Research Policy 50 (2021) 104129

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Should there be lower taxes on patent income?

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ARTICLE INFO

JEL codes:
H32
H34
K34
O34

Keywords:
Patent box
IP box
innovation tax
EPO
invention incentive
patent ownership

ABSTRACT

A “patent box” is a term for the application of a lower corporate tax rate to the income derived from the ownership of patents. This tax subsidy instrument has been introduced in a number of countries since 2000. Using comprehensive data on patents filed at the European Patent Office, including information on ownership transfers pre- and post-grant, we investigate the impact of the introduction of a patent box on international patent transfers, on the choice of ownership location, and on innovative activity in the relevant country. We find that the impact on transfers is small but present, especially when the tax instrument does not contain a development condition and for high value patents (those most likely to have generated income), but that innovation as proxied by R&D and patents is not affected. We also find that introducing a patent box reduces patent transfers out of the country. These results call into question whether the patent box is an effective instrument for encouraging innovation in a country, rather than simply preventing or facilitating the shifting of corporate income to low tax jurisdictions.

1. Introduction

During the past decades, a number of countries have introduced a range of policies designed to encourage innovative activity by firms resident in the country. This policy focus has been driven by increased awareness of the importance of innovation for economic growth and arguments that firms left to their own devices would not invest enough in innovation from society’s point of view (Arrow, 1962; Westmore, 2013). Among these policies are several that make use of the tax system. The oldest implicit subsidy is widespread due to being incorporated in standard accounting practices:[1] R&D is generally expensed, which corresponds to accelerated depreciation given its economic life (Hall 2005, *inter alia*). In addition to this, a number of countries have introduced R&D tax credits that effectively provide a reduction in the *cost* of performing R&D.[2]

Recently several countries have implemented special treatment for the taxation of corporate *income* that derives from the ownership of patents or, in some cases, other intellectual property (IP). This policy instrument (often called a “patent box” or “IP box”) is generally presented as a measure to encourage the location of innovative activity by multinationals in the country that introduces it. However, many analysts have expressed skepticism about the policy’s effectiveness, given the multiple avenues available to such companies for the shifting of income associated with intangible assets (e.g., Griffith et al. 2014; Sullivan 2015). The patent box creates an additional route for shifting income, because transferring ownership of a patent from one country to another that has a more favorable tax treatment is a straightforward and relatively low cost procedure. In fact, one of the reasons for its introduction may have been the perception by governments that income from intangible assets of all kinds is relatively easy to shift to low tax jurisdictions, and therefore taxing such income at a lower rate provides an incentive for firms to keep their intangible assets in the country. Although this may be the real rationale behind the introduction of such a tax instrument, it is often argued by those proposing patent boxes that such a tax instrument is an innovation incentive, as this argument is perceived as more defensible than a purely tax revenue-based argument.

Given the widespread use of R&D tax credits to incentivize innovative activity, one may well ask whether the addition of a patent box is

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[1] These include the US Generally Accepted Accounting Principles (GAAP) (http://www.fasb.org/home) and various International Accounting Standards Board (IASB) standards (https://www.iasplus.com/en/re-sources/ifrsf/iasb-ifrs-ic/iasb).

[2] For details on this tax instrument, see various publications by the OECD (http://www.oecd.org/sti/rd-tax-stats.htm), and for evidence on its effectiveness, see Hall and Van Reenen (2000) and Appelt et al. (2016). Online Appendix Table B-1 indicates which of the countries in our sample currently have some kind of R&D tax credit.

https://doi.org/10.1016/j.respol.2020.104129
Received 21 June 2019; Received in revised form 3 September 2020; Accepted 15 September 2020
Available online 29 September 2020

worthwhile. Clearly there are differences between subsidizing R&D and subsidizing the income from patents: the first is an *ex ante* incentive that targets a decision variable of the firm, whereas the second is *ex post* and will only be effective when R&D has been in some sense successful. Klemens (2016) points out a number of ways in which an *ex ante* incentive may be more desirable. These include reduced incentives for shifting expenses to the higher tax rate area, difficulties in allocating income to the patent, and less distortion towards incremental development that generates income on the whole product versus invention of a completely new product. To this one could add that a patent box provides an extra incentive for the kind of R&D that least needs encouragement: R&D whose returns are appropriable via the patent system. If the argument for subsidizing R&D and innovative activities is that they create spillovers and public goods in the form of knowledge, it seems odd to encourage firms to direct their efforts toward patentable inventions, unless it is thought that encouraging publication of an invention would enhance spillovers enough to counteract the quasi-monopoly position the patent creates.

A more substantive difference between R&D tax incentives and patent boxes is that R&D covers a limited range of innovative activities that are more or less technological, and some successful patented innovations are likely to come from other activities, especially in the service sector. Even in manufacturing, not all patenting requires R&D activities, but may come from optimizing production or logistics. On the other hand, a limitation of the patent box is that it requires a patent or patents and some desirable innovative activities may not be patentable. A final objection is that encouraging firms to patent solely in order to receive a tax subsidy is perverse in an environment where there may already be too many patents, in the sense that some of those patents would be found invalid if challenged (US Federal Trade Commission, 2016 and references therein). As Klemens (2016) says, “The patent box thus gives new life to zombie patents,” by which he means patents that would not survive if challenged.[3]

One of the ways in which the patent box may induce nonproductive corporate behavior is that it may encourage firms to transfer some or all of their patents to jurisdictions that offer favorable tax treatment to income derived from patents, possibly without inducing any additional inventive activity. In this paper we investigate the extent to which this has happened following the introduction of a patent box in several European countries. We also consider the impact of such patent boxes on inventive activities. We look closely at four questions:

- When a country introduces a patent box, is there an increase in the number of patents transferred to that country? Is there a decrease in the number transferred out of that country?
- How do the above effects change depending on the tax rates and specific provisions of the patent box?
- Does patentable invention in a country increase after the introduction of a patent box? That is, does this policy instrument have the effect often proclaimed by policy-makers?
- Are more valuable patents (patents that are more likely to generate income, via own profits or licensing) those that are transferred in response to the patent box?

To examine these questions, we use a new dataset created by Gaessler and Harhoff (2018) on patent transfers. The dataset entails ownership information changes of European bundle patents between 1981 and 2016 originating from the registers of the European Patent Office (for the pre-grant period) and the German Federal Patent and Trademark Office (for the post-grant period). Given that European patents are most frequently validated and renewed in Germany, this dataset effectively captures a maximum of possible EP transfers during their post-grant period. We combine these data with patent data from PATSTAT (April 2018 edition) and detailed data on the various patent box measures that have been introduced in European countries during the past two decades. We perform analyses at the aggregate (country) level and also at the level of individual patents, where we use patent characteristics to examine which patents are transferred.

Given that there are only 16 countries with patent boxes, with varying provisions and some introduced near the end of our estimation sample, our results are in some cases imprecise, in the sense that standard errors are large enough to render the coefficients insignificant, but not able to rule out some impact of the various provisions. Nonetheless, we have several fairly robust findings: first, the patent box does seem to reduce transfer of patents out of a country considerably, by about 30 per cent. Second, the main provision of the patent box that matters is the requirement that the patented invention be developed further in the country in which the patent income is to be taxed at a lower rate. This provision causes transfers to be insignificant, whereas without it, the difference in patent income tax rates between two countries induces a fairly large amount of transfer. Third, if there is any impact on invention activities (proxied by patent filings and R&D spending) from the introduction of a patent box, it is negative, clearly contradicting the argument that this tax instrument represents an innovation incentive. Finally, we find that transferred patents are of relatively greater value as indicated by the conventional patent metrics.

These results suggest that the particular design of the patent box determines to what extent IP rights are reallocated. Requiring that further development of the invention take place within the country in order to enjoy the lower tax rate seems to mitigate transfers for purely tax reasons. This finding provides support for the incorporation of such rules into the OECD Base Erosion and Profit Shifting (BEPS) recommendations (OECD 2015).

The structure of the paper is as follows. The next section provides a brief introduction to the design of patent boxes, and Section 3 reviews the literature on corporate taxation, the patent box, and international patent transfers. This is followed by sections describing the econometric models we will estimate (Section 4) and the data we will use (Section 5). The core of the paper presents the results of our aggregate analysis of patent transfer and patentable invention, as well as a patent level analysis of transfer choice. The paper concludes in Section 7.

2. Patent box description

In our sample of 51 countries (the list is shown in Online Appendix Table B-1), there are 13 that have introduced some kind of IP or patent box between 1971 and 2014, and one (Ireland) that has discontinued it.[4] The potential effectiveness of an IP or patent box depends on its design, and on its interaction with the rest of the corporate system. This makes the analysis of its effects somewhat challenging, as the sample size is rather small once all the design features are controlled for.[5] The important distinctions are the following:

Coverage – in some cases, all forms of intellectual property income are covered, rather than simply patents. This could include software, copyrights, trademarks, utility models, and even trade secrets as well as know-how in a few cases. There is also variation in coverage over royalties from others’ use of the firm’s IP and capital gains from their sale.

[3] Presumably the tax authorities would not want to get into the business of challenging patent box patents for validity.

[4] The Irish patent box was discontinued as part of the national recovery bill following the 2008 crisis. A new “knowledge box” that is compliant with OECD’s BEPS (Base Erosion and Profit Shifting) was introduced in 2015, at the very end of our sample period. See http://www.oecd.org/tax/beps/ for more information on BEPS policies.

[5] Evers et al. (2015) and Alstadsæter et al. (2018) review the provisions of the regime for the 13 countries. The fact that these reviews do not always agree precisely as to the details of the patent box indicates how complex the instrument can be.

Gross or net income – Belgium, Hungary, and Portugal allow IP-related expenses to be deducted from ordinary income, which is a substantial tax advantage. Most schemes require these expenses to be deducted and the reduced tax rate applied to the net income from IP.

Existing IP – schemes vary in whether they cover existing patents or only those newly obtained, in some cases requiring further development of the IP within the relevant country.

Acquired IP – similarly, there is variation in the coverage of IP acquired from others, and in whether there is a further development requirement.

