Should There Be Lower Taxes On Patent Income?

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Should there be lower taxes on patent income?

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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 invention in the relevant country. We find that the impact on transfers is small but present, especially when the tax instrument contains a development condition and for high value patents (those most likely to have generated income), but that invention itself is not affected. This calls into question whether the patent box is an effective instrument for encouraging innovation in a country, rather than simply facilitating the shifting of corporate income to low tax jurisdictions.

JEL codes: H32, H34, K34, O34

Keywords: patent box, IP box, innovation tax, BEPS, EPO, invention incentive, patent ownership

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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 an R&D tax credits that 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 intended to encourage the location of innovative activity by multinationals in the country that introduces it. However, many economists and other analysts have expressed skepticism about its effectiveness, given the multiple avenues available to such companies for the shifting of income associated with intangible assets (Griffith et al. 2014; Sullivan 2015). The patent box creates another 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 has 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 necessary or 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 used 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 fewer 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

[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/resources/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). Appendix Table B1 indicates which of the countries in our sample currently have some kind of R&D tax credit.

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. 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 FTC 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. In this paper we investigate the extent to which this has happened following the introduction of a patent box in several European countries. We look closely at four questions:

1. 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?
2. How do the above effects change depending on the tax rates and specific provisions of the patent box?
3. Does patentable invention in a country increase after the introduction of a patent box? That is, does this policy instrument have the desired effect?
4. 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) that contains all registered patent ownership information changes of patents granted or validated in Germany between 1981 and 2014. Given the high German validation and renewal rates, this dataset effectively captures all transfers of granted European patents during their lifetime. We combine these data with patent data from PATSTAT (April 2017 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.

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

Given only 13 countries with patent boxes, with varying provisions and some introduced very 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 them insignificant, but not able to rule out impacts. We do 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, contradicting the argument that this tax instrument represents an innovation incentive. Finally, we find that transferred patents are of relatively greater value 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.

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 transfer. This is followed by sections describing the econometric models we will estimate and the data we will use. The core of the paper follows in three sections that present 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 Appendix Table B1), 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:

1. 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

[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, after our sample ends. See http://www.oecd.org/tax/beps/ for more information on BEPS policies.

[5] Evers, Miller and Spengel (2014) 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.

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.

2. 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.
3. 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.
4. 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. 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 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 things regarding the CFC rules are worth noting: First, when a country has a CFC regime, the rules usually produce a black list that contains all of the "tax havens" in our sample, at the very least. 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]

[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.

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 patents. Almost none have examined other consequences of the patent box. In this section we review the most relevant ones.[7]

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 percent 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. 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.

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

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

country by each of these multinationals, they find that the tax advantage of a patent box does induce firms to locate their patents in a 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 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

[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.

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

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 percent, but only if the patent box is not subject to a nexus requirement.

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 in response to the patent box, although by their estimates the increase is about half of the lost tax revenue. This makes it a somewhat less attractive policy for inducing R&D when compared to the approximately unit elasticity estimates for the R&D tax credit (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):

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

[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 patent box schemes are unlikely to be as useful as R&D tax credits in stimulating R&D.

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:

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

In our case *i, j* denote seller and buyer country respectively and *t* is the year of patent transfer. *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

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

As suggested by Santos-Silva and Teneyro (2006), this model can be estimated by pseudo-maximum likelihood, that is, Poisson 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 the overdispersion, which is clearly present.[12]

The above analysis is to some extent simply descriptive, rather than being derived from the applicant's choice problem. 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

[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.

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 estimated.

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*:

$$(\tau_{st} - \tau_{bt})\left[X_i\beta\right] + \varepsilon_{ist} - \varepsilon_{ibt} > C_j = \mathrm{Z}_j\gamma \quad . \tag{6}$$

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:

$$\pi_{itb} \geq \underset{k\neq b}{Max}\left[\pi_{itk}\right], \tag{6}$$

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

$$\pi_{itb} - C_{bj} \geq \underset{k\neq b}{Max}\left[\pi_{itk} - C_{kj}\right] . \tag{6}$$

[13] As we discuss in 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.

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] Note that attempting to model that for the disturbances (which will contain country dummies and will also be clustered on owner characteristics). 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:

$$C_{kj} = -Z_j \gamma + \upsilon_{kj} . \tag{6}$$

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:

$$\begin{aligned} \Pr(transfer) &= \Pr\left\{ \pi_{its} \leq \underset{k \neq s}{Max}\left[\pi_{itk} - C_{kj} \right] \right\} \\ &= \Pr\left\{ \underset{k \neq s}{Max}\left[(1-\tau_{tk}) X_i \beta - \upsilon_{kj} + \varepsilon_{itk} \right] - X_i \beta + \tau_{ts} X_i \beta + Z_j \gamma \geq \varepsilon_{its} \right\} \end{aligned} . \tag{6}$$

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 unobservatble 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 under the following conditions:

1. Higher seller tax rates (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).
4. The coefficients of the value indicators and the value indicators interacted with the tax rate should be equal and opposite.

All of these 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.

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

5. Data

The data for our study come from PATSTAT (European Patent Office, April 2017 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 9.0 (Feenstra, Inklaar and Timmer 2015), the OECD Main Science and Technology Indicators (OECD 2018), and the UNESCO Statistics Database. Our tax information comes from OECD (2016) as well as various prior studies of the IP box detailed below.

There are approximately 1.2 million registered ownership transfers of European patents (EP) in the MPI 2018 patent transfer database. About two-thirds of these transfers are within a group of firms, while only about 12 percent 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. 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 95 percent of the international transfers in the database.[16] The complete country list is shown in Appendix Table B1, and the list of the patent box countries only in Appendix Table B2.

We combine these data with tax data from Alstadsæter et al. (2018), Evers et al. (2015), and the OECD on corporate taxation and the tax treatment for intangible assets including patent boxes.[17] Figure 1a shows the distribution of corporate tax rates during the 2000-2014 period for the 37 countries which have corporate taxation (that is, excluding the 14 tax havens) and Figure 1b 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 percent and the median reduction for patents is around 18 percent.

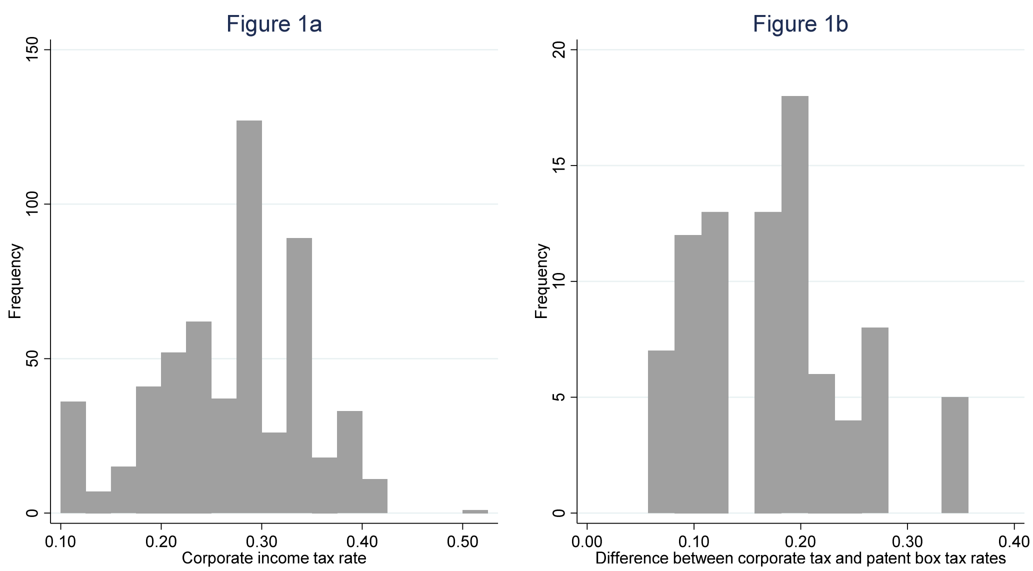
[15] The Max Planck Institute for Innovation and Competition Patent Transfers Data 2018. For information on data access, see: https://www.ip.mpg.de/en/research/innovation-and-entrepreneurship-research/data-access.html.

[16] 101,091 transfers out of 106,642 over the 2000-2014 period. A small share of patent transfers includes cases of co-ownership with multiple origin and/or destination countries. We account for this by using fractional counts.

[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.

The median tax rate on patent-related income for those countries and years that have a patent box is 7 percent.

Figure 1



6. Results

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 2000-2014, which is when most of the patent boxes were introduced.[18] The total number of observations in our data is therefore 38,250 = 15*50*51.[19] Figures 2 and 3 show the aggregate EP patent transfers into and out of the countries that introduced the patent box during the 2000-2014 period as a function of the number of years before and after its introduction. The figures also show the transfers of EP patents restricted to be within a firm group. Both curves in Figure 2 show the expected increase in transfers during the two years following the patent box introduction, with the within group curve increasing somewhat more. The effect diminishes after 2 years, probably because the desired transfers have been completed, but also because there are fewer countries with a patent box at longer lags. There is also a hint of patent box anticipation three years prior to its introduction. It is difficult to get precise dates for all the

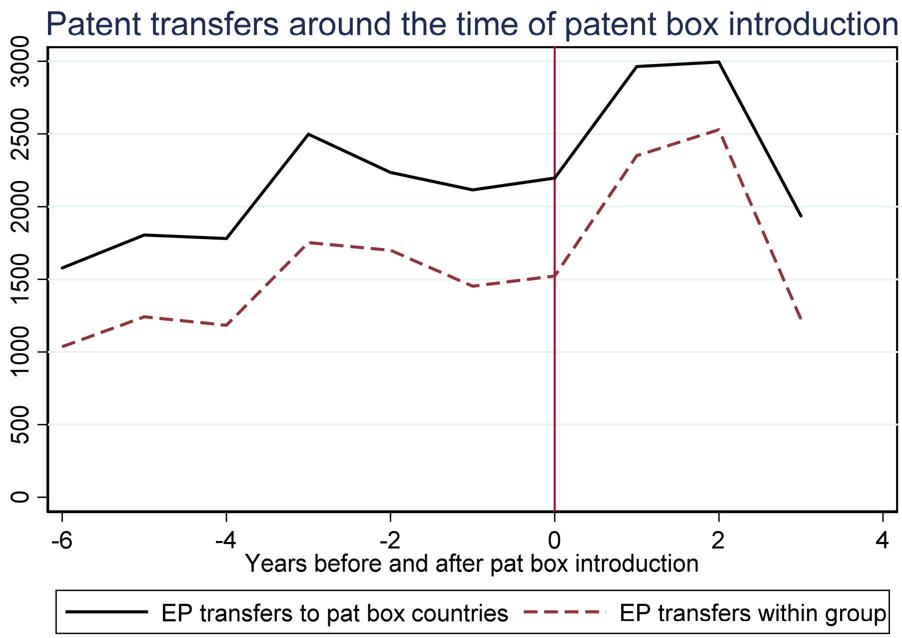
[18] There are two exceptions: France (1971-) and Ireland (1973-2010, 2015-). As our transfer data begins only in 1981, France does not contribute to identification, and for Ireland identification comes from the box removal rather than introduction. The recently re-introduced patent box in Ireland is outside our sample years.

