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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 patent filings 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.

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1. Introduction

During the past 15 years several countries have introduced special treatment for the taxation of corporate income that derives from the ownership of patents or, in some cases, other IP. This policy instrument (often called a "patent 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 such avenue for shifting income, because transferring ownership of a patent from one country to another that has more favorable tax treatment is a straightforward and relatively low cost procedure.

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 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.

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 which 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.[1]

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 three questions:

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

1. When a transfer of patent ownership occurs between countries, is the choice of target country affected by the difference in tax treatment in the two countries and the presence of a patent box? That is, we relate the probability of an ownership transfer to the difference in the marginal tax rates faced by corporate income generated by patents in the two countries.
2. Is the choice of priority country influenced by that country's treatment of patent income? We are motivated to some extent by the observation that the share of patents with a priority country that differs from the location of the invention has risen in the recent past.
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?

In addition, we hypothesize that more valuable patents (that is, patents that are more likely to generate income, via own profits or licensing) are more likely to be subject to transfer.

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 patent transfers in Europe during the period and we focus our analysis on the transfers of granted European patents (which will also be German patents with very high probability). 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. Using these data, we look at the impact of corporate taxes and the patent box on two choices: whether to transfer patents across countries and whether to choose a priority country for patenting that differs from the country of inventor residence. We argue that the latter choice may be driven by a preference to patent in a country with favorable tax treatment of patent income. We perform both analyses at the aggregate (country) level and also at the level of individual patents, where we are also able to use patent characteristics to examine which patents are transferred. In addition, we look at whether the presence of a patent box (and therefore an implicit subsidy to innovation) increases inventive activity in a country.

2. Tax treatment of innovation

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 (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 such as the US Generally Accepted Accounting Principles (GAAP)[2] and various International Accounting Standards Board (IASB) standards:[3] 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 credit that provides a reduction in the cost of performing R&D. For

[2] http://www.fasb.org/home

[3] https://www.iasplus.com/en/resources/ifrsf/iasb-ifrs-ic/iasb

details on this tax instrument, see various publications by the OECD[4] and for evidence on its effectiveness, see Hall and Van Reenen (2000) and Appelt et al. (2016). Appendix Table A1 indicates which of the countries in our sample currently have some kind of R&D tax credit.

In our sample of 51 countries (the list is shown in Appendix Table A1), there are 13 that have introduced some kind of IP or patent box between 1971 and 2014, and one (Ireland) that has discontinued it.[5] 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. 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. 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 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

[4] http://www.oecd.org/sti/rd-tax-stats.htm

[5] 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.

(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). 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 each of these groups of studies. Tables 1a and 1b provide an overview of the empirical studies that we found directly relevant to the study of patent boxes. These analyses differ along a number of dimensions. The majority have been done at the firm level, and a few at the country or patent level. Two look within firm or country at the differences across technologies. The years covered are generally within the 1995-2015 period, which is the period when most of the IP boxes have been introduced. There are relatively few papers that incorporate a patent box into the analysis and the results are somewhat mixed, although generally positive both for the location of patents, and for R&D. We review a selection of the most relevant papers in this section of the paper.

Table 1a: 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

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. Hence, MNEs should have strong incentives to locate the ownership of patents in a low-tax country and may even have incentives to locate the creation of the associated invention in the same country, assuming that the locus of creation can be shifted easily.[6] If shifting the creation and ownership of patents is not constrained, then corporate patenting should be more likely the lower is the corporate tax rate. Moreover, as these authors point out, in high-tax countries these firms may be more likely to use trade secrecy, because there is no tax advantage to having clearly identifiable royalty income from patents.[7] This would again impact the number of patents filed when tax rates are high. As they point out, the absolute level of

[6] For a survey of evidence on R&D location choice, see Hall (2011).

[7] The argument with respect to trade secrets is fairly weak, because there are countervailing effects such as the danger of losing secrecy if the trade secret is spread to other (even multiple) tax locations. In particular, if the technology is to be used in multiple sites, there would be a tendency towards patenting in order to have better legal recourse. There are also substantial differences in trade secrecy legislation across countries.

tax tariffs may not be decisive as firms will optimize patenting within the range of tax systems they are operating in. Hence, the differences between tax tariffs across the countries in which a firm is operating should be an important determinant of the location of patenting. Moreover, the location rationale may also be affected by withholding taxes on royalty payments for patent use and also by Controlled Foreign Company (CFC) rules, which typically allow for recapture of tax on passive income generated in designated tax haven countries (Griffith et al. 2014, Boehm et al. 2015). They control for these rules in the empirical exercise.

