column (2) also includes the user cost of capital as a control. Consistent with previous findings (e.g. Bloom *et al.*, 2002; Wilson, 2009), our estimates suggest that an increase in the user cost of R&D capital leads to a decline in corporate R&D investment. It is also apparent that the evolution of domestic R&D input incentives does not drive our results regarding the implementation of patent box regimes in affiliate countries. The respective coefficient remains significantly positive and similar in magnitude throughout all specifications.

In column (3) we add firm- and group-level controls. The significantly positive coefficients of total assets and the firm age indicate that, consistent with previous findings, larger and also older firms conduct more R&D activity. Again, the coefficient of BOX decreases relatively to the previous specifications but remains significantly positive. It suggests that the number of patent output of a firm increases by about 73.67 percent when a patent box without nexus requirements is implemented in one of the locations of its affiliates.

In columns (4) to (6) of Table 4 we also account for the heterogeneity in the tax rate changes induced by different patent boxes. Instead of a simple implementation dummy, we use the tax rate divergence between the location of the firm and the patent box country that results from the patent box regime. More specifically, we take the difference between the corporate income tax rate in the residence country of the firm and the applicable tax rate for patent profits in the relevant affiliate country after the introduction of the patent box and interact it with our implementation dummy BOX. We then repeat regressions (1) to (3) using our more sophisticated measure for the patent box implementation. Again, the coefficient of interest is significantly positive. Focusing on conservative specification of column (6) that also includes the full set of controls, our results suggest that a patent box that induces a tax difference of 1 percentage point between the residence country of the firm and the relevant affiliate country raises the number of patent output by 2.10 percent. For example, take the example of a firm residing in Germany that has an affiliate in Hungary. The patent box implementation in the affiliate location in 2003 implied a tax differential of 31.2 percent. Our estimates suggest that this increased research activity in the German firm by 66.21 percent.

Table 5: Accounting for Quality Differences

	No. of new Patent (quality-weighted)					
	(1)	(2)	(3)	(4)	(5)	(6)
BOX	0.596***	0.447**	0.480**			
	(0.204)	(0.198)	(0.213)			
$BOX \times \Delta t$				0.017**	0.016**	0.018**
				(0.008)	(0.008)	(0.008)
R&D exp.		0.344***	0.473***		0.360***	0.476***
		(0.067)	(0.074)		(0.069)	(0.075)
Log GDP p.c.		0.242	1.514***		0.223	1.546***
		(0.229)	(0.280)		(0.234)	(0.282)
CIT		-0.003	-0.001		-0.004	-0.001
		(0.002)	(0.003)		(0.002)	(0.003)
GDP Growth		-0.018***	-0.009		-0.018***	-0.009
		(0.006)	(0.006)		(0.006)	(0.006)
User Cost of		-0.260	0.419		-0.139	0.388
R&D		(0.531)	(1.014)		(0.536)	(1.024)
Real interest		-0.833	-0.946		-0.837	-1.015*
rate		(0.516)	(0.603)		(0.538)	(0.614)
No. of affiliates			0.000			0.000
			(0.001)			(0.001)
Log Age			0.098***			0.108***
			(0.024)			(0.025)
Log Total Assets			0.030***			0.029***
			(0.006)			(0.006)
Working Capital			0.000			0.000
			(0.000)			(0.000)
Log Capital			0.018***			0.018***
Intensity			(0.005)			(0.005)
N	262,455	240,515	191,270	251,118	230,026	188,195
No. of firms	22,467	21,166	17,415	21,378	20,131	16,971
Pseudo LL	-77,200	-71,472	-58,192	-73,445	-67,965	-56,583

Estimation of a Poisson fixed effects model. The dependent variable is the number of new patents measured weighted by their relative quality per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

Our main results in Table 4 show strong and positive cross-border externalities of patent boxes without nexus requirements. This suggests that these patent boxes reduce not only the user cost of capital for R&D investment of domestic firms but also of their foreign affiliates by providing them with an effective profit shifting opportunity that reduces their prospective tax burden.

In a second step, we use quality-weighted patent count as a dependent variable to account for the fact that patents may vary strongly with regard to their quality, usefulness and applicability (see Hall *et al.*, 2010). Table 5 presents the results from repeating the regressions of Table 4 with this new dependent variable.