[19] Two of the tax haven jurisdictions (Jersey and Aruba) have no patents to transfer, so the total number of observations is actually 49*50*15 = 36,750. In addition, France has a patent box during the entire estimation period, which means it will not contribute to identification of the patent box impact in the presence of the country dummy.

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]

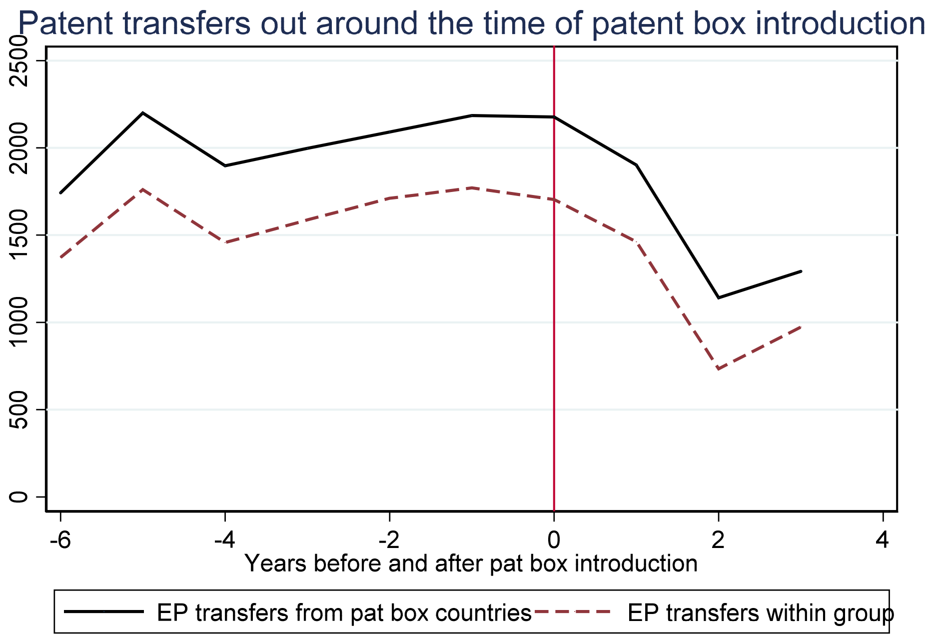
Figure 3 shows that after the introduction of the patent box, patent transfers out of the country with the box decline significantly, from a total of 2000 to 1000 over two years. This suggests at least some success, if the goal was to keep intangible income within the country. However, both Figures 2 and 3 suffer somewhat from truncation due to the relatively recent date of introduction of some of the patent boxes (notably that in the UK). In what follows, we estimate models for patent transfer controlling for differences across countries and time.

Figure 2



[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.

Figure 3



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 9.0 (Feenstra et al. 2015), while the R&D figures come from 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, so we focus here on the results that are based on the 37 country sample, which includes all 13 countries that have introduced a patent box by 2014.[21] These results are shown in Tables 1 and 2. Results for the 51 country sample are shown in Appendix Tables B3 and B4.

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

We parametrize the tax rates 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 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 a dummy 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.[22] 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. 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, although the standard errors are quite large.[23]

Columns 1 and 2 in Table 1 show that the patent box has an insignificant impact on patent transfer to the country, whereas with the patent box has a strongly negative impact on transfer from the country. 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. The coefficient on the seller's patent box dummy implies a 28 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 -1.52 implies an average impact that is almost the same, 27 per cent.

As Figure 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 2, this idea is explored by including dummies for the patent box only in years 0 through 3 following the patent box introduction. The results show that there may be a transitory impact of the patent box on transfers to a country which is strongest in

[22] 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.

[23] 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.

year 2. That is, it takes some time after the patent box introduction for transfers to that country to respond. However the sum of the 4 coefficients is insignificant, equal to 0.40 with a standard error of 0.60, once again too large to draw strong conclusions. Our conclusion is that introducing a patent box may encourage some patent transfer into the country, and also discourages patent transfer out of the country. We also note that the encouragement effect could be larger but it is less well-determined than the discouragement effect. 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 results are quite similar, with a hint that the impact on transfers out is slightly higher, whereas the impact on patent retention is slightly weaker. However, it is quite clear that the regressions are almost at the limit of what can be identified from these data.

Table 1

Inter-country patent transfer flows

Dependent variable: Number of patents transferred from seller country to buyer country during the year

Variable	*All* *(1)*	*All* *(2)*	*All* *(3)*	*Within group* *(4)*	*All* *(5)*	*All* *(6)*	*All* *(7)*	*Within group* *(8)*
Buyer corporate tax rate	0.64	0.81	1.11	0.36	-1.19	-0.99	-0.67	-1.21
	(1.29)	(1.28)	(1.35)	(1.88)	(1.30)	(1.28)	(1.32)	(1.67)
Dummy for buyer patent box	-0.07				-0.17			
in all years after introduction	(0.15)				(0.13)			
Buyer patent tax rate wedge		-0.03				-0.46		
in all years after introduction		(0.76)				(0.67)		
Dummy for buyer patent box			0.00	0.00			-0.07	-0.07
in year of introduction			(0.12)	(0.16)			(0.11)	(0.14)
Dummy for buyer patent box			0.13	0.23			0.05	0.13
in year after introduction			(0.23)	(0.27)			(0.22)	(0.24)
Dummy for buyer patent box			0.40*	0.63**			0.31	0.52**
two years after introduction			(0.24)	(0.26)			(0.23)	(0.25)
Dummy for buyer patent box			-0.11	-0.21			-0.20*	-0.32*
three years after introduction			(0.15)	(0.20)			(0.12)	(0.17)
Seller corporate tax rate	0.97	1.11	1.40	1.64	0.41	0.61	0.75	0.69
	(1.06)	(1.03)	(1.00)	(1.30)	(1.39)	(1.41)	(1.41)	(1.92)
Dummy for seller patent box	-0.33**				-0.32**			
in all years after introduction	(0.13)				(0.13)			
Seller patent tax rate wedge		-1.52**				-1.36**		
in all years after introduction		(0.63)				(0.67)		
Dummy for seller patent box			0.01	0.17			0.00	0.17
in year of introduction			(0.23)	(0.28)			(0.24)	(0.29)
Dummy for seller patent box			-0.32*	-0.24			-0.34*	-0.24
in year after introduction			(0.19)	(0.22)			(0.19)	(0.19)
Dummy for seller patent box			-0.23*	-0.19			-0.22	-0.16
two years after introduction			(0.13)	(0.22)			(0.18)	(0.28)
Dummy for seller patent box			-0.21	-0.16			-0.20	-0.16
three years after introduction			(0.14)	(0.17)			(0.15)	(0.16)
Chi-squared	4157.9	4173.6	4243.1	3221.0	4309.3	4339.4	4370.2	3286.4
Chi-sq degrees of freedom	92	92	98	98	100	100	106	106

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.

19,980 observations on 1,332 country pairs, 2000-2014

Coefficient significance is denoted by * p<0.1, ** p<0.05, *** p<0.01.

All regressions include complete sets of dummies for the 37 buyer and seller countries and years.

Regressions in columns5-8 also include the buyer and seller aggregate patent applications, population, GDP per capita, and R&D intensity, all in logs.

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 pursue this approach in Table 2. Denoting the statutory corporate tax rate as τ and the tax rate on patent income as ρ, we define the following variables:

$$\begin{aligned} difftax &= \tau_S - \tau_B \\ diffbox &= (\tau_B - \rho_B) - (\tau_S - \rho_S) = (\rho_S - \rho_B) - (\tau_S - \tau_B) \end{aligned} \qquad (7)$$

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).

Table 2 shows the results of estimation with these variables, and additional results are shown in Appendix Table B5. 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 (shown in Table B3); 2) whether acquired patents are eligible (shown in Table B3); 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 substantially reduces transfers, while countries without that requirement see an increase in transfers from the patent box. 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 percent increase in the tax advantage from a patent box is associated with an increase of about 14 percent (standard error 6 percent) if existing and/or acquired patents are included and minus 6 percent (standard error 10 percent) if they are excluded. This result is consistent with the profit-shifting results of Koethenbuerger et al. (2016).

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 11 per cent, so it is well within our data. Again, we caution that the confidence interval for this point is quite broad, given the standard errors.

Columns 4 and 8 in Table 2 show the results for within-group transfers, as in Table 1. They are quite similar to those for all the international transfers, with the exception of the CFC rules, which have a somewhat stronger impact when interacted with the patent box differential and a weaker impact interacted with the overall corporate tax differential.

Table 2

Inter-country patent transfer flows - exploring tax variables

Dependent variable: Number of patents transferred from seller country to buyer country during the year

Variable	*All* *(1)*	*All* *(2)*	*All* *(3)*	*Within group* *(4)*	*All* *(5)*	*All* *(6)*	*All* *(7)*	*Within group* *(8)*
Difference:	0.18	0.35	-0.31	0.28	0.80	0.79	0.68	0.88
seller corp tax-buyer corp tax	(0.88)	(0.90)	(0.95)	(1.24)	(0.98)	(0.97)	(0.98)	(1.28)
Difference:	0.60	1.36**	0.34	0.40	0.28	0.72	0.03	0.09
buyer-seller patent tax wedge	(0.49)	(0.63)	(0.56)	(0.74)	(0.50)	(0.62)	(0.57)	(0.73)
D (dev condition on use)*buyer-		-1.95*				-1.04		
seller patent tax wedge		(1.03)				(0.94)		
D (CFC rules apply to buyer)			-0.37**	-0.22			-0.37**	-0.24
			(0.17)	(0.27)			(0.15)	(0.22)
D (CFC) * seller-buyer corp			3.32***	1.21			2.34*	0.65
tax difference			(1.13)	(1.77)			(1.36)	(1.67)
D (CFC) * buyer-seller patent			1.27	2.22*			1.37	2.26*
box difference			(1.04)	(1.26)			(1.02)	(1.24)
Chi-squared	4,036.6	4,052.4	4,158.6	3,056.8	4,271.7	4,295.0	4,405.3	3,538.3
Degrees of freedom	90	91	93	93	98	99	101	101

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.