Karkinsky and Riedel match PATSTAT patent data (October 2007 version) to information on ownership structures within MNEs compiled by Bureau van Dijk in the AMADEUS data-base. The matched data comprises patent applications filed by firms from 18 European countries: Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Their econometric specification focuses on the tax determinants of the patent application count by a multinational affiliate i in year t. As controls they use log GDP, log number of researchers in the respective country, indicators for the strength of property rights (Ginarte and Park 2007), for the lack of corruption and log number of employees of the affiliate. By using panel estimators, they can control for affiliate and year fixed effects. The results suggest that the corporate tax rate (relative to the tax rates of other group members) 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 and applicant country using filing data from the EPO for 1990-2007. They study the decision to file a patent for an invention that was made in an EU or OECD country in a different country as a function of patent quality and the applicant country tax rate, as well as the probability that higher quality patents are those applied for from tax haven countries. They show that low-tax countries tend to attract foreign-owned patents and that high-tax countries are more likely to file their patents in tax haven countries, especially if the patents are of "high quality" by the usual measures. Low tax countries include various island tax havens, Ireland, Liechtenstein, Luxembourg, and Switzerland. 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 to the above analysis, Griffith et al. (2014) are able to distinguish among different location choices for the patent application by using a random coefficients logit model to study a firm's decision about the location of patent ownership. The owner affiliate can contract (*ex ante*) with the inventor location for R&D services, bear the risk of the R&D process and retain ownership of its output. Rights to the use of the patented invention are then licensed to the R&D-performing and other affiliates in exchange for licensing fees. Griffith et al. model the quasi-rent that the parent firm gets from selecting a particular location for ownership as a function of the tax rate, the quality of the idea, the strength of IP rights in the respective country, the size of the local market, and the level of innovativeness of the country in which ownership of the patent resides. The econometric model is a mixed logit, where location choice can also be allowed to depend on the unobserved characteristics of the idea and the location. 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 an interaction between the target and the home country. The authors use data on the statutory corporate tax rate (which is argued to be close to the effective 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.

A particular advantage of this econometric setup is the computation of country-specific tax elasticities. For example, the authors estimate that the share of patents located in Luxembourg has a semi-elasticity of 3.9% with respect to the tax rate, while Germany has a much lower one of 0.5%. In general, own semi-elasticities are more pronounced for smaller than for larger countries. The authors provide results for a simulation exercise in which the introduction of patent boxes is considered. They find that while patent boxes attract patent income, they also lead to a substantial reduction in tax revenues. Countries that introduce patent boxes in the time period considered attract more new patents, but the increased share of patent filings is not sufficient to outweigh the effect of the lower tax rate.

Patent box literature

We now turn to those papers that explicitly analyze the impact of the patent box instrument on patent location and transfer, shown in Table 1b. 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. Their sample comprises 33 countries (the EU28, the USA, Canada, Switzerland, the Republic of Korea, and China) and the firms account for almost 90% of global R&D spending. Firms active in three broadly defined sectors (pharmaceuticals, motor vehicles, and information and communication technologies) are included. Using various negative binomial models for the number of patents of a particular technology type located in a country by each of these multinationals, they find that the tax advantage of a patent box does induce firms to locate their patents in a country. However, interpretation of the regressions is problematic, since they include both a dummy for the presence of a patent box and the tax advantage of such a box. These variables are very highly correlated and are essentially two different error-ridden indicators of the same underlying concept. As predicted, the better measure enters positively and the other negatively (Hall, 2004).

Table 1b: 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

Alstadsæter et al. (2018) also examine the impact of the detailed provisions of the patent box, finding somewhat inconsistent results across technologies. Broader scope of patent box benefits makes affiliate locations more attractive, and high-value patents are more impacted than low-value ones. 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, this prevents purely opportunistic shifting of patent filings and in this case patent boxes have a substantial positive impact on domestic inventions.

Bösenberg and Egger (2017) look at patent filings and patent trade (ownership transfer) as a function of all the possible tax incentives that affect patenting. To this end, they construct 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 (EMTR, widely known as the "B index", Warda 2002)[8] and the effective

[8] 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 (in spite of the terminology used by Bösenberg and Egger 2017), but is negatively related to it. This implies that the expected impact of the b-

average tax rate (EATR) on the profit from R&D, which includes information on the corporate tax rate. They also include dummies for the presence of a tax holiday, grant, and/or patent box. Notably, they do not incorporate the patent box rate into the EATR on R&D profits.