Because of the fear that the introduction of patent boxes would lead to wasteful tax competition among countries without a concomitant increase in innovative activity, the OECD Base Erosion and Profit Shifting (BEPS) project recommended in 2015 that there be a local development requirement for the patent to be eligible (OECD 2015, 23). BEPS refers to such a requirement as a "nexus" requirement, that is, a requirement for significant economic presence in the country. In the case of the IP or patent box, this is interpreted as requiring some further development in the country in question for the income associated with the patent to be eligible for a reduce tax rate. Although 2015 is later than the period we study here, several countries in our sample already had such a further development requirement if income from the patent was to be eligible: Belgium, Spain, the UK, the Netherlands, and Portugal.

Another feature of many tax systems that will affect the ability of multinationals to use patent boxes to reduce their tax burden are the rules related to controlled foreign company (CFC) income (Deloitte Consulting, 2014). These rules, which are common in large developed economies, require that if a foreign company is 50% or more owned by a domestic company, its income should be taxed at the domestic company rate if the foreign tax rate is less than the domestic tax rate by some amount. The cutoff varies by country, but it is usually between half and three quarters of the domestic rate. The rules surrounding the CFC regimes can be very complex, specifying types of income affected, ownership rules, etc. Two aspects regarding the CFC rules are worth noting: First, when a country has a CFC regime, the rules usually specify a black list of countries that coincides with the "tax havens" in our data. Second, following a Court of Justice of the European Union decision in 2006, these rules cannot be applied within the European Economic Area (EU 28 plus Norway, Iceland, and Liechtenstein).[6]

3. Literature review

Over the past years, a considerable number of contributions have studied the relationship between taxation and patents empirically. A smaller number have focused specifically on the impact of a patent box on the location of patent ownership. Almost none have examined other consequences of the patent box. In this section we review the most relevant studies.[7]

3.1. Corporate taxation and patent literature

The first group of papers focuses on the impact of corporate taxation systems on the firm's choice of patent system and filing location. Karkinsky and Riedel (2012) are among the first to study patent filing behavior of multinational enterprises (MNEs) with respect to tax differences. Given that patents account for a sizable share of the asset value of a typical MNE and that transfers of these assets are difficult for tax authorities to observe and monitor, they represent a major opportunity for profit shifting across tax jurisdictions. The results suggest that the corporate tax rate impacts patent applications filed by a multinational affiliate negatively. The effect is relatively large and appears to be robust to a number of checks. In various specifications, the results indicate that an increase in the corporate tax rate of one per cent is associated with a reduction in the number of patent applications of 3.5% to 3.8%.

Boehm et al. (2015) add to the understanding of the patent location decision by studying the divergence between inventor (invention) and applicant (ownership) country using EP patent filings for 1990-2007. They show that low-tax countries tend to attract foreign-invented patents from high-tax countries, especially if the patents are of "high quality" by the usual measures, such as citations or international patent family size. The effects are relatively small but significant, and are reduced slightly in the case where the inventor country has implemented CFC rules. Note that although they distinguish between tax havens and other countries as applicant locations, they do not analyze the full destination choice decision.

In contrast, Griffith et al. (2014) study a firm's decision about the location of patent ownership and distinguish among different location choices by using a random coefficients logit model. The firm's tax rate is not only affected by time and target country, but also by its home location, since Controlled Foreign Company (CFC) rules introduce variation at the dyad level. The authors use data on the statutory corporate tax rate and their sample consists of about 1,000 of the largest patenting firms at the EPO during the period 1985 to 2005, covering about 70% of corporate patent applications. In general, semi-elasticities are more pronounced for smaller than for larger home countries. In a simulation exercise, they find that the introduction of a patent box attracts patent income, but also leads to a net reduction in tax revenues.

3.2. Patent box literature

We now turn to those papers that explicitly analyze the impact of the patent box instrument on patent location and transfer. Alstadsæter et al. (2018) analyze the use of patent box regimes by the 2,000 largest corporate R&D performers worldwide for the period 2000-2011. Using various negative binomial models for the number of patents of a particular technology type located in a country by each of these multinationals, they find that the tax advantage of a patent box does induce firms to locate their patents in the respective country. However, interpretation of the regressions is problematic, since they include a dummy for the presence of a patent box and the highly correlated indicator for the tax advantage of such a box.[8] While the authors find a tax advantage for the firm using patent boxes, there are small negative effects on local invention. However, if there is a local development requirement, patent boxes seem to have a substantial positive impact on domestic inventions by the observed firms.

Bösenberg and Egger (2017) look at patent filings and pre-grant patent transfers as a function of all the possible tax incentives that affect patenting. They use a country level dataset with comprehensive information on R&D tax incentives for 106 countries between 1996 and 2012. The two main measures they create are the effective marginal R&D cost due to its special tax treatment (widely known as the "B index", Warda 2002)[9] and the effective average tax rate (EATR) on the profit from R&D. They find that patent filings in a country respond to

[6] Bräutigam et al. (2017) contains a useful discussion of how this impacted the IP boxes. Mutti and Grubert (2009) explain how an MNC can mitigate the impact of the US CFC rules.

[7] In Online Appendix A, Tables A1 and A2 provide an overview of the empirical studies that we found directly relevant to the study of patent boxes.

[8] These variables represent essentially two different error-ridden indicators of the same underlying concept. As predicted, the marginally better measure enters positively and the other negatively (Hall, 2004).

[9] Technically, the B-index is the ratio of the after-tax cost of R&D to the after-tax profits of the firm, so it is equal to unity when there is no special tax treatment for R&D, and is less than one in the case of special R&D treatment. Thus it is not really the effective marginal tax rate on R&D, but is merely related to that tax rate. This implies that the expected impact of the B-index and the EATR on R&D are the same. A lower B-index is expected to encourage R&D, as does a lower effective average tax rate on the profits from R&D.

EATR but not to the B-index or the presence of a patent box, although the signs of these coefficients are as expected. Patent trade responds to the EATR in the sending country and to the B-index in both countries, with an ambiguous sign on the B-index for the destination country.[10]

Bradley et al. (2015) examine worldwide patent applications by inventors and applicants in a country as a function of the patent box and its associated tax rate between 1990 and 2012. They find that a lower patent box tax rate is associated with an increase in domestic inventor patenting, but not with the propensity for inventor and owner countries to differ. They also find that regimes allowing the use of acquired IP lower domestic inventor activity and conjecture that domestic invention activity is substituted by the use of acquired IP from other countries.

Like Bösenberg and Egger (2017), Ciaramella (2017) studies pre-grant ownership changes of EP patents in response to the introduction of the patent box. The results suggest that a one per cent increase in the tax rebate associated with the patent box would induce about a 10 per cent increase in patent transfers to that country, and that the response of higher quality patents would be even slightly more sensitive. She also confirms that patent box design matters: restricting the use of acquired and existing patents and requiring further development of the patented invention both discourage patent transfers in response to the availability of a lower tax rate.

Schwab and Todtenhaupt, 2018 look at a different consequence of the introduction of a patent box. They argue that because a patent box in one of the countries in which they have affiliates is effectively a reduction in the cost of R&D capital that they face, it should increase their R&D activity overall. They confirm this idea using a panel of multinational firms active in Europe during the 2000-2012 period. Firms that are exposed to a patent box for one of their affiliates increase their patent output by about 15 per cent, but only if the patent box is not subject to a nexus requirement. They do not provide evidence on the quality of the additional patents.

Finally, Mohnen et al. (2017) study the impact of the Dutch patent box on R&D person-hours in the firms that take it up. They use a differences-in-differences approach and find an increase in R&D person hours in response to the patent box, although by their estimates the increase in R&D spending is only about half of the lost tax revenue. This makes it a relatively unattractive policy for inducing R&D when compared to the approximately unit elasticity estimates for R&D tax credits (Hall and Van Reenen, 2000).

4. Models

A firm investing in innovation faces a number of decisions: 1) the location choice for its R&D investments, 2) whether to file for patents on the result, 3) if so, the location of the first filing, and 4) the location of ownership of the patents. The tax treatment of R&D and patents will affect all these decisions to varying degrees. The R&D location decision is likely to be most sensitive to the availability of skilled personnel, the market size in the country, and possibly the (tax) cost of doing R&D. Unless the patent box has a strong requirement that the associated R&D be done in the country, this decision is unlikely to be driven by its availability.[11] Similarly, patent coverage by itself is driven by the need to exclude others in the country in question, the cost of such exclusion, the adequacy of patent enforcement in the country, the availability of adequate trade secret protection, and the like. Conditional on the existence of patentable inventions, the availability of a patent box should matter mainly for the location of ownership of the patent and the ability to attach revenue to that ownership. That is, patenting is driven by a set of considerations that are fairly orthogonal to the choice of locus for patent ownership, with one exception. The exception is that more profitable patents will be preferred for transfer to a lower tax jurisdiction.

Our analysis is performed at two levels of aggregation: country level and patent level. The first, which aggregates all transfers to the sending country-receiving country-year level, allows us to examine the impact of the tax variables and other country-level variables on the decision to transfer ownership of patents and the location to which to transfer them. The second allows us to examine the choices at the individual patent level, which means that we can include patent characteristics in our analysis.

In the aggregate analysis, we estimate a count data model for the number of patents transferred from country S to country B in year t (or invented in country S but country B is chosen as the location of the applicant):

$$E(\#transfersS\rightarrow B|X_{St},X_{Bt}) = \alpha_S + \beta_B + \lambda_t + f(X_{St},X_{Bt}). \tag{1}$$

The function *f(.,.),* which is intended to capture the relative attractiveness of country S and country B as a location for the profits from patents, is proxied by a range of variables that describe the changing tax environment in both countries over time, as well as other country characteristics. We use a gravity model of the choice, where the dependent variable is the number of patents transferred that year from one country to another, controlling for country and year fixed effects as well as the two country's GDP, population, R&D, and patenting activity. In effect this is a simple trade model, applied to patent trade.