Throughout the specifications, the coefficients of the patent box implementation dummy as well as the one for the more sophisticated measure of the patent box induced tax difference remain significantly positive. Again, after including location-, firm- and group-specific controls suggests that our results are not driven by macroeconomic factors or endogenous firm selection. We note that the coefficients for the variables of interest are slightly smaller than in the regression with a simple patent count. This may reflect that there exist cross-border externalities of patent boxes not only with respect to the quantity of patent output but also with respect to their quality. Given our theoretical analysis, this is not surprising and we turn to this additional effect in more detail below.

Finally, we are interested in the cross-border effect of patent boxes with some nexus requirement on R&D activity. In Table 6 we thus present results of a Poisson fixed effects estimation that relates the simple and quality-weighted patent count to a dummy BOX_{Nexus} that switches to one when the residence country one of the foreign affiliates of the firm implements a patent box with some nexus requirement.

Column (1) reports the results of the parsimonious fixed-effects regression containing only the implementation dummy. Consistent with our theoretical analysis above, the corresponding coefficient is negative which suggests that patent boxes with some nexus requirement lure away R&D activity from locations abroad. However, this effect is not symmetric to the one obtained for patent boxes without nexus requirements. We observe that its magnitude is substantially smaller (about one tenth) and the coefficient estimate is not robust when including the full set of controls. Our findings are similar when we use the quality-weighted patent count as dependent variable. Thus, we cannot identify the same clear-cut result derived for the case of full nexus requirement. Nevertheless, we can conclude

Table 6: Patent Boxes With Nexus Requirement

	No. of new Patents		No. of new Patents (quality-weighted)	
	(1)	(2)	(3)	(4)
BOX_{Nexus}	-0.056**	0.032	-0.102***	-0.037
	(0.028)	(0.029)	(0.029)	(0.031)
R&D exp.		0.373***		0.477***
		(0.066)		(0.074)
Log GDP p.c.		0.663***		1.482***
		(0.257)		(0.282)
CIT		0.003		-0.001
		(0.003)		(0.003)
GDP Growth		-0.002		-0.009
		(0.006)		(0.006)
User Cost of R&D		-1.121		0.488
		(0.895)		(1.011)
Real interest rate		-0.424		-0.932
		(0.565)		(0.603)
No. of affiliates		0.000		0.000
		(0.001)		(0.001)
Log Age		0.099***		0.096***
		(0.022)		(0.024)
Log Total Assets		0.039***		0.031***
		(0.006)		(0.006)
Working Capital		0.000		0.000
		(0.000)		(0.000)
Log Capital Intensity		0.018***		0.018***
		(0.005)		(0.005)
N	271,251	194,139	262,455	191,270
No. of firms	23,200	17,706	22,467	17,415
Pseudo LL	-132,827	-99,065	-77,192	-58,193

Estimation of a Poisson fixed effects model. The dependent variable is the number of new (quality-weighted) patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

Table 7: Patent Quality

	Patent Quality			
	(1)	(2)	(3)	(4)
BOX	-0.258**	-0.279**		
	(0.114)	(0.125)		
BOX_{Nexus}			-0.091***	-0.079***
			(0.012)	(0.014)
R&D exp.		0.103***		0.119***
		(0.036)		(0.039)
Log GDP p.c.		-0.217*		-0.289**
		(0.130)		(0.135)
CIT		-0.000		0.001
		(0.002)		(0.002)
GDP Growth		-0.003		-0.000
		(0.003)		(0.003)
User Cost of R&D		0.006		0.619
		(0.552)		(0.552)
Real interest rate		-0.278		-0.230
		(0.326)		(0.343)
No. of affiliates		-0.000		-0.000***
		(0.000)		(0.000)
Log Age		-0.005		-0.013
		(0.015)		(0.016)
Log Total Assets		-0.022***		-0.021***
		(0.004)		(0.004)
Working Capital		0.000***		0.000***
		(0.000)		(0.000)
Log Capital Intensity		-0.000		-0.001
		(0.003)		(0.004)
N	52,293	41,578	44,760	34,346
No. of firms	22,152	17,526	18,129	13,560
Pseudo LL	-20,925	-18,002	-18,436	-15,6771

Estimation of an OLS fixed effects model. The dependent variable is the logarithm of average patent quality per year and firm for patents for which the majority of inventors does not reside outside the country of residence of the firm. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.

that, consistent with the theoretical model, positive cross-border externalities of patent boxes only occur when the lack of nexus requirement allows some post-development profit shifting.