19,980 observations on 1,332 country pairs, 2000-2014

Coefficient significance is denoted by * p<0.1, ** p<0.05, *** p<0.01.

All regressions include complete sets of dummies for the 37 buyer and seller countries and years.

Regressions in columns 5-8 also include the buyer and seller aggregate patent applications, population, GDP per capita, and R&D intensity, all in logs.

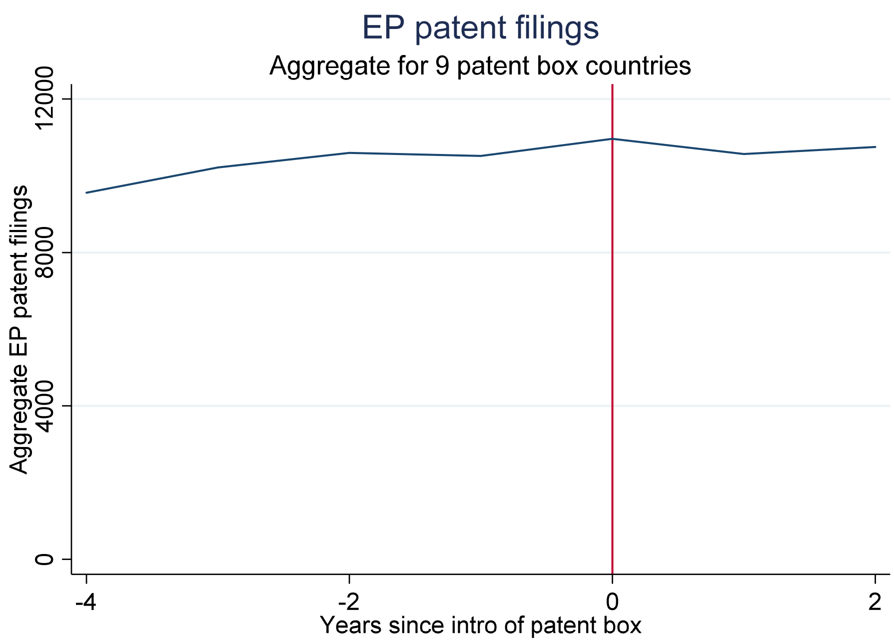
These results lead us to two conclusions. Overall, the presence of a patent box may induce some transfers to the jurisdiction, albeit with a bit of lag. However, the most significant impact of a patent box is to prevent patents from being transferred, as intended by the tax authorities. The results also 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. Along with CFC rules, 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.

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 resident 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.

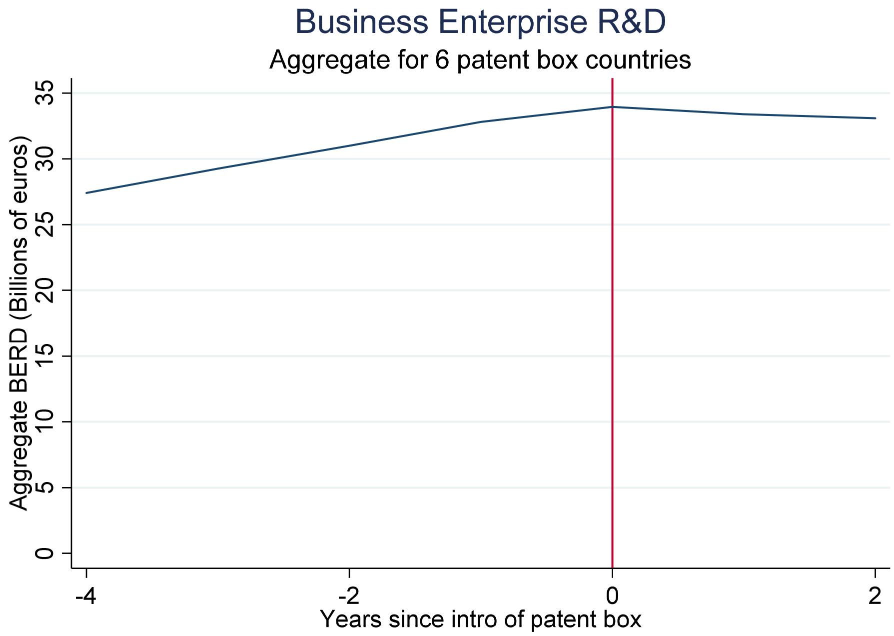
Because of patent data truncation due to lags in PATSTAT (April 2017 edition), the filings in 2015 and 2016 are incomplete. This means that the window we can examine ends in 2014 which excludes several countries from the analysis.[24] In addition, in the case of France, there is no pre-patent box data. In Figures 4 and 5 we show the simple trends around accession time for all the countries in our dataset that have introduced a patent box and for which we have data before and after its introduction. In the case of EP filings these countries are Belgium, Cyprus, Hungary, Liechtenstein, Luxembourg, Malta, the Netherlands, Spain, and Switzerland. 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.

Figure 4



[24] The patent boxes in Portugal and the UK are too new, and for France and Ireland we have no data prior to the box introduction.

Figure 5



The two graphs are quite similar: both show a slow increase until the date of the patent box introduction and then the curve is either flat or declines slightly. Note, however, that the years of patent box introduction 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 some simple aggregate patent regressions for 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, and a set of country and year dummies. In the case of the patent filings regression, we also include the R&D-GDP ratio of the country. The method of estimation for both sets of regressions is ordinary least squares, because most country-year cells have a large number of counts and there are no zeroes.

The estimation results are shown in Tables 3 and 4. 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 negative and either insignificant or barely significant. 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. Nothing changes the basic result, however. In both regressions, the two patent box variables are insignificant or slightly significant but with the wrong sign: if anything, the presence of a patent box *reduces* patentable invention in the country. Both inventor filings and R&D depend positively on GDP per capita, and inventor filings also on R&D intensity.

As mentioned earlier, Alstadsaeter et al. (2015) 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 in columns 4 to 6 of Table 3, which add the dummies for the inclusion of existing patents, acquired patents, and requirement for separate development. None of these enter significantly. The regression is also at the edge of identifiability, because of the relatively few patent box observations, especially when we separate them into those with development restrictions. So we conclude that our results are inconsistent with those of Alstadsaeter et al. (2015), although with the caveat that standard errors are large. Another source of difference is that our estimates are based on country aggregates and those of Alstadsaeter et al. on large R&D-doing firms only, most of which are multi-nationals.

Table 3

Inventor filings by country

Dep. Var. = Log EP patent filings from inventors in the country

	(1)	(2)	(3)	(4)	(5)	(6)
D (patent box)	-0.21*	-0.13*				
in all years after introduction	(0.10)	(0.06)				
Patent tax rate wedge			-0.49*	-0.39	-0.05	-0.65*
in all years after introduction			(0.24)	(0.58)	(0.46)	(0.29)
D (including existing patents)				-0.13		
* patent tax wedge				(0.62)		
D (including acquired patents)					-0.76	
* patent tax wedge					(0.52)	
D (development restriction)						0.32
* patent tax wedge						(0.52)
Corporate tax rate		-1.45	-1.43	-1.42	-1.34	-1.38
		(1.12)	(1.14)	(1.14)	(1.14)	(1.16)
Log population		-0.97	-1.00	-1.01	-1.01	-0.95
		(1.19)	(1.21)	(1.23)	(1.20)	(1.23)
Log GDP per capita		1.55***	1.51***	1.51***	1.53***	1.52***
		(0.34)	(0.35)	(0.35)	(0.35)	(0.35)
Log R&D expenditure over GDP		0.70***	0.72***	0.72***	0.72***	0.72***
		(0.19)	(0.19)	(0.19)	(0.19)	(0.19)
Number of coefficients	53	57	57	58	58	58
R-squared	0.98	0.99	0.99	0.99	0.99	0.99
Standard error	0.31	0.25	0.25	0.25	0.25	0.25
Log-likelihood	-112.7	18.2	16.3	16.4	18.1	16.6

555 observations on 37 countries for the years 2000-2014.

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 least squares with robust standard errors, clustered by country

Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Table 4

Country-level Business R&D spending

Dep. Var. = Log BERD (Business enterprise R&D)

Variable	*(1)*	*(2)*	*(3)*	*(4)*
Lagged log BERD				0.78***
				(0.03)
Dummy for patent box	-0.08			
in all years after introduction	(0.04)			
Dummy for patent box		0.00		
in year of introduction		(0.03)		
Dummy for patent box		-0.04		
in year after introduction		(0.04)		
Dummy for patent box		-0.05		
two years after introduction		(0.05)		
Dummy for patent box		-0.03		
three years after introduction		(0.04)		
Patent tax rate wedge			-0.41	-0.05
in all years after introduction			(0.22)	(0.09)
Corporate tax rate	-0.06	-0.09	-0.05	-0.23
	(0.46)	(0.46)	(0.46)	(0.14)
Log population	-0.08	-0.06	-0.07	-0.11
	(0.52)	(0.57)	(0.52)	(0.13)
Log GDP per capita	1.60***	1.60***	1.59***	0.46***
	(0.21)	(0.21)	(0.21)	(0.07)
Observations	503	503	503	469
R-squared	0.996	0.996	0.996	0.999
Standard error	0.113	0.114	0.113	0.058

32 countries 2000-2014. All estimates include country and year dummies.

Method of estimation is least squares with robust standard errors, clustered by country.

Significance levels: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Our conclusion from this investigation of the impact of introducing a patent box on aggregate innovative activity in a country is that we cannot see any impact, at least at the macroeconomic level.

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 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 2.5 million EP patents filed between 1991 and 2014; of these patents 4.2 percent were subject to an ownership transfer across countries between 2000 and 2014. [25] We focus on the first time that the patent is transferred, and drop the few cases where there is more than one transfer. Figure 5 shows the share of transfers as a function of the filing date of the patent, together with the number of EP patents transferred by transfer year. In the subsequent analysis, we exclude transfers to and from tax havens. This restriction reduces the number of transfers from 100,936 to 91,351.