The general form of a gravity model is the following:

$$Y_{ijt} = \alpha_i\alpha_j\lambda_t\prod_k X_{kit}^{\beta_k}\prod_k X_{kjt}^{\gamma_k}\eta_{ijt}. \tag{2}$$

In our case i and j denote seller and buyer country respectively, and t is the year of patent transfer. α_i and α_j are country-level fixed effects for seller and buyer country, respectively. Y is the number of patents transferred, X_i and X_j are the characteristics of countries i and j, and η is a disturbance, which may be heteroskedastic. For estimation, and assuming that the disturbance η is independent of the right hand side variables, the equation is transformed:

$$Y_{ijt} = \exp\left(\ln\alpha_i + \ln\alpha_j + \ln\lambda_t + \sum_k \beta_k \ln X_{kit} + \sum_k \gamma_k \ln X_{kjt}\right)\eta_{ijt} \tag{3}$$

or

$$E\left[Y_{ijt}|i,j,X_{it}X_{jt}\right] = \exp\left(\ln\alpha_i + \ln\alpha_j + \ln\lambda_t + \sum_k \beta_k \ln X_{kit} + \sum_k \gamma_k \ln X_{kjt}\right). \tag{4}$$

As suggested by Santos-Silva and Teneyro (2006), this model can be estimated by pseudo-maximum likelihood, e.g., a Poisson estimator with robust standard errors. They show that this estimator is preferred for gravity models in terms of bias and has the additional benefit that zeroes in the dependent variable are allowed, which is not true of the usual log linear treatment of the gravity equation. See that reference for details. We use a random effects Poisson model with robust standard errors clustered on the buyer-seller country combinations for estimation. That is, there are fixed country effects, but random effects for the country (buyer-seller) combinations. This model is more robust to misspecification than the alternative negative binomial model, and the standard error estimates allow for overdispersion which is clearly

[10] The regressions show signs of misspecification, as the Poisson and negative binomial results differ greatly in their coefficients.

[11] However, it is interesting to note that the Dutch innovation box allows its use in the case where the firm has obtained an R&D certificate, which is needed to use the R&D tax credit. Bongaerts and Ijzerman (2016) report that the vast majority of Dutch firms using the innovation box (82%) make use of this feature rather than using income from a patent. This fact alone suggests that, at least for the Dutch context, patent box schemes are unlikely to be as useful as R&D tax credits in stimulating R&D.

present.[12]

The above analysis is to some extent simply descriptive, rather than being derived from the applicant's choice problem. This is a consequence of our desire to estimate at the aggregate level in order to see the overall impact of the introduction of a patent box. A more complete model would need to be analyzed at the firm or patent level. At any period in time, the firm faces the choice of keeping the patent where it is or transferring it to another tax jurisdiction. The reasons for transfer include mergers/acquisitions, asset sales, or tax considerations. Our focus is the latter, and we are forced to assume that the tax effect is roughly orthogonal to the other causes of transfer, due to the absence of accurate data on these other causes. An alternative interpretation is that our estimates encompass any tax advantage motivations deriving from M&A activity. We address this question later when we focus in our empirical work on intra-group transfers across countries, which are arguably purely tax motivated.

Our second empirical model examines the choice of which patent to transfer. In principle, a firm considering transferring ownership of a patent across countries faces a multitude of choices, and would choose based on the tax rate on patent income in the home and potential transfer country, the transfer cost, and whether it had a subsidiary in the country.[13] The underlying model of transfer is described below and then we derive the (simplified) logit model that we actually estimate.

The after-tax income (profit) derived from patent *i* held by entity *j* in country *s* at time *t* depends on a set of value indicators X_i:

$$\pi_{its} = (1-\tau_{ts})(X_i\beta) + \varepsilon_{its}. \tag{5}$$

τ_{ts} is the tax rate on patent income in country *s* at time *t*. If the patent is transferred to country *b*, we assume it will earn after-tax income as follows:

$$\pi_{itb} = (1-\tau_{tb})(X_i\beta) + \varepsilon_{itb}. \tag{6}$$

At time t, the patent will be transferred to country *b* if the following condition holds, where the transfer occurs at a transactions cost *C* that depends on characteristics of the patent owner *j*:

$$(\tau_{st}-\tau_{bt})[X_i\beta] + \varepsilon_{ist} - \varepsilon_{ibt} > C_j = Z_j\gamma. \tag{7}$$

However, the above condition is sufficient only if there is a single country *b* to which the patent can be transferred (this is related to the reason that the coefficients of *W* are not identified in a hazard rate or simple logit model). To fully describe the problem in the case of several possible countries, we need the following condition:

$$\pi_{itb} \geq \underset{k\neq b}{Max}[\pi_{itk}], \tag{8}$$

which is recognizable as the specification of a random utility model, so it can in principle be estimated by logit or nested logit if the disturbances are assumed to be extreme value distributed. The version above is conditional on a transfer being made. To add the possibility that no transfer is made, define $C_{sj} = 0$ in the case of no transfer, and $C_{kj} > 0$ otherwise, rewriting the equation as

$$\pi_{itb} - C_{bj} \geq \underset{k\neq b}{Max}\left[\pi_{itk} - C_{kj}\right]. \tag{9}$$

In this derivation, we assume that the costs of the transfer are determined by the entity transferring the patent, whether the buyer or the seller actually pay these costs.[14] For estimation, we specify these costs as a linear regression function of the patent owner characteristics *Z*; the negative sign reflects the fact that our indicators are expected to be associated with lower costs of transfer:

$$C_{kj} = -Z_j\gamma + \upsilon_{kj}. \tag{10}$$

Transforming equation (9) to a form that can be estimated by a simple logit model of transfer and writing the costs of transfer as, we obtain the following:

$$\begin{aligned}\Pr(transfer) &= \Pr\left\{\pi_{its} \leq \underset{k\neq s}{Max}\left[\pi_{itk} - C_{kj}\right]\right\} \\ &= \Pr\left\{\underset{k\neq s}{Max}\left[(1-\tau_{tk})X_i\beta - \upsilon_{kj} + \varepsilon_{itk}\right] - X_i\beta + \tau_{ts}X_i\beta + Z_j\gamma \geq \varepsilon_{its}\right\}.\end{aligned} \tag{11}$$

The first term in this equation is clearly unobservable due to the presence of the disturbance, which varies across the *k* possible transfer countries. This precludes identification of the coefficients of characteristics of the recipient countries *W*. Therefore, the only coefficients that can be identified are those of the patent characteristics *X* and the owner characteristics *Z*. We control as best we can for the unobservable maximum across potential transfer countries using the applicant year and country dummies (note that variation of the set of countries available for transfer is isomorphic to the single current owner country because we include a closed set of 37 countries in our estimation sample).

Transfer is more likely when

1. seller tax rates are higher (interacted with the patent value indicators). For most countries and years, this is the corporate tax rate, while for countries that have introduced a patent box, it will be the patent box rate. For the government/non-profit sector, the rate will be zero.
2. the value of the patent in generating income is higher. That is, the value indicators *X* are larger.
3. the cost of making the transfer is lower, which we proxy using the dummies for the type of patenting entity and its cumulative patent holdings (as an indicator of the salience of patents to the entity).

Note that equation (11) suggests a simple consistency check of the empirical model: the coefficients of the value indicators and of the value indicators interacted with the tax rate should be equal and opposite. All of the variables in equation (11) are measurable for the patents that are actually transferred. However, as noted the characteristics *W* of the transfer country (including its tax rates) are not defined for those patents that are not transferred. Therefore, in the empirical analysis in Section 6 we focus on the impact of the tax rate in the country from which the transfer is made (τ_{its}) and the value proxies (*X*) of the patent.

5. Data

The data for our study come from PATSTAT (European Patent Office, April 2018 edition) and the MPI 2018 patent transfer database (Gaessler and Harhoff 2018).[15] For the aggregate country-level portion of the study, we add data from the Penn World Tables 9.1 (Feenstra et al. 2015),[16] the OECD Main Science and Technology Indicators (OECD,

[12] Experiments with the negative binomial model and its random effects version produced unstable results, supporting the view that this distributional assumption was not justified.

[13] As we discuss in Online Appendix D, full estimation of a model of patent transfer as a function of the characteristics of the patent (*X*), of the current country (*Z*), and the potential countries to which the patent might be transferred (*W*) proved difficult to impossible, probably because we have limited variability in the tax variables, especially those for the patent box.

[14] We do not observe the price at which the transfer is made, so cannot allocate costs between the parties.

[15] The Max Planck Institute for Innovation and Competition Patent Transfers Data 2018. For information on data access, see: https://www.ip.mpg.de/en/research/innovation-and-entrepreneurship-research/data-access.html. We updated these data to include additional transfers through 2017, although due to selection issues, our analysis stops at 2016.

[16] https://www.rug.nl/ggdc/productivity/pwt/ for the latest version of PWT.

2018), and the UNESCO Statistics Database. Our tax information comes from OECD (2016) and KPMG, 2020 as well as various prior studies of patent boxes. Details are given below.

There are approximately 1.64 million registered ownership transfers of European patents (EP) in the MPI 2018 patent transfer database. About two-thirds of these transfers are within firm groups. Only about 11.4 per cent are across countries. The most common transfers are to and from Germany and the United States and Switzerland. Granted patents are far more likely to be transferred and transferred patents are uniformly distributed across technology areas. In contrast to other studies on patent transfers, the used data entails pre- as well as post-grant patent transfers. In fact, a considerable share of transfers occurs after patent grant, when the rights holder presumably faces lower uncertainty about the patent's validity and commercial value. For more detail on the raw data, see Gaessler and Harhoff (2018).

For the study here, we restrict the sample to transfers among 51 countries for which we have tax information. Our sample includes 27 European countries, the US, Canada, Mexico, Chile, Israel, Turkey, Australia, New Zealand, Japan, Korea, and 14 "tax haven" countries or jurisdictions, mostly in the Caribbean. It includes approximately 95 per cent of the international transfers in the database. The complete country list is shown in Online Appendix Table B-1, and the list of the patent box countries only in Online Appendix Table B-2.