5.2 R&D Quality

In Table 5, we present the result for estimating the cross-border spillover of a patent box implementation on the average quality of patents. Column (1) contains the parsimonious regression result relying on a single dummy indicating whether the firm runs an affiliate in a country with a patent box without nexus requirement implemented. The negative coefficient suggests that the patent box implementation leads to a reduction in relative patent quality. This result is robust when including the full set of control variables. In columns (3) and (4), the regressions are repeated but with a dummy with value one if firms have an affiliate residing in a country with a patent box *with* nexus requirement implemented. Having an affiliate in such a country reduces the average quality of domestic patents, albeit to a lesser extent.

The negative cross-border effect of patent boxes with and without nexus requirement possibly reflects a decrease in the average profitability of granted patents, which is consistent with our theoretical findings above. Note that even though the direction of the effect does not depend on the nexus requirement of the patent box, our model suggests that the underlying mechanism differs between the two types of patent boxes. This may also explain the difference in the magnitude of the coefficients. The estimated effect on average patent quality is about three times larger for a patent box without nexus requirement than for a patent box with nexus requirement.

6 Conclusion

In this paper, we combine information on firm ownership, research activity and output-related R&D tax incentives to identify cross-border spillover effects of tax policy within multinational groups. In particular, we analyze the impact of the introduction of a patent box without nexus requirement in a foreign affiliate location that allows domestic firms to reduce the user cost of capital by shifting patent profits abroad. Our results indicate that this foreign tax incentive transmits to the domestic firm which increases its research activity by approximately 74 percent or 2 percent per percentage point of induced tax rate differential. Consistent with our theoretical analysis that limits positive cross-border externalities to patent boxes without nexus requirements, we do not find this effect for patent boxes with nexus requirements. Furthermore, we show that, following the predictions of our theoretical model, cross-border spillovers of patent boxes on average patent quality are generally negative.

These results have several important implications. First, they support theoretical analyses by Desai *et al.* (2006) and Hong & Smart (2010), who argue that the presence of low-tax countries reduces the user cost of capital for investment in high-tax countries. Although it remains questionable if tax havens are beneficial from an overall welfare perspective, it is interesting to observe that one relevant channel through which they might cause positive externalities can actually be observed in the data. Our results are of course limited to investment in intangible assets which are particularly mobile with regard to the allocation of related profits. The effect may be weaker for investments whose profits cannot be shifted as easily.

Second, these findings inform the ongoing debate on patent boxes. Some countries have argued that patent boxes are not effective in fostering research activity but merely constitute an instrument for harmful tax competition. Our results indicate that if patent box regimes include non-domestically developed patents, other countries without patent box regimes may indirectly benefit because the implicit tax reduction for multinational companies increases corporate R&D activity there. An assessment of the overall welfare impact is precluded by the fact that we do not observe foregone revenue in the location of the domestic firm. Nevertheless, the results presented above suggest that the expected increase in domestic tax revenue resulting from restricting profit shifting opportunities to foreign patent box countries must be weighed against the negative impact on domestic research activity. Somewhat surprisingly, those patent boxes that provide the best opportunity for profit shifting are actually the regimes that have the strongest positive effect on research activity in non-patent box countries.

Results from our theoretical analysis suggest that there are two consecutive firm responses to the introduction of foreign patent boxes without nexus requirements. Companies first raise R&D output and then locate the resulting patent rights to the patent box location. In our empirical analysis we have verified the first step which is relevant for the cross-border implications of patent boxes on real R&D activity. Since we lack data on the post-application relocation of patents, we cannot identify the second step. We note, however, that empirical findings of previous studies suggest that profit shifting via the transfer of patent rights is a very relevant phenomenon (see Dischinger & Riedel, 2011; Karkinsky & Riedel, 2012). Furthermore, we are interested in the impact of patent boxes on corporate R&D investment rather than on the resulting profit allocation. As is generally the case for corporate investment decisions, the former effect depends on the expected tax rate on future profits. Thus, the change of prospective taxation induced by the patent box, which we capture in our empirical specification, is decisive.