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:

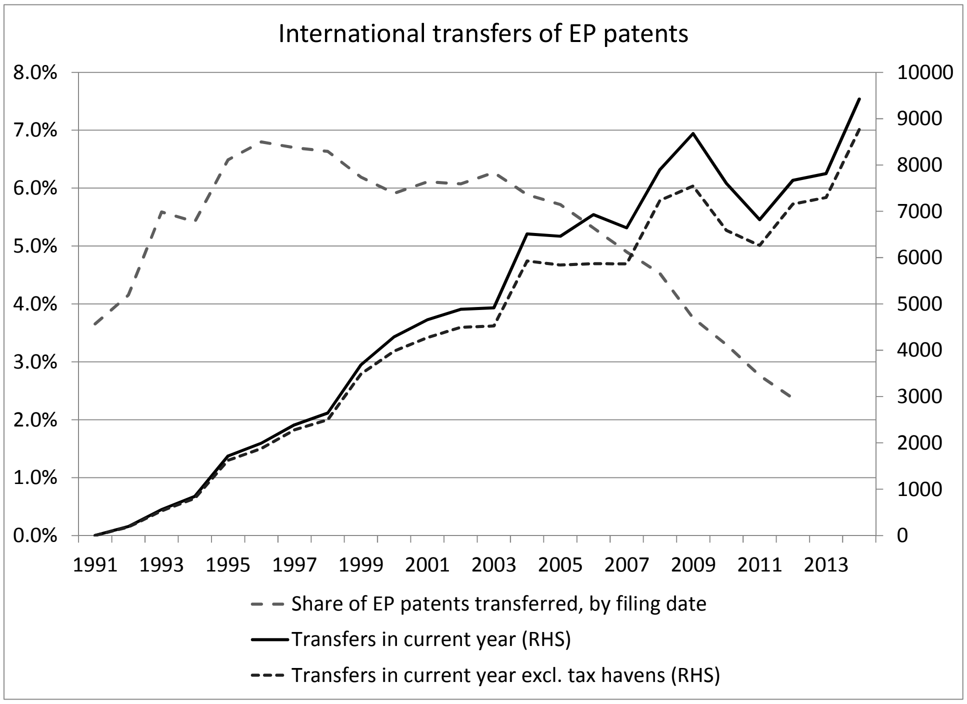
$$\beta_0 = \hat{\beta}_0 - \log\left[\left(\frac{1-\psi}{\psi}\right)\left(\frac{\overline{y}}{1-\overline{y}}\right)\right] \tag{7}$$

where $\hat{\beta}_0$ is the estimated intercept, ψ is the population share of transferred patents, and $\overline{y}$ is the share of the transferred patents in the sample. For our 10 per cent sample, this correction factor is equal to 2.3.[26] Note that for rare events, the correction factor is approximately equal to the log of the oversampling probability ($\overline{y}$ / ψ).

[25] Of course, not all patent applications in the recent years that will eventually be granted have been granted by April 2017, the date of our PATSTAT data.

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

Figure 6



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.
- 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 removing the dummy variable effects 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 Appendix Table C1. 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). Correlation matrices for the variables are shown in Appendix Table C2, 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 5 shows the result of estimating a logit model for the probability of international transfer using equation (6). 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 0.804. None of the predictors of transfer cost matter. However, the tax rate in the selling country has a strong positive impact on the probability of a transfer, in addition to the impact from the interactions with patent value. We display the distribution of the tax rate effect with respect to patent value in Figure 7a below.

Table 5

Logit model of the probability of a transfer

Variable	*Mean*	*(1)*	*(2)*	*Marginals for (2)*
Selling country tax rate *	-0.00002	-0.265	-0.323*	-0.0100*
patent value index		(0.196)	(0.195)	(0.0060)
Patent value index	0.00	0.341***	0.359***	0.0111***
		(0.053)	(0.054)	(0.0170)
Selling country tax rate	0.323		1.137**	0.0352**
			(0.469)	(0.0146)
Log (cumulative patents)	5.25	0.023	0.023	0.0006
for patent owner		(0.031)	(0.031)	(0.0010)
Patent owner a multinational	0.614	0.118	0.118	0.0050
research firm		(0.092)	(0.092)	(0.0028)
Patent owner a corporation,	0.283	-0.034	-0.033	-0.0008
not multinational		(0.052)	(0.052)	(0.0016)
Log likelihood		-381,438.8	-381,318.6	
Chi-squared		1,910.3	1,910.4	
Degrees of freedom		88	89	
R-squared		0.052	0.053	

2,800,073 patent-year observations; 91,351 transfers

Heteroskedastic standard errors clustered on 72,998 patent owners.

All equations include seller country, year, and tech dummies.

Figure 7a 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 95 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 0.025 to 0.05 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 0.007 = 0.2*0.035, which corresponds to an increase of the average transfer probability for our over-sampled data equal to 0.7%. Over the complete population of EP patents, the increase would be 0.07% on an average transfer probability of 0.34%, a semi-elasticity of about 0.2. 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.

Figure 7a: Marginal tax rate effect

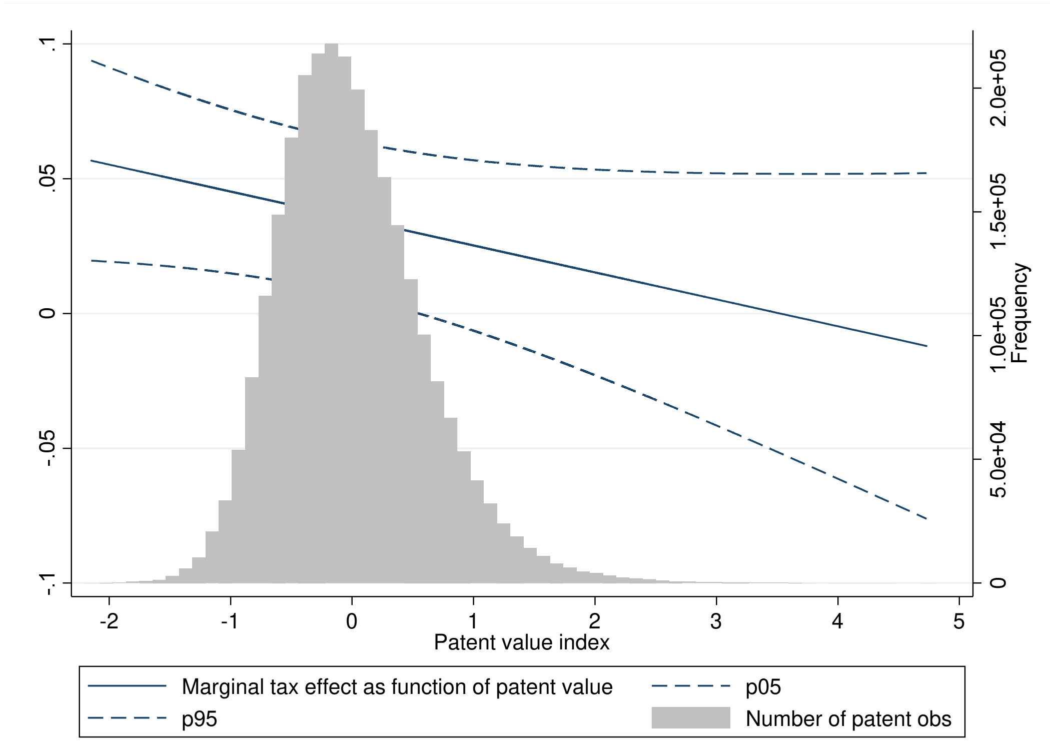


Figure 7b shows a similar plot, this time of the marginal effect of patent value as a function of the statutory tax rate on patent income. The histogram of the tax data makes it clear that the observations are concentrated in a few cells, which are however widely enough spread to yield identification. Over the populated tax rate region of 0.2 to 0.4, the marginal effect of value ranges from 0.009 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 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.

Figure 7b: Marginal patent value effect

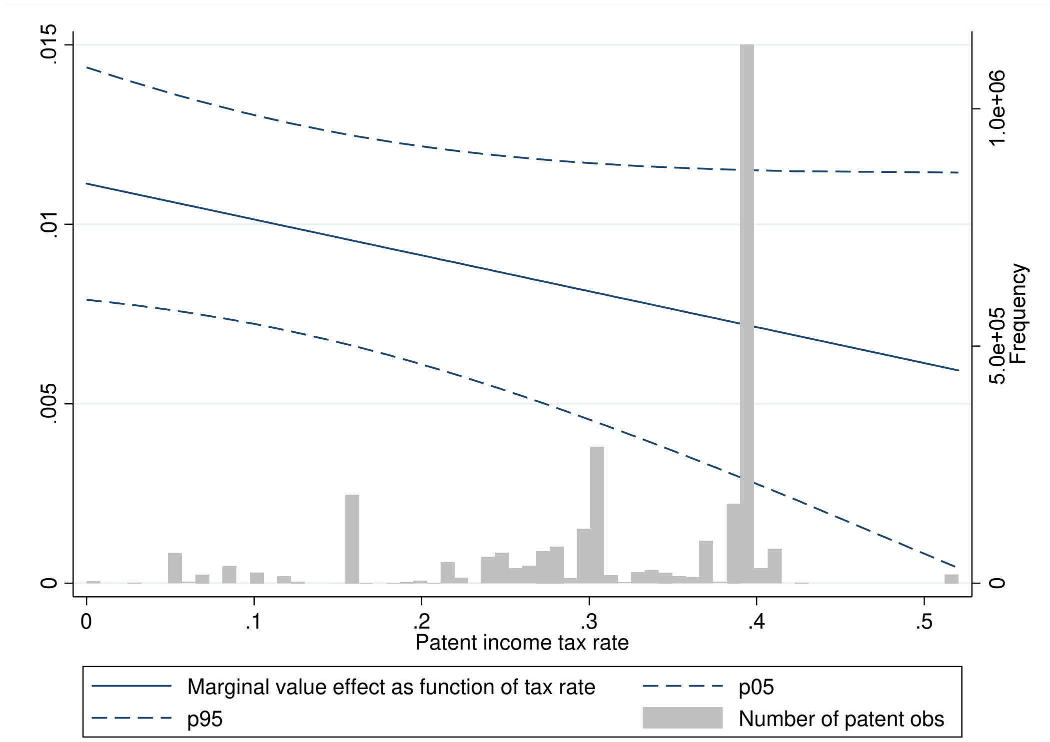


Table 6 explores the variation across the different types of transfers: whether they are potentially tax-motivated or not, whether they are within a corporate group or arm's length. The first two columns report the results of multinomial logit estimation with three possible choices for each patent: no 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.