We combine these data with tax data from Alstadsæter et al. (2018), Evers et al. (2015), Dinkel and Schanz (2015), the OECD, and KPMG, 2020 on corporate taxation and the tax treatment for intangible assets including patent boxes.[17] Fig. 1 (top) shows the distribution of corporate tax rates during the 2000-2016 period for the 37 countries which have corporate taxation (that is, excluding the 14 tax havens) and Fig. 1 (bottom) shows the distribution of the wedge between the rate on ordinary income and that on patent-generated income for those countries that have a patent box, during the years in which they have the box. The median corporate tax rate is 28 per cent and the median reduction for patents is around 18 per cent. The median tax rate on patent-related income for those countries and years that have a patent box is 7 per cent.

6. Results

6.1. Aggregate analysis – Patent transfers

Our initial exploratory analysis is at the aggregate level. We observe the number of patent transfers from each of 51 countries to the other 50 countries (excluding within country transfers). For estimation, we restrict the transfer sample to 2000-2016, which is when most of the patent boxes were introduced.[18] The total number of observations in our data is therefore potentially 38,250 = 15*50*51. Fig. 2 shows the aggregate EP patent transfers into and out of the countries that introduced the patent box during the 2000-2016 period as a function of the number of years before and after its introduction.[19] International transfers did indeed respond to the introduction of the patent box, with transfers out declining and transfers in increasing. There is also a hint of patent box anticipation one to three years prior to its introduction. It is difficult to get precise dates for all the countries as to when the patent box first became a real probability, but we do know that for the UK, the legislation was actually in place long before the date when coverage began in 2013.[20] Note that Fig. 2 is truncated at lag 2 due to the relatively recent date of introduction of some of the patent boxes.[21] In what follows, we estimate models for patent transfer controlling for differences across countries and time, which allow us to include all the 16 countries with a patent box in 2016.

Fig. 2 combines data for a number of countries with differing dates of patent box introduction. Because there may also be calendar year trends in the probability of patent transfer as well as possible selection due to incomplete patent data at the end of the period of observation, we probe the aggregate patent box impact using a gravity model of patent transfer. In this estimation, we control for the level of transfer in both buyer and seller country as well as the calendar year of transfer using dummy variables. Thus, identification of the patent box effects comes from comparing a seller or buyer country's transfers before the patent box introduction to transfers after, controlling for the overall trends in patent transfer.

As described in Section 4, we estimate a count data model for the number of patents transferred from country *S* to country *B* in year *t*. We include a range of variables that describe the changing tax environment in both countries over time, as well as some other country characteristics. The statutory corporate tax rate of *S* (seller country) and *B* (buyer country) is included in most regressions. This rate excludes any advantage due to the patent box. To model the patent box, we used either a dummy for its presence, or the magnitude of the reduction from the corporate tax rate (corporate tax rate less the tax rate on income attributed to patents). The other country characteristics included are population, real GDP per capita, EP patent applications per capita, and the R&D-GDP ratio plus a dummy for those few observations where R&D spending was unobtainable. The population and GDP numbers come from the Penn World Tables 9.1 (Feenstra et al. 2015), while the R&D numbers come from OECD, 2018 augmented by the UNESCO Institute for Statistics database (United Nationals Institute for Statistics 2018) and are also available from the International Monetary Fund statistical database.

In practice we found that excluding the 14 tax haven countries from the sample made little difference to the estimates, as they had no variability in tax rates across the period, so we focus here on the results that are based on the 37 country sample, which includes all 17 countries that have introduced a patent box by 2015.[22] The main results of estimation are shown in Table 1. Supplementary results are shown in Online Appendix Table B-5. Results for the 51 country sample are shown in Online Appendix Tables B-3 and B-4.

We parametrize the tax rate function *f(.)* in a number of ways. In all versions we include the nominal corporate tax rate of the buyer and seller countries. In the first version we include dummies for the patent

[17] We checked the coding of the existing/acquired IP exclusions and the development conditions attached in various sources. Determining the precise definition of eligible IP turns out to be difficult, and there is some conflict among the various research papers. In addition, given the ability of firms to create local subsidiaries, it is not clear that these restrictions bite in some cases. Unfortunately using more nuanced definitions of these variables leaves us with no degrees of freedom to identify their effects.

[18] There are two exceptions: France (1971-) and Ireland (1973-2010, 2015-). As our transfer data begins only in 1981, France does not contribute to identification except when we use the magnitude of the tax reduction, and for Ireland identification comes from the box removal rather than introduction. The recently re-introduced patent box in Ireland is just outside our sample years. As is well-known, the low overall corporate tax rate in Ireland has in any case induced patent transfer to that country whether or not there is favorable tax treatment.

[19] Fig. B-2 in the Online Appendix shows the same but restricted to EP patent transfers within corporate groups.

[20] See https://www.gov.uk/guidance/corporation-tax-the-patent-box. This document, dated January 2007, describes the patent box to be introduced in 2013.

[21] These figures include data only from the 11 countries that have at least three years of data post-patent box, including the year it was introduced: Belgium, Switzerland, Cyprus, Spain, UK, Hungary, Ireland, Liechtenstein, Luxembourg, Malta, and the Netherlands, This excludes France, Italy, Greece, South Korea, Portugal and Turkey as well as countries that introduced a box post-2016.

[22] The sample is 27 European countries, Australia, Canada, Chile, Israel, Japan, South Korea, Mexico, New Zealand, Turkey, and the US.

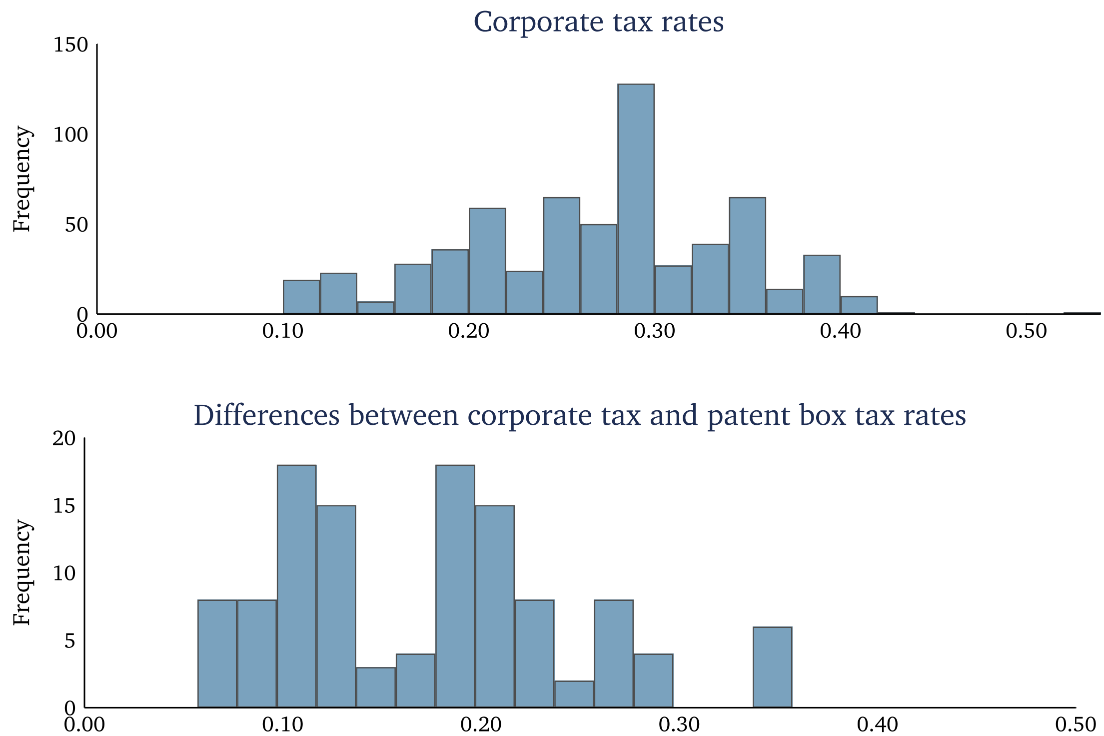

Fig. 1. Distribution of corporate income tax rates

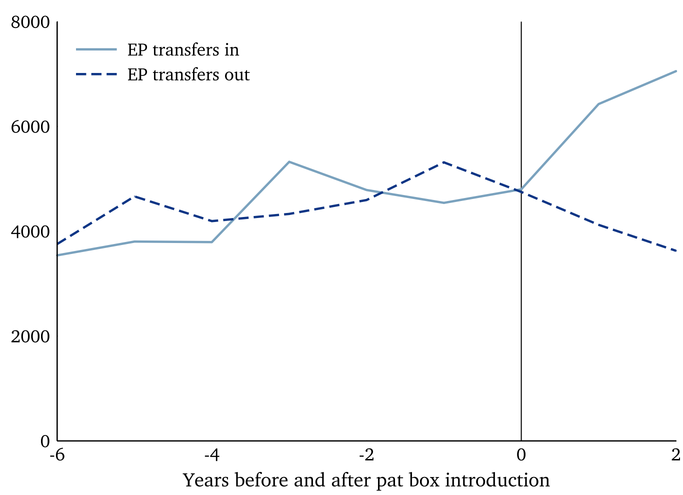

Fig. 2. Patent transfers between countries around the time of patent box introduction

box in the buyer and seller countries in all the years when it was available (columns 1 and 5 of Table 1). In the second we include the magnitude of the difference between the ordinary income and patent income tax rates for both countries (columns 2 and 6 of Table 1). In the third version we explore the timing of the response to the introduction of the patent box: instead of including the wedge between ordinary and patent income for every year following its introduction, we include dummies only for the introductory year and 3 lags (columns 3, 4, 7, and 8 of Table 1). The assumption is that the introduction of the patent box triggers patent transfers, possibly with a lag, but that after that adjustment, there will be no additional transfers, because new patents can simply be taken out with ownership residing in the patent box country.