Nevertheless, future research may aim at measuring the impact on the subsequent allocation of patent profits. This would provide a more comprehensive picture of the underlying economic mechanism and would enable us to determine whether it is the change in prospective or the actually realized tax burden of R&D investment that drives the positive cross-border spillovers of patent boxes.

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Appendix

A.1 Patent Boxes and Average Patent Quality

Let us denote by Π, Π' and Π'' the average profits of realized projects of firm i in h without a patent box in p, with a patent box in p that has no nexus requirements and with a patent box in p that requires full nexus, respectively. The average profits are given by

$$\Pi = \int_{\tilde{\pi}}^{\bar{\pi}} \pi_s f(\pi_s)\, d\pi_s,\ \Pi' = \int_{\tilde{\pi}'}^{\bar{\pi}} \pi_s f(\pi_s)\, d\pi_s,\ \Pi'' = \int_{\tilde{\pi}}^{\tilde{\pi}''} \pi_s f(\pi_s)\, d\pi_s. \tag{A.1}$$

Note that

$$\Pi > \Pi' \iff \int_{\tilde{\pi}'}^{\bar{\pi}} \pi_s f(\pi_s)\, d\pi_s - \int_{\tilde{\pi}}^{\bar{\pi}} \pi_s f(\pi_s)\, d\pi_s > 0$$
$$\iff \int_{\tilde{\pi}'}^{\tilde{\pi}} \pi_s f(\pi_s)\, d\pi_s > 0$$

where the last inequality follows from $\tilde{\pi} > \tilde{\pi}'$. Furthermore

$$\Pi > \Pi'' \iff \int_{\tilde{\pi}}^{\bar{\pi}} \pi_s f(\pi_s)\, d\pi_s - \int_{\tilde{\pi}}^{\tilde{\pi}''} \pi_s f(\pi_s)\, d\pi_s > 0$$
$$\iff \int_{\tilde{\pi}''}^{\bar{\pi}} \pi_s f(\pi_s)\, d\pi_s > 0$$

where the lase inequality holds whenever $\tilde{\pi}''$ is interior (i.e. $\tilde{\pi}'' < \bar{\pi}$).

A.2 Composite Patent Quality Indicator

Patent quality is a latent variable which is not directly observable in the data. To approximate it, we follow the approach proposed by Lanjouw & Schankerman (2004) and employ a multiple-indicator model with one unobserved common factor. We use three different indicators, namely forward citations, patent family size and number of patent classifications codes (IPC classes). Therefore, the underlying equations for the multiple-indicator model are

$$y_{k,s} = \lambda_k v_s + \boldsymbol{\beta X} + e_{k,s},\ k \in \{1,2,3\}$$

where $y_{k,s}$ is the value of quality indicator k for patent s, v_s indicates the common factor, λ_k represents the factor loading, $\boldsymbol{X}$ contains common controls and $e_{k,s} \sim N(0,\sigma^2)$ is the idiosyncratic component with $Cov(e_{k,s}, e_{k,r}) = 0$, $s \neq r$. Since the term $\lambda_k v_s$ is latent, we estimate the reduced form of the equations:

$$y_{k,s} = \boldsymbol{\beta X} + u_{k,s},\ k \in \{1,2,3\}$$

where $u_{k,s} = \lambda_k v_s + e_{k,s}$ combines a common component $\lambda_k v_s$ and a idiosyncratic component $e_{k,s}$. We estimate these equations using three stage least squares employing for $\boldsymbol{X}$ controls for the year of application and main technology class of the patent. To gather λ_k and v_s, we conduct in a further step a factor analysis using maximum likelihood to decompose $u_{k,s}$. The estimated factor loadings are presented in Table A.1.