Table 6

Multinomial Logit model of the probability of a transfer

Dependent vaiable	*Transfer to pat box/no pat box country*		*Arms' length vs within group transfer*		*Type of first International transfer of patent (1-4)*			
Variable	*Patent box country*	*Country without patent box*	*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	20,265	71,352	41,688	49,929	33,759	37,593	7,929	12,336
Selling country tax rate *	-0.211	-0.468**	-0.531***	-0.312	-0.559**	-0.385	-0.345	-0.088
patent value index	(0.333)	(0.208)	(0.206)	(0.301)	(0.233)	(0.319)	(0.337)	(0.500)
Patent value index	0.300***	0.425***	0.425***	0.387***	0.450***	0.415***	0.304***	0.296*
	(0.099)	(0.056)	(0.057)	(0.081)	(0.066)	(0.081)	(0.096)	(0.153)
Selling country tax rate	0.333	0.823	0.666	1.051**	0.673	0.834	-0.615	0.918
	(0.917)	(0.503)	(0.637)	(0.512)	(0.719)	(0.618)	(1.203)	(1.327)
Log (cumulative patents)	0.040	0.011	-0.098***	0.110**	-0.113***	0.118***	-0.035	0.083
for patent owner	(0.081)	(0.026)	(0.026)	(0.047)	(0.020)	(0.041)	(0.105)	(0.108)
Patent owner a multi-	0.657***	0.033	0.021	0.341**	0.019	0.103	0.058	1.193***
national research firm	(0.186)	(0.093)	(0.082)	(0.156)	(0.080)	(0.166)	(0.227)	(0.261)
Patent owner a corp,	0.232**	-0.08	0.012	-0.115	-0.016	-0.196*	0.169*	0.272*
not multinational	(0.097)	(0.056)	(0.038)	(0.105)	(0.042)	(0.115)	(0.101)	(0.157)
Log likelihood	-419,587.4		-433,406.1		-472,233.9			
Chi-squared	8,529.6		3,629.5		18,113.7			
Degrees of freedom	176		176		352			
R-squared	0.066		0.066		0.078			

Sample is all granted EP patents with filing date between 1990 and 2014 that are transferred between 2000 and 2014 and a 10 per cent sample of patents not transferred.

2,727,759 patent-year observations; 91,617 transfers

Heteroskedastic standard errors clustered on 74,643 patent owners.

A complete set of country, year, and technology dummies are included in the estimation.

All right hand side variables are in log form, with the exception of the multinational and corporation dummies.

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.

Our first not very surprising 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.

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 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, although we did find evidence that more valuable patents are those transferred and that multinationals tended 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 it suggests that the primary stated goal of introducing a patent box 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 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 13 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. It is challenging then to distinguish two countries, one of which has an existing patents exclusion, and the other which does not. That is probably why there is so much variation in the results of the prior literature.

In spite of this extensive caveat, our results do lead to one conclusion 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. 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. [1] 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.

[1] 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).

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Appendix A: Literature review tables

Table A1: Literature on corporate taxation and patent location

Paper	*Data*	*Level*	*#Obs*	*Years*	*Obs/year*	*Dependent variable(s)*	*Independent variables*	*Method*
Dischinger & Riedel (2011)	European MNEs with intang.	group member	6,223	1995-2005	566	intangible assets (D and log ratio to sales)	corp tax rate, tax diff btwn sub and parent, log sales, pop, R&D, GDP, growth in GDP per cap, corruption index, unemployment	logit FE; OLS FE; IV and GMM on first differences
Ernst & Spengel (2011)	EP apps; AMADEUS match	firm	80,484	1998-2007	8,048	EP patent filings	corp tax, EATR, B-index, GDP per cap, pubRD, Tertiary ed, GP index, Openness, Hi tech exports, Emply, assets	logit FE ; neg bin FE
Karkinsky & Riedel (2012)	EP apps; AMADEUS match; 18 EU countries	firm affiliate	64,061	1995-2003	7,118	EP patent filings	corp tax rate, tax diff btwn sub and parent, royalty rate, CFC rules, R&D, GDP,corruption index, IP strength	OLS FE
Griffith, Miller & O'Connell (2014)	EP apps; AMADEUS match; 18 EU countries	patent	379,849	1985-2005	18,088	filing country choice	GDP, RD/GDP, inventor presence, tax rate, patent box rate, IP strength, industry-location-firm size dummies	random coefficient mixed logit
Boehm, Karkinsky, Knoll, & Riedel (2015)	EP apps - corporate; match to AMADEUS	patent	530,805	1978-2006	18,304	applicant/inventor divergence at pat level	corp tax rate, pat quality, rule of law, corruption, GDP and GDP per cap; CFC; year country industry FE	probit FE
Dinkel & Schanz (2015)	worldwide patstat - MNEs matched to AMADEUS	group-country	62,717	2005-2012	7,840	D(pat abroad) D (country) N pats in country	Tax attractiveness (corp tax rate, royalty rate, witholding roy rate, all scaled); D(RD tax), D(transfer price), CFC, sales, GDP, RD per cap, distance, app-reg, emp-inventors	probit FE (ind & year) neg bin FE
Dudar, Spengel & Voget (2015)	royalty payments	country pairs	~20,000	1990-2012	~900 ~60 countries	royalty streams	royalty tax, tax difference, corporate tax, IP box dummies, CFC rules, TP rules, R&D, GDP, POP in recipient country, trade between	Poisson PML

Table A2: Literature on patent boxes

Paper	*data*	*level*	*#obs*	*years*	*obs/year*	*dependent variable(s)*	*independent variables*	*method*	*pat box result*
Alstadsaeter, Barrios, Nicodeme, Skonieczna and Vezzani (2018)	EP apps; ORBIS data for EU scoreboard firms in 33 countries	firm-technology-industry	~160,000	2000-2011	4444?	EP patent filings	GDP, inventor presence, tax rate, patent box rate, triadic pats, IP strength, country dummies	random effects neg binomial; R coeff mixed logit	filings wrt box: -5.0 (semi-elasticity)
Bösenberg & Egger (2017)	EP apps; 106 countries	country-technology	639; 9425	1996-2012	49; 2600	filings and transfers	B-index, EATR, pat box dummy; researchers per cap, GDP, avg pat characteristics	Poisson FE (year)	seller: 0.43*** buyer: 0.23***
Bradley, Duchy, and Robinson (2015)	worldwide patstat	countries	1,487	1990-2012	~70 countries	inventor patent apps; owner patent apps; pats with inv country not owner country, etc	Patent box, pat box rate, other tax vars, GDP, population, patent system quality	Panel OLS	domestic inventing increases if rate falls; no impact on mismatch owner-inventor
Dudar, Spengel & Voget (2015)	royalty payments	country pairs	~20,000	1990-2012	~900 ~60 countries	royalty streams	royalty tax, tax difference, corporate tax, IP box dummies, CFC rules, TP rules, R&D, GDP, POP in recipient country, trade between	Poisson PML	Royalties increase if IP box covering acquired and self-generated patents
Koethenbuerger, Liberini & Stimmelmayr (2016)	MNCs from Orbis	subsidiaries	85,944 (30,798 matched)	2007-2013	12,715 (4,498 matched, 2,942 patenters)	stated profit before tax	D(patent box),(new pat entrant), and interactions; assets, leverage	diff-in-diff; ind-year, ctry-year Fes	pat box used for profit shifting
Schwab & Todtenhaupt (2016)	MNCs from Orbis/AMADEUS with sub in patent box country match to PAtSTAT	firm	271,251	2000-2012	20,865	worldwide pat grants	patent box, R&D/GDP, GDP per cap, corp tax, GDP growth R&D user cost. Real interest rate, firm age, assets, work cap, capital intensity	Poisson FE (firm & year)	pat box in other countries has positive spillovers on domestic R&D
Ciaramella (2017)	EP apps	firm	329,398	1997-2015	~16,000	patent transfers during the exam phase at the EPO	pat box, corp tax rate, CFC; log GDP, distance, language, RD/GDP	Neg Bin FE (year)	buyer: 1.2*** seller: insig
Mohnen, Vankan & Verspagen (2017)	Dutch firm data	firm		2007-2013	~15,000	R&D person-hours	use of patent box	diff-in-diff	pat box positive for domestic R&D

Appendix B: Simple statistics and additional estimates for aggregate data

Table B1

Sample countries

Code	*Country*	*R&E tax credit @*	*CFC rules^*	*Years with patent box*	*Gross or net income*	*Includes existing patents*	*Includes acquired patents*	*Develop-ment condition*	*Patents transferred out 2000-2014*	*Patents transferred in 2000-2014*	*Diff-erence*
AT	Austria	x							2521	1135	-1386
AU	Australia	x	x						1202	587	-615
AW*	Aruba									10	10
BB*	Barbados								196	2269	2073
BE	Belgium	x		2007-	gross	yes%	yes%	yes	1140	1639	498
BM*	Bermuda								48	635	587
BS*	Bahamas								29	157	128
CA	Canada	x	x						3918	2172	-1745
CH	Switzerland			2011-	net	yes	yes	no	6353	10521	4168
CL	Chile	x							13	43	30
CW*	Curacao								85	628	542
CY	Cyprus			2012-	net	yes	yes	no	139	197	58
CZ	Czech Republic	x							45	104	60
DE	Germany		x						13804	11633	-2171
DK	Denmark		x						1171	957	-214
EE	Estonia		x						10	20	10
ES	Spain	x	x	2008-	net	yes	no%	yes	468	408	-61
FI	Finland		x						1466	3034	1567
FR	France	x	x	1971-	net	yes	yes#	no	4821	5136	316
GB	UK	x	x	2013-	net	yes	yes%	yes	12825	5792	-7032
GG*	Guernsey								0	93	93
GI*	Gilbraltar								12	86	74
GR	Greece	x							35	51	16
HK*	Hong Kong								21	339	318
HU	Hungary	x	x	2003-	gross	yes	yes	no	94	265	171
IE	Ireland	x		1973-2010		yes	no%	yes	431	1695	1264
IL	Israel		x						930	1075	145
IM*	Isle of Man								23	63	40
IS	Iceland	x	x						27	155	128
IT	Italy	x	x						1920	1281	-639
JE*	Jersey									59	59
JP	Japan	x	x						4626	2817	-1809
KR	South Korea	x	x						686	816	130
KY*	Cayman Islands								98	1587	1489
LI**	Liechtenstein			2011-	net	no	yes	no	283	275	-8
LU	Luxembourg			2008-	net	yes	no	no	500	2386	1886
MC*	Monaco								66	50	-16
MT	Malta			2010-	not deduct.	yes	yes	no	32	95	63
MX	Mexico		x						82	200	118
NL	Netherlands	x		2007-	net	no	yes%	yes	7826	11426	3600
NO	Norway	x	x						466	867	401
NZ	New Zealand		x						182	107	-76
PL	Poland								55	94	39
PT	Portugal	x	x	2014-	gross	no	no%	yes	48	147	99
SE	Sweden	x	x						3153	3948	795
SG*	Singapore								186	1352	1167
SI	Slovenia	x							49	29	-20
SK	Slovakia	x							29	35	6
TR	Turkey	x							15	40	25
US	US	x	x						28878	21081	-7797
VG*	Virgin Islands (British)								87	1501	1414
	Total								**101091**	**101091**	**0**

* denotes countries that are tax havens; most do not have GDP data on PWT either.

if held for at least 2 years. ^ CFC rules in 2014. % if further developed.