The first four columns of Table 1 show the results for Poisson random effects estimation of the number of international patent transfers from one country to another on the tax variables and complete sets of dummies for buyer and seller countries as well as year dummies, while the next four columns add the various country characteristics.[23] The country dummies already control to some extent for the fact that the average number of patents, the size of the economy and its technological intensity vary enormously across countries, so adding these characteristics to the regression only controls for their change over time.[24] We found that only the buyer country population and per capita patenting entered the regression significantly. We also found that neither of the general corporate tax rates entered the regression significantly when including the country variables, although the standard errors are quite large.[25]

Columns 1 and 2 in Table 1 show that the patent box has an insignificant (and negative) impact on patent transfer to the country, whereas the patent box has a strongly negative impact on transfer from the country and the corporate tax rate the (expected) positive impact. Thus once we control for seller, buyer, and year, only changes in the potential seller's tax rates have any noticeable effect on the number of patents transferred, with the lower tax rates on patent box income in the seller country discouraging the transfer of patents.[26] The coefficient on the

[23] We cluster the standard errors by origin-destination country pairs. Our estimation strategy means that the average transfer effects (to and from) for each country are treated as fixed effects, while the average transfer effect between specific pairs of countries is treated as a random effect, conditional on each country's own average transfer probability.

[24] In a further robustness check, we included the annual volume of manufacturing exports from the seller country to the buyer country (and vice versa) to proxy for the strength of bilateral trade relationships. Our results for the other coefficients were not changed by the inclusion of these variables.

[25] Identification is marginal in the presence of country and year dummies, because the within variance of corporate tax rates is about 10 per cent of the total.

[26] This aggregate result is somewhat at odds with the firm-level results of Schwab and Todtenhaupt (2018), who find a positive patent box effect of the buyer country on patent transfers by multinationals. Note that we do find a positive effect at lag 2, but neither the first three lags nor including all the lags yields a significant coefficient.

Table 1
Inter-country patent transfer flows.

Dep. Var. = Number of patents transferred from seller country to buyer country during the year								
	All	*All*	*All*	*Within group*	*All*	*All*	*All*	*Within group*
Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Buyer corporate tax rate	0.84	0.94	1.56	0.17	-0.37	-0.19	0.45	-0.76
	(1.31)	(1.30)	(1.41)	(2.04)	(1.23)	(1.22)	(1.37)	(1.71)
Dummy for buyer patent box	-0.06				-0.15			
in all years after introduction	(0.14)				(0.12)			
Buyer patent tax rate wedge		-0.10				-0.42		
in all years after introduction		(0.71)				(0.66)		
Buyer patent tax rate wedge			-0.33	0.20			-0.42	0.00
in year of introduction			(0.67)	(0.77)			(0.67)	(0.78)
Buyer patent tax rate wedge			0.51	-0.31			0.34	-0.46
in year after introduction			(0.85)	(0.74)			(0.82)	(0.74)
Buyer patent tax rate wedge			1.65**	1.50			1.43*	1.41
two years after introduction			(0.82)	(1.09)			(0.79)	(1.06)
Sum of buyer patent tax rate			1.84	1.39			1.35	0.95
wedge coefficients 0-2			(1.38)	(1.59)			(1.36)	(1.53)
Seller corporate tax rate	1.69*	1.82*	2.37**	2.31	1.53	1.79	2.38*	2.13
	(0.94)	(0.94)	(0.96)	(1.43)	(1.22)	(1.25)	(1.32)	(1.92)
Dummy for seller patent box	-0.36***				-0.38***			
in all years after introduction	(0.12)				(0.11)			
Seller patent tax rate wedge		-1.84***				-1.83***		
in all years after introduction		(0.59)				(0.56)		
Seller patent tax rate wedge			0.39	1.11			0.40	1.11
in year of introduction			(0.50)	(0.66)			(0.49)	(0.70)
Seller patent tax rate wedge			-0.33	0.06			-0.32	0.09
in year after introduction			(0.62)	(0.94)			(0.57)	(0.85)
Seller patent tax rate wedge			-0.80	-0.64			-0.77	-0.63
two years after introduction			(0.58)	(0.94)			(0.60)	(0.97)
Sum of seller patent tax rate			-0.73	0.53			-0.70	0.57
wedge coefficients 0-2			(1.13)	(1.50)			(1.08)	(1.48)
Chi-squared	4732.3	4699.5	4752.3	3134.9	4889.5	4859.4	4940.6	3221.7
Chi-sq degrees of freedom	94	94	98	98	102	102	106	106

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.
22,627 observations on 1,332 country pairs, 2000-2016.
All regressions include complete sets of dummies for the 37 buyer and seller countries and years.
Regressions in columns 5-8 also include aggregate EP patent applications, population, GDP per capita, and R&D intensity, all in logs, for both buyer and seller.
Significance levels:
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

seller's patent box dummy implies a 38 per cent reduction in transfers due to the presence of a patent box. Because the average difference between the corporate tax rate and the patent box rate is 0.18 for those countries that have a patent box, the coefficient estimate of -1.84 in column 2 implies an average impact that is almost the same, 33 per cent.

As Fig. 2 suggests, we might expect that the patent box impact on patent transfer is transitory, because patent applications after the introduction of a patent box will simply be made from the relevant jurisdiction. In column 3 of Table 1, this idea is explored by including the difference between the two tax rates only in years 0 through 2 following the patent box introduction. We show the individual coefficients and their sum in the table. Transfers into the country respond significantly to the introduction of the patent box only after two years; the toal impact in the first three years is again insignificant, but with a one-sided p-value of 0.9. Similarly the sum of the coefficients on the potential seller's patent box wedge is negative with a one-sided p-value of 0.74. Because the coefficient for all years following the patent box introduction is robustly negative, it appears that the patent box encourages patents to stay in the country over the longer run. Thus both results (for seller and buyer countries) show the predicted impact of the patent box, but with considerable imprecision. In general, the results when we include the country variables for population, GDP, R&D, and patenting are very similar (columns 5 to 8).

Columns 4 and 8 of Table 1 show estimates where we restrict the transfers to those that are within the group, that is, transfers within a multinational firm. In this case, the impact of the patent box on retention in the selling country is even stronger. However, it is also quite clear from the standard errors that the regressions are almost at the limit of what can be identified from these data.

In principle, the decision to transfer IP from one jurisdiction to another should depend primarily on the difference in tax rates in the two regimes, rather than on their absolute level. We explored this possibility along with the impact of variations in patent box rules in Online Appendix Table B-5, with limited success. Denoting the statutory corporate tax rate as τ and the tax rate on patent income as ρ, we defined the following variables:

$$\begin{aligned} &\mathit{difftax} = \tau_S - \tau_B \\ &\mathit{diffbox} = (\tau_B - \rho_B) - (\tau_S - \rho_S) = (\rho_S - \rho_B) - (\tau_S - \tau_B) \end{aligned} \tag{12}$$

These variables are defined in such a way that their expected coefficients are positive (the greater the seller tax rate is relative to the buyer tax rate, the higher the likelihood of a transfer).

Online Appendix Table B-5 shows the results of estimation with these variables and we summarize them here. Neither *difftax* nor *diffbox* is significant by itself in predicting patent transfers. The variable *diffbox* is also interacted with several other features of the tax system in the regressions following: 1) whether existing patents are eligible; 2) whether acquired patents are eligible; 3) whether there is requirement of further development of the invention in the country; 4) whether CFC rules apply between the seller and buyer country. Measuring the impact of all these results is challenging due to an absence of sufficient variation across countries (see Table A1). Therefore, we examine them one at a time. Allowing existing and/or acquired patents to benefit from the patent box does not have a significant impact on the number of transfers to that country, although the large standard errors do not warrant strong conclusions.

In contrast, the requirement for further development of the patented invention in the buyer country does appear to reduce transfers, while countries without that requirement see an increase in transfers from the patent box. A one-sided test that the development coefficient is negative yields a p-value of 0.946. We can compute the potential impact of a change in the patent box tax advantage for systems with and without this feature, finding that the response to a 10 per cent change in the tax advantage from a patent box is associated with an increase of about 12 per cent (standard error 7 per cent) if further development of the patent in not required and minus 17 per cent (standard error 11 per cent) if it is not. This result is consistent with the profit-shifting results of Koethenbuerger et al. (2016) and suggests that the BEPS requirements will mitigate the transfer of patents purely for tax-motivated reasons.

CFC requirements imposed on the buyer country by the seller country also reduce the likelihood of transferring patents, although if the gap in corporate tax rates is large enough, it is able to override this impact. The point at which the CFC impact turns positive is a corporate tax rate difference of about 13 per cent, so it is well within our data range. Again, we caution that the confidence interval for this point is quite broad, given the standard errors.

These results lead us to two conclusions. Overall, it is difficult to see an impact from the presence of a patent box on patent transfers to a country. However, there is a significant impact of patent boxes in preventing the transfer of patents and their associated income, as may have been intended by legislation and the tax authorities. The results also show that if a country's patent box does not require further development of the invention in the country, more patent transfer to the country will be induced. The development requirement is more important in our data than whether or not pre-existing or acquired patents are included among the patents eligible for special tax treatment, although clearly these rules are related.

6.2. Aggregate analysis – Inventive activity

The innovation policy argument for the introduction of a patent box is that it should encourage invention and innovative activity in the relevant country. In this section of the paper we look at how such activity changed after a patent box was introduced, using two indicators of inventive activity: EP patent filings from inventors residing in the country and the level of business R&D spending. The analysis is admittedly very aggregate, but still indicative of whether the patent box has an impact on the level of innovative activity in a country.

Because of patent data truncation due to lags in PATSTAT (April 2018 edition), the filings in 2017 and 2018 are incomplete. This means that the window we can examine ends in 2016 limits the data availability for some countries and excludes others.[27] In addition, in the case of France, there is no pre-patent box data. In Fig. 3 we show the simple trends in aggregate patent filings and business R&D (BERD) around the time of patent box introduction for all the countries in our dataset that have introduced a patent box and for which we have data 4 years before and 2 years after its introduction. In the case of EP filings these countries are Belgium, Cyprus, Hungary, Ireland, Liechtenstein, Luxembourg, Malta, the Netherlands, Spain, Switzerland, the UK. For R&D, we lose Cyprus, Malta, and Liechtenstein due to lack of R&D data. Figures B1-B4 in the appendices show the graphs for each country.