Table A.1: Factor loadings

Indicator	Factor loading
Forward citations	0.6201
Patent family size	0.3593
Patent classification codes	0.1229

Results from factor analysis of the residuals from regressing each indicator on year and industry class dummies. Factor loadings represent both weighting of the indicator and correlation between indicator and patent quality.

We use the estimated factor loadings to calculate the composite quality indicator for each patent. The composite quality indicator is a relative measure to determine the quality of patents and is normally distributed with mean zero. To construct the quality-weighted annual patent count, we transform the distribution by adding the value of the patent with lowest patent quality so that all composite quality indicators turn positive. After this transformation the composite quality indicator for each patent has a positive value and can be used as weight for summing up patent output. The implied relative ordering of the quality of patents is unaffected by this transformation.

A.3 User Cost of R&D Investment

The computation of the user cost strongly follows the derivation of Bloom *et al.* (2002) who extend its standard expression as presented by Hall & Jorgenson (1967) to R&D investment. The user cost is defined as the pre-tax financial return ρ for a marginal R&D investment project (i.e. a project with zero economic rent). The economic rent of any R&D project is given by

$$\begin{aligned} R &= (1+i)\, dV_t = dD_t + dV_{t+1} \\ &= \frac{(\rho+\delta)\left(1-\tau^{CIT}\right) + (1-\delta)\left(A^D + A^C\right)}{1+r} - \left(1 - \left(A^D + A^C\right)\right) \end{aligned}$$

where dV_t is the change in the market value of the firm and dD_t is the change in dividends paid out by the firm that results from the investment. i denotes the nominal and r the real market interest rate and δ is the economic rate of depreciation. A^D and A^C are the net present values of the additional deductions and the tax credit, respectively, and are given by

$$A^D = \frac{\phi\,(1+r)}{\phi + r}\tau^{CIT},\ A^C = \varphi \tag{A.2}$$

where ϕ is the additional deduction rate and φ is the credit rate. To obtain the user cost, we set $R = 0$ and solve for ρ. This yields

$$\rho = \frac{1 - \left(A^D + A^C\right)}{1 - \tau^{CIT}}\,(r + \delta) \tag{A.3}$$

We compute ρ_{ct} for every country and year and follow Bloom *et al.* (2002) in setting $\delta = 0.3$ and $r = 0.05$. Tax policy variables are obtained from the IBFD database.

A.4 Consolidated Affiliates

For the results in Table A.2, we consolidated firm data of affiliates located in the same country which are member of the same group. The point estimates for the BOX dummy are very similar to the results in Table 4 and 5.

Table A.2: Consolidated group affiliates

	No. of new Patents		No. of new Patents (quality-weighted)	
	(1)	(2)	(3)	(4)
BOX	0.627***	0.582***	0.638***	0.499**
	(0.194)	(0.194)	(0.211)	(0.209)
R&D Exp.		0.247***		0.381***
		(0.072)		(0.070)
Log GDP p.c.		0.597**		1.571***
		(0.280)		(0.269)
CIT		-0.002		-0.001
		(0.006)		(0.003)
GDP Growth		-0.013**		-0.017***
		(0.006)		(0.006)
User Cost of R&D		-0.846*		1.032**
		(0.432)		(0.507)
Real interest rate		-0.977		-0.982
		(0.913)		(0.653)
Log Age		-0.093***		-0.095***
		(0.015)		(0.016)
Log Total Assets		0.000***		0.000***
		(0.000)		(0.000)
Working Capital		0.000		0.000
		(0.000)		(0.000)
Log Capital Intensity		0.001***		0.000***
		(0.000)		(0.000)
N	208,166	181,602	205,016	178,920
No. of firms	17,972	16,315	17,680	16,049
Pseudo LL	-109,197	-96,460	-63,853	-56,892

Estimation of a Poisson fixed effects model. The dependent variable is the number of (quality-weighted) patents per year and firm for which the majority of inventors does not reside outside the country of residence of the firm. All firm data of firms belonging to the same multinational group is consolidated at the country level. Cluster robust standard errors (clustered at the firm level) are provided in parentheses. All regressions include firm- and year-fixed effects. Stars behind coefficients indicate the significance level, * 10%, ** 5%, *** 1%.