The empirics in the paper relate patent filings and patent trade across countries to the tax variables, patent characteristics, country characteristics and distances between countries. They find that 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.[9] It also appears that more valuable patents are more likely to be transferred. Note that the patent trade measure in this paper is based mainly on transfers prior to grant by applicant country. However, focusing only on pre-grant transfers may limit applicability. As Gaessler (2016) shows, many transfers occur post-grant, hence it is unclear to what extent the results presented by Bösenberg and Egger (2017) are affected by selection issues. Given the patent renewal evidence that it may take years to determine whether a patentable invention is valuable, post-grant transfers suggest that firms wait in order to determine which patents to transfer.

Dudar et al. (2015) use data on 61 countries worldwide 1990-2012 to examine royalty flows between countries in response to tax differences. They find a large effect, in that a one percent decline in tax rates between jurisdictions leads to a 6 percent increase in royalty flows, which is larger than most of the results for patents in the literature. They argue that this is consistent with the idea that higher quality intangibles in the form of patents are more likely to be transferred. As to patent boxes, they find that when they apply to acquired and self-generated IP in the recipient country, royalty payments to that country do increase.

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. This time period means that they have relatively few patent box observations (about 12 percent) and they do not have transfer data, so they infer the impact on transfers from changes in the mismatch between inventor and patent owner country. 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, suggesting some kind of substitution between domestic invention activity and the use of acquired IP from other countries, although this conclusion is fairly speculative.

Koethenbuerger et al. (2016) looks at whether multinationals who were able to benefit from the introduction of a patent box because they owned patents succeeded in increasing their affiliate profits in the patent box country, when compared to multinational affiliates in the same country

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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.

[9] The regressions show signs of misspecification, as the Poisson and negative binomial results differ greatly in their coefficients. For consistency, it would have been better to report Poisson results with robust standard error estimates, since the negative binomial model is more subject to inconsistency of the mean estimate.

whose parents did not have patents. They use a difference-in-difference analysis with a carefully chosen control sample of multinationals. They also find that this profit-shifting benefit was confined to affiliates in countries where existing and/or acquired patents were covered by the respective patent box. Their result does suggest that in the absence of the nexus requirement, profit shifting via patent transfer does take place in response to the introduction of the patent box.

In an interesting study, Schwab and Todtenhaupt (2018) look at a different consequence of the introduction of a patent box. They argue that because a patent box in one of the countries in which they have affiliates is effectively a reduction in the cost of R&D capital that they face, it should increase their R&D activity overall. They confirm this idea using a panel of multinational firms active in Europe during the 2000-2012 period. Firms that are exposed to a patent box for one of their affiliates increase their patent output by about 15 percent, but only if the patent box is not subject to a nexus requirement, consistent with the results of Alstadsæter et al. and Koethenbuerger et al. Using confidential German data, they are also able to look at the R&D spending choice by German multinationals and find that this too responds to the introduction of a patent box without a nexus requirement. Unfortunately, the countries without a nexus requirement are a rather small set: France, Hungary, Malta, and Cyprus. Like many of the studies, including ours, identification necessarily rests on the variation in patent box design across only a few countries.

Like Bösenberg and Egger (2017), Ciaramella (2017) studies the transfer of EP patents during the examination phase at the EPO in response to the introduction of the patent box, but at the firm level and for the 1997-2015 period. Restricting the analysis to transfers made before the patents are granted covers about 60 per cent of all transfers by her computations. 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 slightly higher. 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. The effective patent box coefficient is insignificantly different from zero when further development is required.

In one of the only papers to look at the impact of the patent box on R&D spending, 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, 4) the location of ownership of the patents, and 5) any other locations in which to file. 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.[10] 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 three location decisions: where to apply for the first (priority) patent on an invention, the location of the applicant country when a patent is applied for, and where and when to transfer ownership of patents.[11] 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 priority application or as the location of the applicant):

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

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 applied for that year by the inventor-priority/applicant country pair, controlling for country and year fixed effects as well as the two country's GDP, population, R&D, and patenting activity.

The general form of a gravity model is the following:

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

[10] 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.

[11] Although the transfer choice and priority choice are open to any applicant, presumably only applicants with locations in multiple countries are free to choose the country from which they apply.