The two series are quite similar: both show a slow increase until the date of the patent box introduction and then the curve flattens.[28] Note, however, that the years of patent box introduction for some of the countries cluster around 2007 and 2008, so we cannot be sure that the flat trend is not due to the effects of the great recession. To explore this, and also to control for country differences, we estimate two sets of simple aggregate patent regressions: 1) the log of filings by inventors in a country as a function of the existence of a patent box, the statutory corporate tax rate, the population, real GDP, R&D intensity (R&D-GDP ratio), and a set of country and year dummies; and 2) the log of business-funded R&D as a function of the same variables, excluding R&D intensity. The method of estimation for the first model is Poisson maximum likelihood with robust standard errors, clustered on country, and for the second it is ordinary least squares, again with robust standard errors.[29]

The estimation results are shown in Tables 2 and 3. The first column in both regressions is essentially a difference-in-difference estimation for the impact of the patent box, as the regression includes only the patent box dummy and a complete set of country and year dummies. In both cases the coefficient is insignificant. In the case of the patent box the p-value for a one-sided t-test is 0.93, so we cannot rule out that the impact is slightly positive. The remaining columns add various country and tax variables to the regressions, and use the size of the patent tax wedge instead of the box dummy. The impact of the patent box becomes very insignificant, except in column 6, where we include the interaction of the box with the development condition. In the R&D regressions, the two patent box variables are insignificant and often negative. These negative coefficients are somewhat surprising, but may be explained by a crowding out effect. That is, the relocation of patent ownership by multinationals to the buyer country could be accompanied by other factors that discourage local invention. Another explanation for these negative coefficients may lie in a potential endogeneity of the patent box introduction; that is, a country with stagnant R&D performance may be more willing to introduce a generous patent box. Both inventor filings and R&D depend positively on populations and GDP per capita, and inventor filings also depend on R&D intensity.

As mentioned earlier, Alstadsæter et al. (2018) look at the change in the number of inventors in host and destination country in response to patent transfers at the company level, and find that inventors in the destination country are more likely to increase when there is a further development requirement for the use of a patent box with existing patents that are transferred. We probe this further in columns 4 to 6 of Table 2, which add the dummies for the inclusion of existing patents, acquired patents, and requirement for separate development. The first two do not enter significantly. However, in both the patent filing regression (Table 2, column 6) and the business R&D regression (Table 3, columns 5 and 6), we find similar results to Altstadsaeter et al.: the size of the patent box differential is negative both for patent filings and business R&D when there is no requirement for further development, but insignificant when there is (shown as the derived sum of the two patent tax wedge coefficients in the tables).

Thus, at best, we can conclude that if further development is required of the inventions contained in transferred patents, there is no impact of the introduction of a patent box on aggregate innovative activity. However, prior to the introduction of the BEPS restrictions, there appears to have been a somewhat negative impact, there appears to have been a somewhat negative impact of the patent box introduction on local invention and R&D, contrary to expectations.

6.3. Patent level analysis

We now turn to an analysis of the choice of patents to transfer. We expect that the patents chosen to benefit from reduced corporate taxes will be those that generate greater income for their owner than other

[27] Italy, Greece and Turkey have only 2 years of data post-box including the year of introduction. These countries are excluded from the figures along with France, but not from the regression analysis.

[28] The decline in EP patents filed at the last lag is probably due to some truncation in the total EP filings for 2015 and 2016 which is apparent in the April 2018 PATSTAT edition.

[29] The data are very skew (the US, Germany, and Japan average more than 15,000 filings per year, while a number of countries have fewer than 100, and two countries fewer than 10) and we found that Poisson estimates were more robust than log-linear estimates, being similar to those obtained using minimum distance methods (see Hall et al. 1986 for a fuller discussion).

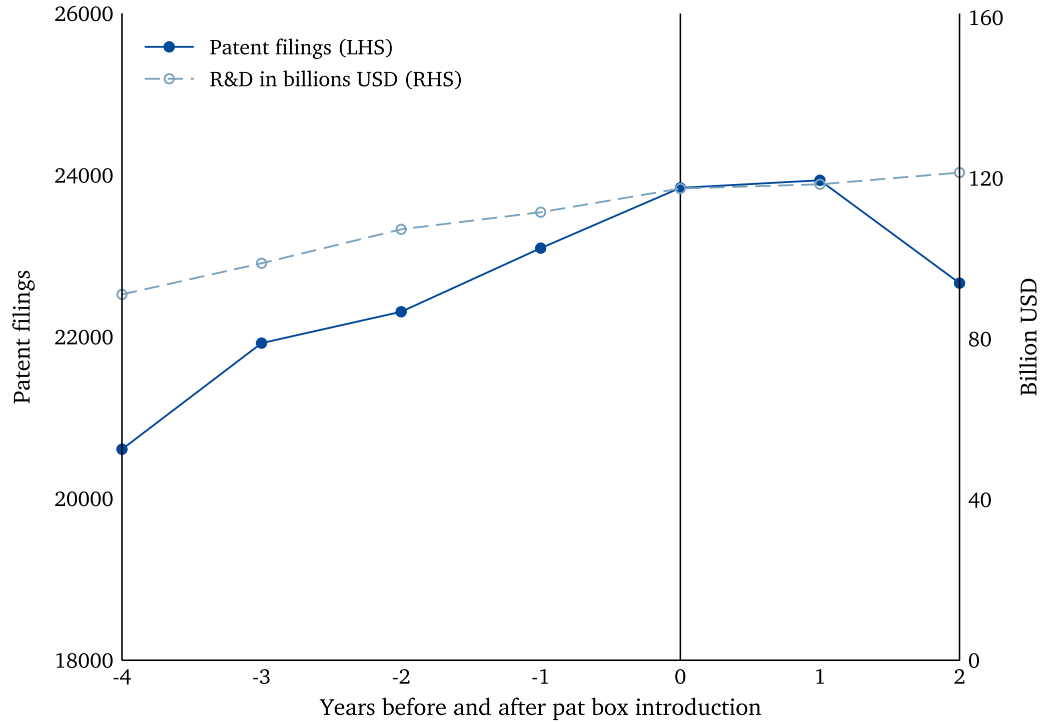

Fig. 3. Aggregate patenting and R&D around the time of patent box introduction

Table 2
Inventor filings by country.

Dep. Var. = EP patent filings from inventors in the country *Variable*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
D (patent box)	0.11	0.00				
in all years after introduction	(0.07)	(0.05)				
Patent tax rate wedge			-0.09	-0.12	0.22	-2.38***
in all years after introduction			(0.25)	(0.15)	(0.37)	(0.63)
D (including existing patents)				0.04		
* patent tax wedge				(0.34)		
D (including acquired patents)					-0.55	
* patent tax wedge					(0.48)	
D (development restriction)						2.55***
* patent tax wedge						(0.61)
Sum of patent tax wedge impact						0.16
with dev. restriction (derived)						(0.23)
Corporate tax rate		0.50	0.49	0.49	0.53	0.58*
		(0.34)	(0.34)	(0.34)	(0.34)	(0.31)
Log population		1.15**	1.17**	1.16**	1.19**	1.35**
		(0.56)	(0.57)	(0.57)	(0.58)	(0.60)
Log GDP per capita		0.90**	0.90**	0.90**	0.92***	1.06***
		(0.36)	(0.36)	(0.36)	(0.35)	(0.32)
Log R&D expenditure over GDP		0.73**	0.73***	0.73**	0.76***	0.75***
		(0.28)	(0.28)	(0.29)	(0.29)	(0.26)
Number of coefficients	53	57	57	58	58	58
Log-likelihood	-16,256.9	-11,507.4	-11,500.7	-11,500.4	-11,431.8	-10,872.8

629 observations on 37 countries for the years 2000-2016.
All regressions include a complete set of country and year dummies, as well as a dummy for missing R&D data (52 observations on 4 small countries).
Method of estimation is Poisson with robust standard errors, clustered by country.
Significance levels: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

patents. Data on the income generated by individual patents is not available to us, but previous work has shown that several measurable patent characteristics are associated with the economic value of patents (Harhoff et al. 2003; Hall et al. 2004). Therefore, we proxy for patent value using some of these measures, as discussed below. We also expect that corporations, especially multinational corporations, will be more likely to take advantage of this kind of tax planning. In what follows, we will distinguish between transfers made to countries with lower tax rates for patent income and other international transfers, and between those made within a corporate group (which are arguably more targeted towards tax benefits) and arm's length transactions due to sale, either of a patent portfolio, or of the entire firm.

Our sample is the approximately 2.8 million EP patents filed between 1991 and 2016; of these patents 5.1% were subject to an ownership

Table 3
Country-level business R&D spending.

Dep. Var. = Log BERD (Business enterprise R&D) *Variable*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
Lagged log BERD						0.90***
						(0.03)
Dummy for patent box	-0.07	-0.06				
in all years after introduction	(0.12)	(0.06)				
Patent tax rate wedge			-0.31		-1.84***	-0.36**
in all years after introduction			(0.42)		(0.41)	(0.11)
Patent tax rate wedge				0.72		
in year of introduction				(0.53)		
Patent tax rate wedge				-0.56		
in year after introduction				(0.48)		
Patent tax rate wedge				-1.10		
two years after introduction				(0.98)		
Sum of patent tax wedge				-0.93		
coefficients 0-2 (derived)				(0.64)		
D (development restriction)					2.02**	0.50**
* patent tax wedge					(0.67)	(0.18)
Sum of patent tax wedge impact					0.18	0.14
with dev. restriction (derived)					(0.52)	(0.15)
Corporate tax rate		1.29*	1.31*	1.34*	1.47*	0.01
		(0.63)	(0.62)	(0.63)	(0.64)	(0.27)
Log population		0.86***	0.86***	0.86***	0.86***	0.09**
		(0.09)	(0.09)	(0.09)	(0.09)	(0.03)
Log GDP per capita		2.54***	2.54***	2.55***	2.54***	0.23**
		(0.19)	(0.18)	(0.18)	(0.18)	(0.07)
Observations	532	532	532	532	532	500
R-squared	0.716	0.980	0.980	0.981	0.981	0.997
Standard error	1.007	0.267	0.267	0.263	0.263	0.100

32 countries 2000-2016, slightly unbalanced. All estimates include country and year dummies.
Method of estimation is least squares with robust standard errors, clustered by country.
Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

transfer across countries between 2000 and 2016.[30] We focus on the first time that the patent is transferred, and drop the few cases where there is more than one transfer. Fig. 4 shows the number of EP patents transferred by transfer year, both including and excluding transfers to our tax haven countries. In the subsequent analysis, we exclude transfers to and from tax havens. This restriction reduces the number of transfers by about one quarter.