** GDP data not available from the Penn World Tables for this country.

@Some kind of R&D tax credit (beyond expensing) available during the period.

Sources: Tax info - Evers et al. (2013), Deloitte (2014), Alstadsæter et al. (2015).

Patent data - authors'computations from Patstat April 2017.

Table B2

Effective average tax rates for countries with a Patent Box

Code	*Country*	*Years with IP box*	*R&E tax credit@*	*Includes existing patents*	*Includes acquired patents*	*Corp tax rate (statutory)*	*IP box rate (statutory)*	*Effective average tax rate ord. income*	*Effective average tax rate IP box*
BE	Belgium	2007-	x	yes%	yes%	34	6.8	21.11	-26.95
CY	Cyprus	2012-		yes	yes	10	2.5	11.69	2.34
FR	France	1971-	x	yes	yes#	34	16	26.56	-6.41
HU	Hungary	2003-	x	yes	yes	20	10	14.25	-2.54
IE	Ireland	1973-2010	x	yes	no%	12.5	0	12.50	0.00
LI**	Liechtenstein	2011-		no	yes	12.5	2.5	6.92	1.39
LU	Luxembourg	2008-		yes	no	29	5.84	21.92	5.47
MT	Malta	2010-		yes	yes	35	0	26.25	0.00
NL	Netherlands	2007-	x	no	yes%	25.5	5	18.75	3.75
PT	Portugal	2014-	x	no	no%	31.5	15	31.50	15.00
ES	Spain	2008-	x	yes	no%	30	12	22.50	-2.95
CH	Switzerland	2011-		yes	yes	21	8.8	9.50	2.74
GB	UK	2013-	x	yes	yes%	22	10	15.75	7.50

if held for at least 2 years.

% if further developed.

** GDP data not available from the Penn World Tables for this country.

@Some kind of R&D tax credit (beyond expensing) available during the period.

Table B3

Inter-country patent transfer flows

Estimates including 14 tax haven countries

Dependent variable: Number of patents transferred from seller country to buyer country during the year

Variable	*All* *(1)*	*All* *(2)*	*All* *(3)*	*Within group* *(4)*
Buyer corporate tax rate	0.54	0.71	0.96	0.17
	(1.26)	(1.25)	(1.32)	(1.81)
Dummy for buyer patent box	-0.05			
in all years after introduction	(0.15)			
Buyer patent tax rate wedge		0.08		
in all years after introduction		(0.75)		
Dummy for buyer patent box			0.00	0.01
in year of introduction			(0.11)	(0.15)
Dummy for buyer patent box			0.15	0.26
in year after introduction			(0.23)	(0.26)
Dummy for buyer patent box			0.38	0.60**
two years after introduction			(0.23)	(0.26)
Dummy for buyer patent box			-0.11	-0.21
three years after introduction			(0.14)	(0.20)
Seller corporate tax rate	0.57	0.70	1.00	1.42
	(1.14)	(1.12)	(1.11)	(1.40)
Dummy for seller patent box	-0.29**			
in all years after introduction	(0.13)			
Seller patent tax rate wedge		-1.40**		
in all years after introduction		(0.65)		
Dummy for seller patent box			0.02	0.17
in year of introduction			(0.21)	(0.25)
Dummy for seller patent box			-0.30*	-0.20
in year after introduction			(0.17)	(0.20)
Dummy for seller patent box			-0.19	-0.22
two years after introduction			(0.13)	(0.20)
Dummy for seller patent box			-0.12	-0.03
three years after introduction			(0.18)	(0.23)
Chi-squared	10166.2	10171.0	9754.7	7866.8
Chi-sq degrees of freedom	119	119	125	125

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.

36,750 observations on 2,450 country pairs, 2000-2014

Coefficient significance is denoted by * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

All regressions include complete sets of dummies for the 37 buyer and seller countries and years.

Table B4

Inter-country patent transfer flows - exploring tax variables

Estimates including 14 tax haven countries
Dependent variable: Number of patents transferred from seller country to buyer country during the year

Variable	*All* *(1)*	*All* *(2)*	*All* *(3)*	*Within group* *(4)*
Difference:	0.03	0.18	-0.34	0.31
seller corp tax-buyer corp tax	(0.85)	(0.87)	(0.94)	(1.23)
Difference:	0.63	1.35**	0.36	0.48
buyer-seller patent tax wedge	(0.49)	(0.61)	(0.55)	(0.73)
D (dev condition on use)*buyer-		-1.91*		
seller patent tax wedge		(1.03)		
D (CFC rules apply to buyer)			-0.23	-0.12
			(0.19)	(0.25)
D (CFC) * seller-buyer corp			2.04	0.29
tax difference			(1.29)	(1.53)
D (CFC) * buyer-seller patent			1.29	2.14*
box difference			(1.02)	(1.23)
Chi-squared	10060.2	10027.8	9661.6	7304.0
Degrees of freedom	117	118	120	120

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.

36,750 observations on 2,450 country pairs, 2000-2014

Coefficient significance is denoted by * p<0.1, ** p<0.05, *** p<0.01.

All regressions include complete sets of dummies for the 51 buyer and seller countries and years.

Table B5

Inter-country patent transfer flows - exploring tax variables

Dependent variable: Number of patents transferred from seller country to buyer country during the year							
						Within	*Within*
	All	*All*	*All*	*All*	*All*	*group*	*group*
Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Difference:	0.18	0.05	0.16	0.35	-0.31	0.70	0.29
seller corp tax-buyer corp tax	(0.88)	(0.87)	(0.88)	(0.90)	(0.95)	(1.12)	(1.24)
Difference:	0.60	0.96*	0.65	1.35**	0.33	1.82**	0.40
buyer-seller patent tax wedge	(0.49)	(0.50)	(0.54)	(0.63)	(0.55)	(0.85)	(0.74)
D (existing patents) * buyer-		-1.40					
seller patent tax wedge		(1.08)					
D (acqired patents) * buyer-			-0.24				
seller patent tax wedge			(1.10)				
D (dev condition on use)*buyer-				-1.95*		-2.29*	
seller patent tax wedge				(1.03)		(1.30)	
D (CFC rules apply to buyer)					-0.37**		-0.22
					(0.17)		(0.27)
D (CFC) * seller-buyer corp					3.31***		1.20
tax difference					(1.13)		(1.77)
D (CFC) * buyer-seller patent					1.27		2.22*
box difference					(1.04)		(1.26)
Chi-squared	4054.3	4131.0	4097.4	4072.5	4175.9	3183.1	3095.2
Degrees of freedom	90	91	91	91	93	91	93

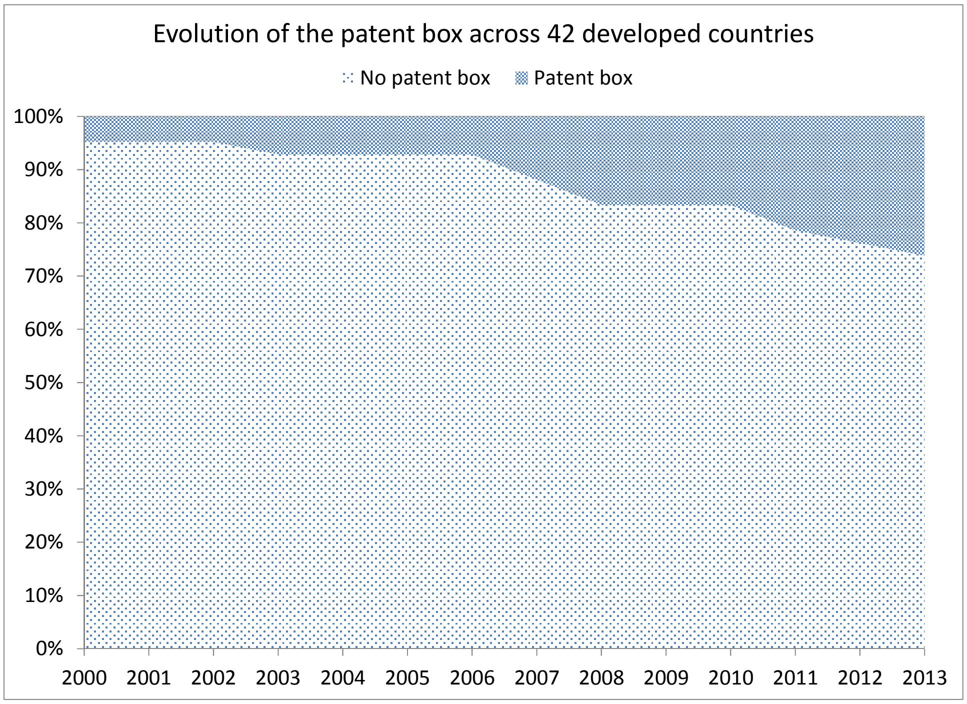
Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.

19,980 observations on 1,332 country pairs, 2000-2014

Coefficient significance is denoted by * p<0.1, ** p<0.05, *** p<0.01.

All regressions include complete sets of dummies for the 37 buyer and seller countries and years.