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:

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

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

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

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 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, the transfer cost, and whether it had a subsidiary in the country. This suggests that a choice model such as logit would be the appropriate way to analyze the choice of the country to which to transfer the patent. However, estimation of such a model would be difficult, given the relative few actual observations available for identification (IP tax changes in 12 countries during the period, with varying rules). Therefore we focus on the choice to transfer as a function of patent and owner characteristics, using a logit model with standard errors clustered at the patent level. We then explore how the type of transfer (to a tax-favored jurisdiction, or within a group) varies with these characteristics.

5. Data

There are approximately 1.2 million registered ownership transfers of European patents (EP) in the MPI 2018 patent transfer database. [12] 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 area. 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 almost all European countries, the US, Canada, Mexico, Chile, 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.[13] The complete country list is shown in Appendix Table A1, and the list of the patent box countries only in Appendix Table A2.

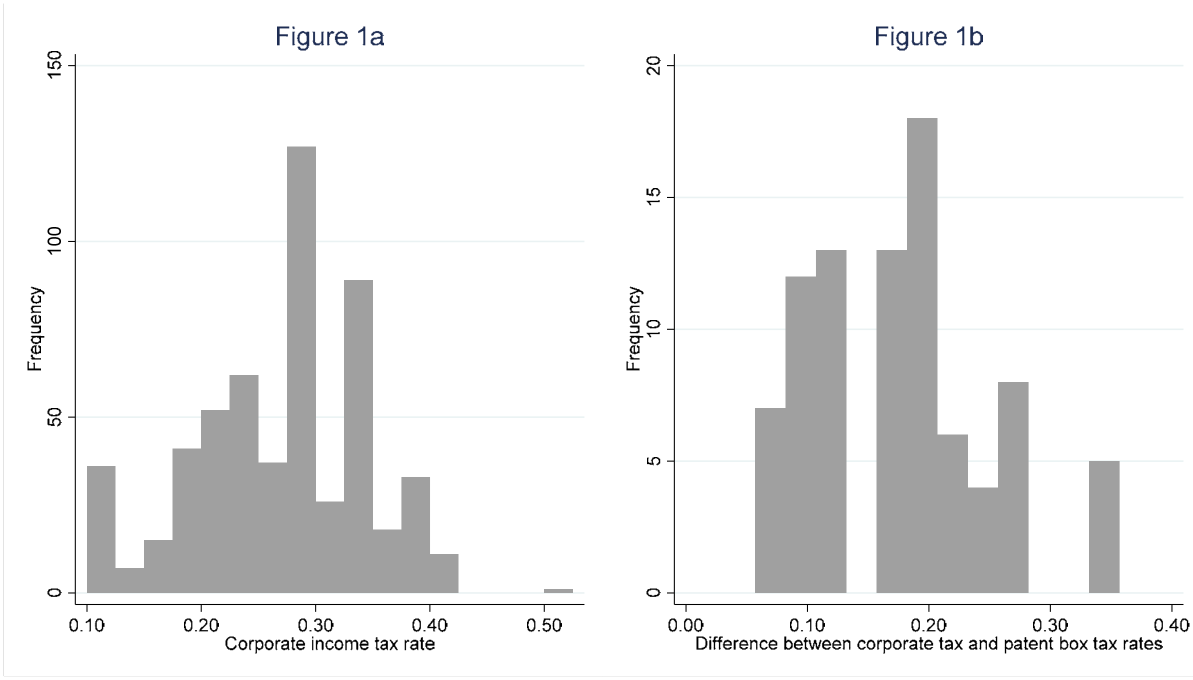
We combine these data with tax data from Alstadsæter et al. (2018), Evers et al. (2015), and the OECD on corporate taxation and the tax treatment for intangible assets including patent boxes.[14] Figure 1a shows the distribution of corporate tax rates during the 2000-2014 period for the 37 countries 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. The median corporate tax rate is 28 percent and the median reduction for patents is around 18 percent. The median tax rate on patent-related income for those countries and years that have a patent box is 7 percent.

[12] The Max Planck Institute for Innovation and Competition Patent Transfers Data 2018.

[13] 101,091 transfers out of 106,642 over the 2000-2014 period.

[14] 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.