Due to the large size of the sample, and the low probability of a transfer in any year (about 0.3%), we draw a random 10 per cent sample of the non-transferred patents for comparison. King and Zeng (2001), among others, show that with known sampling probability, logit coefficient estimates are unaffected by this procedure, with the exception of the intercept. A consistent estimate of the intercept is given by the following:

$$\beta_0 = \widehat{\beta}_0 - \log\left[\left(\frac{1-\psi}{\psi}\right)\left(\frac{\bar{y}}{1-\bar{y}}\right)\right] \tag{13}$$

where $\widehat{\beta}_0$ is the estimated intercept, ψ is the population share of transferred patents, and $\bar{y}$ is the share of the transferred patents in the sample. For our 10 per cent sample, this correction factor is equal to 2.3.[31] Note that for rare events, the correction factor is approximately equal to the log of the oversampling probability ($\bar{y}/\psi$).

As discussed in Section 4, we chose to estimate a simple logit model of the choice to transfer a patent as a function of the patent characteristics X and the patent owner characteristics Z. The patent characteristics we consider are those that are familiar from the literature on patent value:

- Patent family size (docdb measure) – larger sizes are associated both with application in multiple jurisdictions and with more complex continuation/divisional structures, used by firms that anticipate value from the application.
- Number of claims – frequently positively associated with value, although results can be ambiguous, as many dependent claims may also represent breadth restrictions.
- Number of forward citations (5-year) – the number of times the patent has been cited in subsequent patent filings at the EPO during the first 5 years after the application.

Fig. 4. International transfers of EP patents

[30] Of course, not all patent applications in the recent years that will eventually be transferred have been transferred by April 2018, the date of our PATSTAT data. We control for this fact using year dummies in all our regressions.

[31] Log [((1-.00317)/.00317) (0.0309/(1-0.0309))] = Log(315.5*.0317) = 2.302≅Log(10).

- Number of inventors named on the patent – a larger number of inventors may imply greater expense devoted to the invention, in expectation of a greater payoff.

Although all of these value proxies have been shown to be correlated with the underlying value of the patented invention (Harhoff et al. 2003), they vary in different ways, depending on the technology, type of owner, and specificity of the invention. For example, patent family size is likely to be related both to the technology area (complex divisional structures are more likely in pharmaceutical innovation) and to whether the patent owner operates in multiple international markets. Like Lanjouw and Schankerman (2004), we use factor analysis to extract the first common factor from these four variables and use that as our indication of the private value of the patented invention. We first computed the residuals from a regression of each of the four variables on application year, applicant country, and a set of 34 technology class dummies to control for known differences across time and space, and then extracted the first factor from an analysis of these residuals. We found that controlling for all these dummy variables had little effect on the estimated results from using this patent value proxy, although it did improve the explanatory power of our regressions slightly.

We have a limited number of patent owner characteristics *Z*, as they are entirely based on the patent data. They are the following:

- The size of the applicant's patent portfolio at the time of the current patent application, which reflects the saliency of patents in the firm's strategy.
- An MNC dummy for whether the owner is research active in more than two countries (as indicated by patenting from that country at least once during the entire period).
- A dummy for whether the owner is a corporation (as opposed to an individual, university, non-profit, or governmental entity). This dummy excludes the MNC dummy above, which also indicates a corporation.

All of these characteristics are non-time-varying. We also include dummies for the applicant country, the technology area of the patent at the 34 area level, and the analysis year in all of the regressions.

Simple statistics for these variables are shown in Online Appendix Table C-1. Using a non-parametric rank sum test, we find that the distribution of the value-related variables (family size, citations, claims, number of inventors, and the value indices) for the patents that are transferred is significantly to the right of that for patents that are not transferred. The transferred patents also have slightly fewer applicants and their applicants have smaller portfolios, but they are more likely to belong to corporations that patent in multiple countries. Also note that because the distribution of the independent variables is quite skew, we use logarithms of the variables in all the estimations (with the exception of the dummies and the value index, which itself is based on log variables). Correlation matrices for the variables are shown in Online Appendix Table C-2, with and without the year, country, and technology means removed. These correlations are not especially large, with the exception of that between the dummy for multinational patenting corporations and cumulative patent holdings; controlling for year, country, and technology via dummies reduces them slightly.

Table 4 shows the result of estimating a logit model for the probability of international transfer using equation (11). The marginal impact on the probability of a transfer is shown in the last column. Keeping in mind that the sample probability of a transfer is 0.033, the effects are fairly large. For the most part, the signs of the coefficients are consistent with the predictions above and the test for equality between the value coefficient and the negative of the tax rate-value interaction easily passes, with a p-value of 0.809. The only predictor of transfer cost that matters is whether the firm does research in multiple countries, which increases the probability of transfer. The tax rate in the selling country has a strong positive impact on the probability of a transfer, in addition

Table 4
Logit model of the probability of a transfer.

Dep. Var. = 1 if patent transferred internationally *Variable*	*Mean [s.d.]#*	*(1)*	*(2)*	*Marginals for (2)*
Selling country tax rate	-0.000	-0.348*	-0.426**	-0.0123**
* patent value index	[0.200]	(0.194)	(0.193)	(0.0054)
Patent value index	0.000	0.367***	0.391***	0.0113***
	[0.601]	(0.053)	(0.055)	(0.0015)
Selling country tax rate	0.314		1.487***	0.0429**
	[0.101]		(0.573)	(0.0159)
Log (cumulative patents)	5.310	-0.008	-0.008	-0.0002
for patent owner	[2.849]	(0.040)	(0.040)	(0.0011)
Patent owner a multinational	0.625	0.281**	0.281***	0.0081**
research firm	[0.484]	(0.109)	(0.109)	(0.0030)
Patent owner a corporation,	0.278	-0.017	-0.015	-0.0004
not multinational	[0.448]	(0.056)	(0.056)	(0.0016)
Log likelihood		-445,928.8	-445,687.3	
Chi-squared		1,958.8	1,961.5	
Degrees of freedom		90	91	
R-squared		0.049	0.050	

3,463,499 patent-year observations; 106,471 transfers
Heteroskedastic standard errors clustered on 74,513 patent owners.
All equations include seller country, year, and tech dummies.
This column shows the mean and standard deviation of the regressors.
Significance levels: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

to the impact from the interactions with patent value. Because these interaction terms are difficult to interpret, we display the distribution of the tax rate effect with respect to patent value in Fig. 5 (LHS) below.

Fig. 5 (LHS) shows the marginal effect of the seller's tax rate on the probability of transfer as a function of the patent value index, together with its 90 per cent confidence intervals and a histogram of the patent value data. The figure shows that in the area of most of the data, the estimated impact ranges from 0.035 to 0.06 with a standard error of about 0.01. For an example, at the mean of the distribution of patent quality, the impact of a seller tax increase of 20% would be 0.009 = 0.2*0.045, which corresponds to an increase of the average transfer probability for our over-sampled data equal to 0.9%. Over the complete population of EP patents, the increase would be about 0.09% on an average transfer probability of 0.34%, a semi-elasticity of about 0.25. From the regression and the graph, one can also see that as the index of patent value grows, the tax rate impact falls, as a smaller tax change is needed to induce the transfer of valuable patents.[32]

Fig. 5 (RHS) shows a similar plot, this time of the marginal effect of patent value as a function of the statutory tax rate on patent income. The histogram of the tax data makes it clear that the observations are concentrated in a few cells, which are however widely enough spread to yield identification. Over the populated tax rate region of 0.1 to 0.4, the marginal effect of value ranges from 0.01 to 0.007. At the mean marginal effect of 0.008, an increase in the value index from -1.0 to 1.0 would imply an increased likelihood of transfer of about 0.016 = 2*0.008. This translates into a semi-elasticity of about 50% for the transfer probability.

Although both these marginal effects have nontrivial standard errors, over the region of the observed data they are clearly significant and suggest that both the potential seller's tax rate and the value of a patent influence the probability of an international transfer. The results also

[32] To alleviate the concern that potential non-linearity in the effect of patent value and/or the tax rate drives our results, we included quadratic terms on patent value and tax rate in an alternative specification. These quadratic terms do not affect any of the other coefficient estimates. If at all, the coefficients for the tax rate, patent value and the interaction become slightly larger.