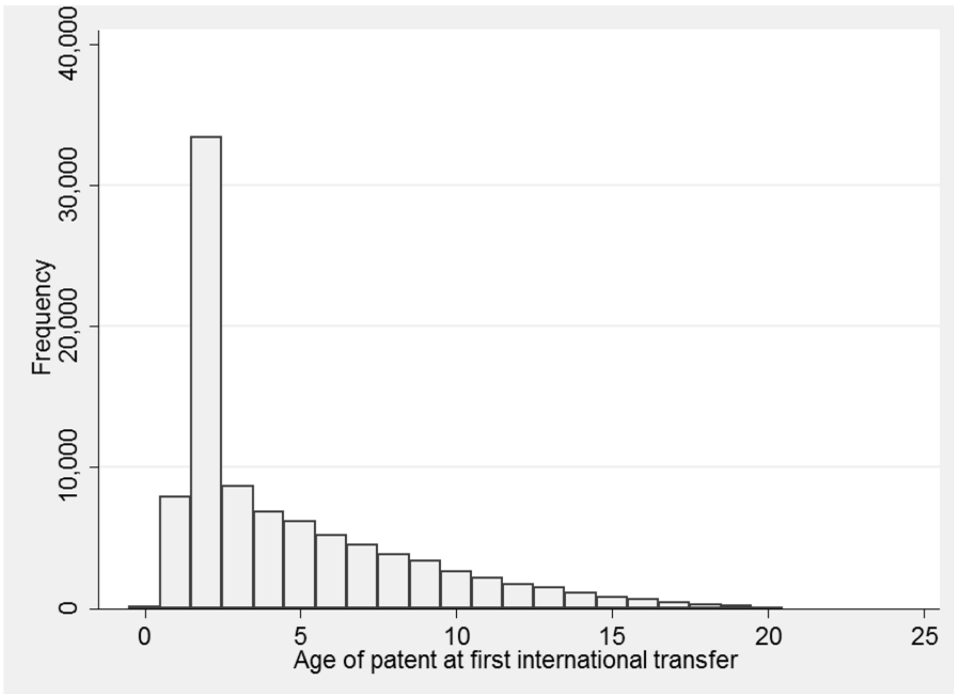
Figure B1


Evolution of the patent box across 42 developed countries
No patent box
Patent box
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

Appendix C: Patent and applicant level data on transfers

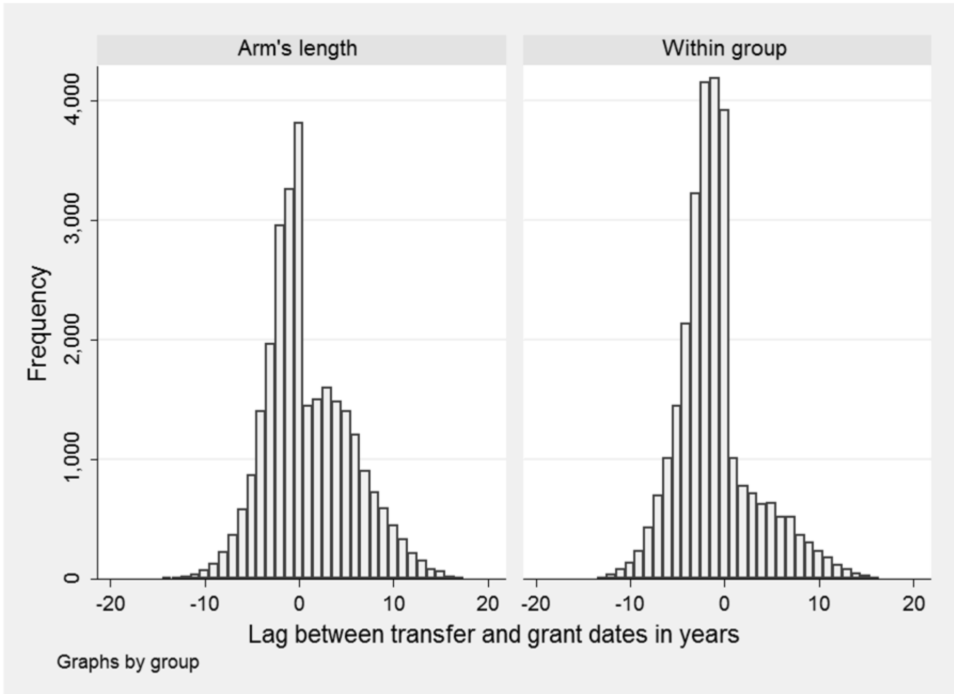
Our analysis sample of (first) international patent transfers consists of 91,617 patents applied for between 1991 and 2014, and transferred between 2000 and 2014.---% of these transfers were to countries with a patent box in effect. Patents are transferred internationally at all ages, but a large number are transferred two years after the year of application, which coincides with the most likely year of grant date (Figure C1).

Figure C1



This is confirmed by Figure C2, which shows the distribution of the age at transfer relative to the grant date for the 61% of the patents that have been granted, separately for arm's length transfers and those within group (i.e., within a multinational). For within group transfers, a large majority take place before the grant (78%). Although the majority of the other transfers also occur before grant (56%), they have a secondary peak two years after grant. In addition, all the transfers for the patents not yet granted take place before grant, perforce. We also examined the distribution of transfer age relative to grant for transfers to countries with and without a patent box at the time of transfer. These look very similar (not shown).

Figure C2



Arm's length
Within group
Frequency
0
1,000
2,000
3,000
4,000
-20
-10
0
10
20
Lag between transfer and grant dates in years
Graphs by group

Table C1

EPO patents applied for 2000-2014: Simple statistics

Variable	*Mean#*	*St.dev.*	*Median*	*IQ range*	*Min*	*Max*
			Internationally transferred patents (N=91,617)			
Family size	8.191	0.573	8	1.83	2	236
Number of claims	14.546	0.551	15	1.82	1	593
5-year forward cites	2.313	0.822	2	4.00	1	142
Number of inventors	3.346	0.438	3	2.50	1	63
Value index	0.189	0.663	0.11	0.86	-1.72	4.25
Value index (dummies removed)%	0.145	0.615	0.08	0.79	-2.13	3.88
Number of applicants	2.016	0.062	2	1.00	2	10
Cumulative applicant patents*	166.3	2.974	158.0	209.00	2	39,584
MNC (multi-country researcher)	0.655	0.475	1	1	0	1
Corporation, not MNC	0.251	0.434	0	1	0	1
Individual	0.077	0.267	0	0	0	1
Government or non-profit	0.017	0.128	0	0	0	1
			Patents that are not internationally transferred (N=237,100)@			
Family size	6.570	0.555	6	1.80	2	428
Number of claims	12.700	0.657	14	1.80	1	396
5-year forward cites	1.934	0.757	2	3.00	1	972
Number of inventors	3.254	0.444	3	2.00	1	55
Value index	-0.061	0.654	-0.14	0.83	-2.03	4.72
Value index (dummies removed)%	-0.044	0.598	-0.11	0.76	-2.18	4.88
Number of applicants	2.023	0.074	2	1.00	2	21
Cumulative applicant patents*	168.5	0.741	199.0	140.54	2	41,459
MNC (multi-country researcher)	0.612	0.487	1	1	0	1
Corporation, not MNC	0.292	0.455	0	1	0	1
Individual	0.050	0.219	0	0	0	1
Government or non-profit	0.045	0.208	0	0	0	1

	Difference in means#			
	Diff	*s.e.*	*T-stat*	*Ranksum test - chisq(1)*
Family size	0.096	0.002	43.4	104.6
Number of claims	0.059	0.002	26.0	45.9
5-year forward cites	0.078	0.003	24.8	58.7
Number of inventors	0.012	0.002	7.1	18.4
Value index	0.250	0.003	97.4	100.2
Value index (dummies removed)%	0.189	0.002	79.7	81.3
Number of applicants	-0.002	0.000	-6.5	-16.9
Cumulative applicant patents	-0.006	0.010	-0.6	-2.2
MNC (multi-country researcher)	0.042	0.002	22.8	27.8
Corporation, not MNC	-0.041	0.002	-24.0	-26.2
Individual	0.027	0.001	27.3	25.4
Government or non-profit	-0.029	0.001	-47.4	-40.4

The geometric mean is shown for all variables except the four sector dummies; the t-test is conducted on the log means for these variables.

* Cumulative patent applications by patent owner in the year 2000 or the year of patent filing, whichever is later.

@ 10 per cent sample of non-transferred patents.

% This index is based on the first four variables with applicant year and country, and technology class means removed.

The ranksum tests whether the distribution of the variable for the transferred patents is to the right of that for non-transferred patents.

Table C2

All EPO patents applied for 2000-2014: 328,717 observations#										
Correlation matrix										
Family size	1.000									
Number of claims	0.092	1.000								
5-year forward cites	0.353	0.188	1.000							
Number of inventors	0.168	0.088	0.171	1.000						
Number of applicants	-0.001	0.003	0.006	0.114	1.000					
Cumulative applicant patents	-0.001	-0.050	0.024	0.097	-0.050	1.000				
MNC (multi-country researcher)	0.058	-0.018	0.053	0.148	-0.103	0.513	1.000			
Corporation, not MNC	-0.042	0.002	-0.039	-0.107	-0.038	-0.423	-0.790	1.000		
Individual	-0.040	0.004	-0.047	-0.158	0.181	-0.205	-0.332	-0.161	1.000	
Government or non-profit	0.003	0.037	0.017	0.073	0.114	-0.051	-0.262	-0.127	-0.053	1.000
Correlation matrix with year, tech, country dummies removed										
Family size	1.000									
Number of claims	0.037	1.000								
5-year forward cites	0.307	0.149	1.000							
Number of inventors	0.112	0.062	0.130	1.000						
Number of applicants	-0.012	0.005	0.004	0.109	1.000					
Cumulative applicant patents	0.020	-0.038	0.018	0.081	-0.039	1.000				
MNC (multi-country researcher)	0.066	-0.020	0.039	0.121	-0.089	0.461	1.000			
Corporation, not MNC	-0.029	0.010	-0.017	-0.071	-0.047	-0.391	-0.780	1.000		
Individual	-0.036	0.007	-0.034	-0.130	0.179	-0.153	-0.286	-0.221	1.000	
Government or non-profit	-0.045	0.015	-0.011	0.036	0.096	-0.022	-0.257	-0.138	-0.060	1.000

All variables are in logs except the four sector dummies

Sample is based on a 10 per cent sample of the non-transferred patents and all of the transferred patents.