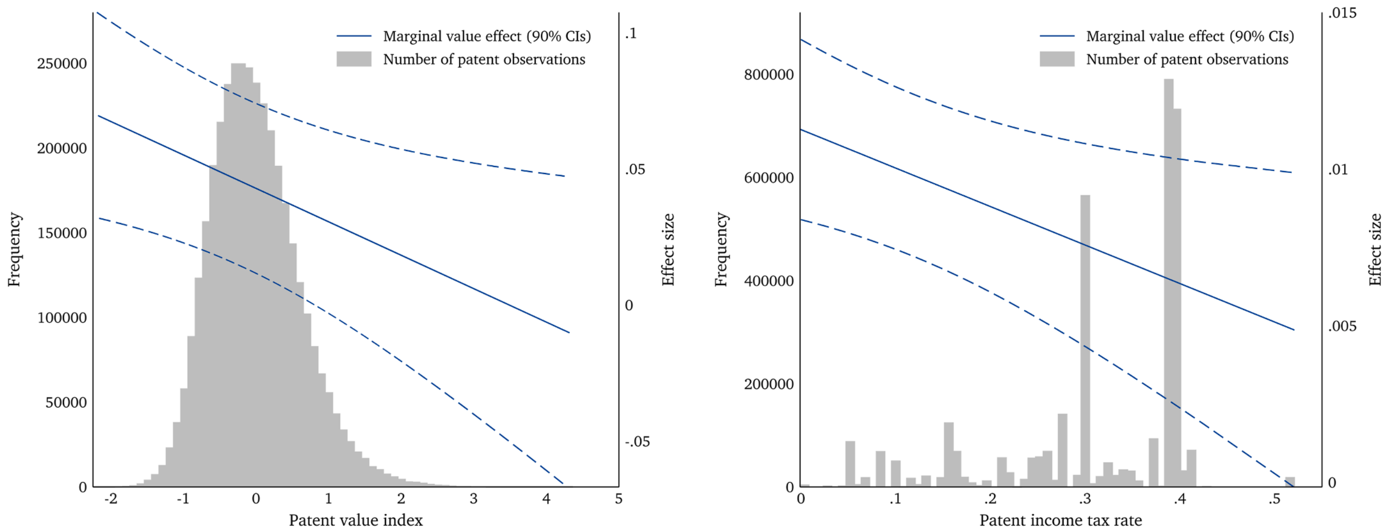

Fig. 5. Marginal tax rate effect (LHS) and marginal patent value effect (RHS)

imply that there is a tradeoff between tax rates and value in the relationship, as predicted by the model and also as one would have expected, given profit-maximizing firms that wish to avoid taxation of those profits.[33]

Table 5 explores the variation across the different types of transfers: whether they are potentially tax-motivated or not, whether they are within a corporate group or arm's length. The first two columns report the results of multinomial logit estimation with three possible choices for each patent: no transfer (the left-out category), transfer to a patent box country, and transfer to a country without a patent box. The next two columns report a similar multinomial logit estimation where we distinguish between arms' length and within group international patent transfers. We define intra-group transfers as those that are dependent or hierarchical in the data of Gaessler and Harhoff (2018). The no transfer choice is again the left-out category. The final four columns report results for a five-choice multinomial logit where group membership has been interacted with the patent box.

Looking first at the standard errors on the tax rate variables, we note that they are very large, and as a consequence in all cases we easily accept the constraint that the coefficient of patent value and the tax rate-patent value interaction are equal and opposite, as implied by the simple model (p-values all much larger than 0.5). But there is simply not enough variability in the tax rates once we split by the patent box for any strong conclusions. The main result of interest is that multinationals and other corporations are more likely than other entities to transfer patents to a country that introduces a patent box, as one would expect. In addition, multinationals are much more likely to make within-group transfers in response to the patent box, and also in response to higher tax rates in the "selling" country.

Our first conclusion from examining the patent level decision to transfer ownership internationally is that more valuable patents (with value measured by the usual proxies) are more likely to be transferred, regardless of whether the transfer is tax-motivated or not. Second, lower taxes in the selling country discourage transfer, but at a diminishing rate as patent value increases. Third, responsiveness to the patent box is much higher for multinationals, who are induced by its presence to transfer their patents to group members in the patent box country. Although the overall results are not that surprising, we see two contributions. First, we have quantified the impact of the patent box and found that it is not small in magnitude, given the overall low rate of transfer. Second, we found that the coefficient constraint implied by a simple model of transfer as a function of tax savings and patent value, with tax savings proportional to value, was satisfied in the data. If one assumes that the income generated by a patent is roughly proportional to its value as measured by the usual indicators, this implies that transfers are indeed being motivated by the tax savings they generate.

7. Conclusions

This paper reports on a comprehensive analysis of the effects of the introduction of a lower corporate tax rate on patent-related income (patent box) in 13 European countries during the 2000-2014 period. Although this change to the corporate tax systems did seem to increase the international transfer of patents into a jurisdiction, at least when there was no requirement for further development domestically, we found relatively little responsiveness overall. However, we did find evidence that transferred patents tend to be more valuable and that multinationals tend to move patents across their group members in response to tax changes. However, neither patented inventions nor R&D investment increased in the countries offering a patent box. These last results are important, as they suggest that the primary stated goal of introducing patent boxes in the respective countries has not been achieved.

Our literature review revealed a wide range of approaches to estimating the patent box effect as well as somewhat inconclusive results. We found in our own explorations that results had sizable standard errors and were sensitive to specification, especially to the precise definition of whether acquired or existing IP was covered by the box. With only 16 countries introducing a patent box, and allowing for both year and country effects, the number of actual degrees of freedom for identification is rather small. Identification is achieved by comparing the change in a country before and after patent box introduction to the change in another country that did not introduce a patent box, controlling for the common trend in the two countries. In order to examine the impact of details in patent box implementation, we need to compare countries that have a patent box, some of which have particular restriction on use, and the others of which do not. Therefore, the number of observations available for identification in the aggregate is actually quite small. That is probably why there is so much variation in the results of the prior literature.

In spite of this important caveat, our results do lead to one conclusion

[33] Note that the effect may turn positive outside of the region where our data is.

Table 5
Multinomial logit model of the probability of a transfer.

Dep. Var. =	Transfer to pat box/no pat box country (1-2)		Arms' length vs within group transfer (3-4)		Type of first international transfer of patent (5-8)			
Variable	Country without patent box	Patent box country	Not within a group	Within a group	Not a group, no pat box	Group, no pat box	Not a group, pat box	Group, pat box
Number of transfers	79,649	26,822	51,624	54,847	39,762	39,887	11,862	14,960
Selling country tax rate* patent value index	-0.480**	-0.280	-0.564***	-0.319	-0.614***	-0.362	-0.405	-0.231
	(0.208)	(0.318)	(0.194)	(0.312)	(0.220)	(0.333)	(0.366)	(0.508)
Patent value index	0.410***	0.331***	0.433***	0.370***	0.448***	0.389***	0.379***	0.320**
	(0.056)	(0.093)	(0.053)	(0.087)	(0.062)	(0.084)	(0.089)	(0.160)
Selling country tax rate	0.663	3.699***	1.148**	1.627*	0.420	0.690	2.855**	4.165***
	(0.691)	(0.840)	(0.560)	(0.860)	(0.627)	(1.011)	(1.169)	(1.566)
Log (cumulative patents) for patent owner	-0.020	0.029	-0.122***	0.094	-0.131***	0.086	-0.088	0.113
	(0.034)	(0.079)	(0.027)	(0.061)	(0.020)	(0.053)	(0.093)	(0.110)
Patent owner a multi-national research firm	0.156	0.736***	0.269***	0.345*	0.224***	0.130	0.450**	1.096***
	(0.108)	(0.190)	(0.085)	(0.178)	(0.082)	(0.184)	(0.227)	(0.275)
Patent owner a corp, not multinational	-0.096	0.322***	0.102***	-0.234**	0.048	-0.336***	0.333***	0.214
	(0.060)	(0.092)	(0.038)	(0.112)	(0.042)	(0.121)	(0.084)	(0.164)
Log likelihood	-494,181.6		-508,029.6			-554,199.6		
Chi-squared	3,877.5		3,567.7			15,294.9		
Degrees of freedom	182		182			364		
R-squared	0.063		0.062			0.076		

All granted EP patents with filing date between 1991 and 2016 that are transferred between 2000 and 2016 and a 10 per cent sample of patents not transferred.
3,463,499 patent-year observations; 106,471 transfers
Heteroskedastic standard errors clustered on 74,513 patent owners.
A complete set of country, year, and technology dummies are included in the estimation.
In columns 1-2, the two types are whether or not the transfer is to a patent box country. In columns 3-4 the two types are whether or not the transfer is within group.
In columns 5-8 the types of transfer are defined by the interaction of the group membership dummy and whether or not the transfer is to a patent box country.
The left-out category is always no transfer.
Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

about the design of these tax instruments: requiring that further development of the invention take place within the country in order to benefit from the lower tax rate does seem to mitigate transfers for purely tax reasons. This provides support for the incorporation of such rules into the BEPS recommendations (OECD 2015). In fact, several countries have already modified their tax rules in this way.

Given the apparent effectiveness of R&D tax credits in increasing firm spending on research and development reported in Hall and Van Reenen (2010) and Appelt et al. (2016), it is perhaps surprising that countries have seen the necessity for the introduction of special tax treatment for income derived from patented inventions.[34] There are (at least) two arguments: the first (benign) one is that some patented inventions are produced with investment other than R&D but still have features that may create public goods in the form of information, justifying a subsidy relative to other investments. The second (less benign) one is that firms with commercially valuable patents are able to use some of their profits for rent-seeking in the form of a reduced tax on some of their income. Put simply, a patent box subsidizes output rather than input, so it benefits mainly firms that have had success with their invention. This may in turn be an encouragement to all firms to undertake such invention, but it seems a fairly inefficient way to do so.

CRediT authorship contribution statement

Fabian Gaessler: Conceptualization, Methodology, Data curation, Writing - original draft, Writing - review & editing. **Bronwyn H. Hall:** Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Dietmar Harhoff:** Conceptualization, Methodology, Data curation, Writing - original draft, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank seminar audiences at the OECD, the Mannheim Tax Summer School 2017, the INNOPAT 2017 Conference, Harvard Business School, the College de France, and the 72nd Annual Congress of the International Institute of Public Finance (Lake Tahoe) for helpful comments. Particular thanks go to Philippe Aghion, Jost Heckemeyer, Deborah Schanz, Joel Slemrod, Mehmet Tosun, and Alfons Weichenrieder. Fabian Gaessler and Dietmar Harhoff gratefully acknowledge financial support from the DFG through Collaborative Research Center TRR 190 "Rationality and Competition."

[34] Another disadvantage relative to R&D incentives is that such an instrument does almost nothing to alleviate the *ex ante* liquidity constraint faced by innovating firms (Hall and Lerner 2010).

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.respol.2020.104129.

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