Table C3

Variable means by type of transfer#

	no transfer@	*non-group, non-tax*	*group, non-tax*	*non-group, tax-related*	*group, tax-related*
Observations	237,100	33,759	37,593	7,929	12,336
Family size	6.57	8.09	8.43	8.01	8.04
Number of claims	12.70	14.64	14.77	14.06	13.90
5-year forward cites	1.93	2.27	2.37	2.26	2.28
Value index	-0.06	0.15	0.24	0.16	0.17
Value index (dummies removed)%	-0.04	0.13	0.17	0.09	0.14
Number of inventors	3.25	3.19	3.48	3.36	3.40
Number of applicants	2.02	2.01	2.01	2.01	2.03
Cumulative applicant patents*	11.2	6.8	18.0	10.6	17.1
MNC (multi-country researcher)	0.61	0.52	0.74	0.58	0.82
Corporation, not MNC	0.29	0.36	0.17	0.33	0.14
Individual	0.05	0.09	0.08	0.08	0.03
Government or non-profit	0.05	0.03	0.01	0.02	0.01

The geometric mean is shown for all variables except the four sector dummies

* Cumulative patent applications by patent owner in the year 2000 or the year of application, whichever is later.

@ 10 per cent sample of non-transferred patents.

% This index is based on the first four variables with applicant year and country, and technology class means removed.

Appendix D: Modelling international patent transfer

Overview

Estimation of a model of international patent transfer as a function of the characteristics of the patent (X), the current country (Z), and the potential countries to which the patent might be transferred (W) proved difficult, probably because we have limited variability in the tax variables, especially those for the patent box. The body of the paper presents simple logit and multinomial logit estimates, with standard errors clustered at patent owner level. This approach allows correlation across time and patents owned by a single entity, but it does not identify effects associated with the characteristics W of the countries to which a patent might be transferred, with the exception of identifying those with a patent box.

We attempted to estimate a number of other econometric models as described in the following:

1. A hazard rate model of transfer as a function of the patent characteristics X, seller characteristics Z, and possibly interactions of X with W. This kind of model allows for the absorbing nature of the first transfer. In principle, transfer to a patent box country versus a non-patent box country could be explored using a competing risks hazard model, but this proved impossible due to lack of convergence.
2. A multinomial probit model similar to the multinomial logit models in the text, which would allow for correlation among the alternatives.
3. A multinomial logit model of choice with random coefficients on the case variables.[2]

With a suitable assumption on the distribution of ε, the model in the text will generate a hazard function for the transfer from country s to country b. Alternatively, given its equivalence to a random utility model, it will generate a multinomial logit or nested logit model under the extreme value assumption. Transfer is more likely under the following conditions:

1. The difference between the tax rates applying to patent income in the two countries is larger. 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 tax-relevant 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.

All of these are measurable for the patents that are actually transferred.

However, a major problem for hazard rate or simple logit estimation is that the potential tax rates in the buyer country are unobserved if we do not observe a transfer. To ameliorate rather than actually solve this problem, we computed average tax rates of patent income in each year across the countries, excluding the country in which the patent is resident. The difference in tax rates in the equation above was then the difference between the tax rate faced by patent income in the potential selling country less the average tax rates across the potential buying countries. In the case

[2] Fixed coefficients would result in as many coefficients as choices for each case variable, and is unlikely to be identified.

of an actual transfer, we used the observed tax rate in the buying country instead, so as not to lose too much precision in our estimates. This estimation strategy was unsuccessful, as one might have expected.

If we believe that the country of patent ownership affects the profits available from a patent in ways other than the tax rate faced by those profits, we can complicate the model as follows:

$$\pi_{its} = (1-\tau_{ts})(X_i\beta + Z_s\delta + \varepsilon_{it})$$

From this equation it is worth observing that case variables (those that are associated with the patent and its original location/owner) are those indexed by *i*, *j*, and *s*. Such variables are identified in the simple logit or hazard rate models. Alternative-specific variables are those indexed by *b*, possibly in product with case variables. These are not identified unless multinomial logit (possibly nested) or multinomial probit with many alternatives are used.

The following case variables are suggested by the model:

- Patent quality measures, interacted with the patent tax rate of the seller.
- Characteristics of the selling country, interacted with the patent tax rate of the seller.
- Characteristics of the patent owner.

It is possible that one also might want to add the non-interacted variables, and the interaction of taxes with the patent owner characteristics. It is also possible to include dummies for the selling country, and for the transfer years. For the tax rate, the sensible variable to use is the nominal tax rate faced by patent income (which may be nothing like the actual tax rate faced by an individual entity, but we do not have the information to compute that). The tax rate we use is the corporate tax rate in the case of no patent box, or the patent box rate.

The alternative-specific variables are the following:

- Patent quality measures, interacted with the patent tax rate of the buyer.
- Characteristics of the buying country, interacted with the patent tax rate of the buyer.

Again, it might be useful to add the non-interacted variables. And note that these variables are not available in the case of no transfer. It is also possible to include dummies for the buying country, although identification may be difficult.

In what follows we present a set of hazard estimates corresponding to the logit estimates in the body of the paper.[3] For simplicity, we measure patent value as the first principal component of the set of 4 value indicator variables (forward cites, claims, family size, and number of inventors). All these variables have positive loadings on the first component, and we know that they measure slightly different things, so it makes sense to use some kind of common aggregate.

[3] The multinomial probit models and random coefficient logit models did not converge, which is most likely due to insufficient variation in the data on patent boxes.

Hazard rate estimation

The natural way to model the decision to transfer a patent internationally is with a survival or hazard rate model.[4] Because the regressors we will use in our initial analysis are constant over time, the results from a hazard rate model will be similar to those from a logit probability model with standard errors clustered across time, as was presented in the text. In the case of the Weibull model with covariates that do not vary over time, the estimates will be identical (Lancaster 1990, p. 104). We present estimates based on a proportional hazard model here; the equivalent logit estimates from the body of the paper are shown for comparison.

We model the decision to transfer a patent using proportional hazard rate models, where the hazard of patent *i*'s transfer at time *t* is given by the following:

$$\begin{aligned} h(X_i, t) &\equiv \Pr(i \text{ transferred at } t \mid i \text{ not yet transferred}, X_i) \\ &= h(t)\exp(X_i\beta) \end{aligned},$$

where i denotes a patent and t denotes the time since the patent's application date. $h(t)$ is the baseline hazard, which is either a non-parametric or a parametric function of time since entry into the sample. The impact of any characteristic x on the hazard can be computed as follows:

$$\frac{\partial h\left(X_i, t\right)}{\partial x_i} = h\left(t\right)\exp\left(X_i\beta\right)\beta \quad \text{or} \quad \frac{\partial h\left(X_i, t\right)}{\partial x_i}\frac{1}{h\left(X_i, t\right)} = \beta$$

Thus if x is measured in logs, β measures the elasticity of the hazard rate with respect to x. Note that this quantity does not depend on the baseline hazard $h(t)$, but is the same for any t.

Figure D1 shows the Kaplan-Meier estimate of the cumulative hazard of an international transfer as a function of patent age. The curve is smooth and shows the large jump between ages 1 and 2 that we also observed in Figure C1. We estimated a number of proportional hazard models, all of which were able to reproduce this curve easily (not shown). We use the Cox proportional hazard model here, as it is the most flexible, and best accommodates the jump in the data at age 1 to 2.

[4] As indicated above, ideally one would model the decision to transfer a patent to a particular country as a function of that country's characteristics as well as the patent characteristics, using a random coefficients logit model as in Griffith et al. (2004), or perhaps a competing risks model. However, we found that there was insufficient variability across countries in the patent box to obtain meaningful estimates using these methods.

Figure D1

Cumulative hazard of an international transfer for EP patents

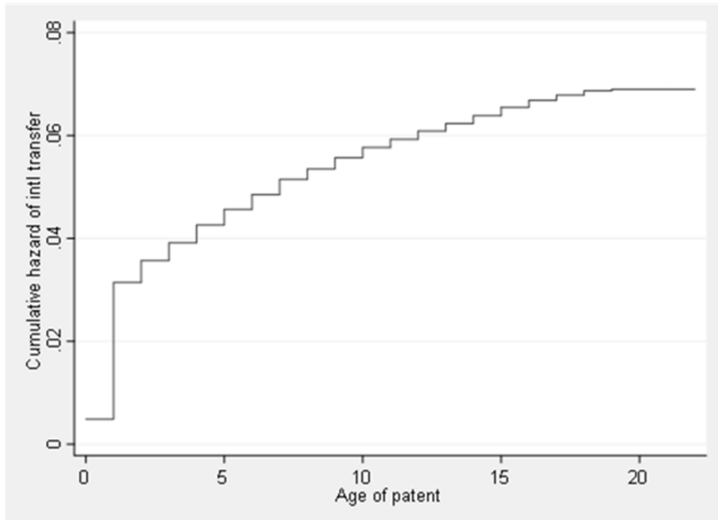


Table D1 presents the results of Cox proportional hazard estimation of the same model as the logit estimation, which is shown for comparison. Note that because hazard rate estimation requires that all observations begin at least with the period before the transfer, the sample sizes are slightly different from the logit model in the text (where a transfer is allowed in the first period). The estimates are still very similar to the logit estimates, as they should be.

Table D1

Cox PH and Logit models of the probability of an international transfer

		Cox PH		*Logit*	
Variable	*Mean*	*(1)*	*(2)*	*(3)*	*(4)*
Selling country tax rate *	-0.00005	-0.240	-0.309*	-0.208	-0.272
patent value index		(0.184)	(0.183)	(0.199)	(0.198)
Patent value index	0.000	0.304***	0.326***	0.325***	0.345***
		(0.050)	(0.050)	(0.054)	(0.055)
Selling country tax rate	0.325		1.249***		1.313***
			(0.430)		(0.462)
Log (cumulative patents)	5.25	0.026	0.026	0.025	0.025
for patent owner		(0.027)	(0.027)	(0.032)	(0.032)
Patent owner a multinational	0.614	0.063	0.062	0.124	0.123
research firm		(0.081)	(0.081)	(0.096)	(0.095)
Patent owner a corporation,	0.284	-0.042	-0.041	-0.040	-0.040
not multinational		(0.048)	(0.048)	(0.054)	(0.054)
Log likelihood		-1,094,370.4	-1,094,215.9	-371,866.7	-371,708.1
Chi-squared		1,920.1	1,914.7	1,813.3	1,825.5
Degrees of freedom		88	89	88	89
R-squared		0.016	0.016	0.057	0.057

2,559,430 patent-year observations for 2001-2014; 91,351 transfers

Heteroskedastic standard errors clustered on 72,998 patent owners.

All equations include seller country, year, and tech dummies.

Method of estimation is Cox proportional hazard in columns 1 and 2 and Logit in columns 3 and 4.