Figure 1



6. Aggregate analysis

International patent transfers

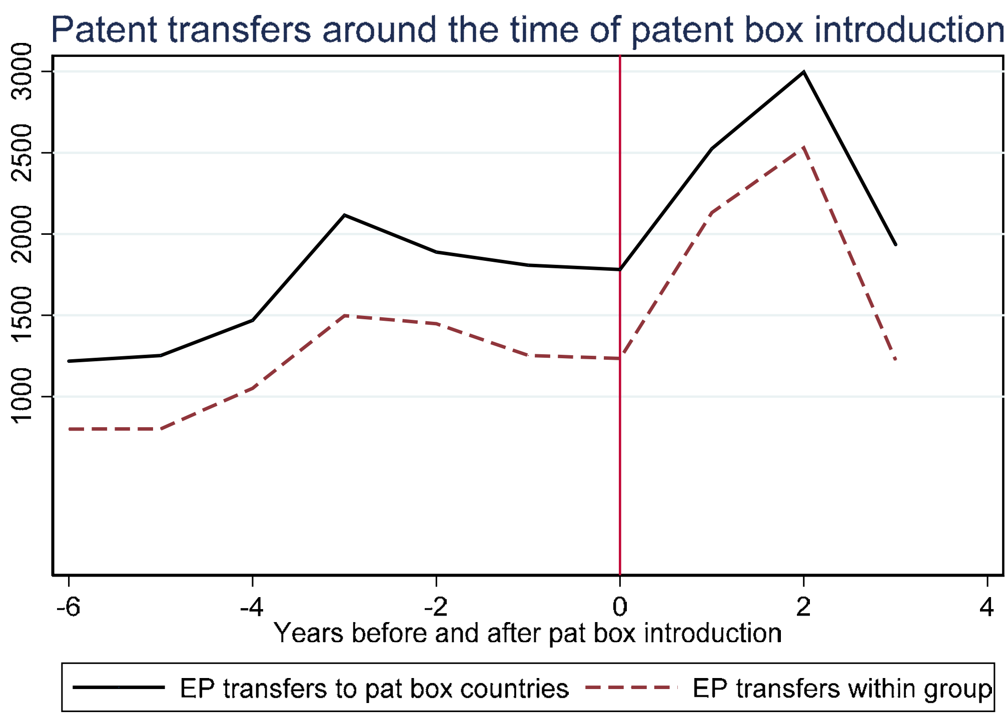
Our initial exploratory analysis is at the aggregate level. We observe the number of patent transfers from each of 51 countries to the other 50 countries (excluding within country transfers). For estimation, we restrict the transfer sample to 2000-2014, which is when most of the patent boxes were introduced.[15] The total number of observations in our data is therefore 38,250 = 15*50*51.[16] Figure 2 shows the aggregate EP patent transfers into 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 figure also shows the transfers of EP patents restricted to be within a firm group. Both curves 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. 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

[15] 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.

[16] 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 (2013).[17]

Figure 2



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 8.1 (Feenstra et al. 2015), while the R&D figures come from the UNESCO Institute for Statistics database 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,

[17] 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.

which includes all 13 countries that have introduced a patent box by 2014.[18] These results are shown in Tables 2a and 2b. Results for the 51 country sample are shown in Appendix Tables B1 and B2.

The first three columns of Table 2a show the basic 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 three columns add the various country characteristics.[19] 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 capital patenting entered the regression significantly.

Columns 1 and 4 in Table 2 include the corporate tax rates and the magnitude of the difference between the corporate tax rate and the patent box rate for both countries. The overall corporate tax rates do not enter the regression significantly, although we do find some evidence for patent box impact on patent transfers. The presence of a patent box is significantly negative for the seller (sending) country but not for the buyer (receiving) 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.

As Figure 2 suggests, we would expect that the patent box impact on patent transfer might be transitory, because patent applications after the introduction of a patent box will simply be made from the relevant jurisdiction. In columns 2 and 5 of Table 2, this idea is explored by including patent box dummies or the patent box tax wedge only in years 0, 1, and 2 following the patent box introduction. The results show that there is a transitory impact of the patent box on transfers to a country which is strongest in year 2. That is, it takes some time after the patent box introduction for transfers to that country to respond.

Columns 3 and 6 of Table 2a 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 even stronger, as we might expect given that the tax benefits are entirely within the firm. The sum of the coefficients on the patent box wedge is 4 or 5, which implies that a change of 10 percent to the wedge (e.g., moving from 10 per cent to 20 percent difference from the corporate tax rate) is associated with a four to five-fold increase in the number of patents transferred.

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

[19] 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.

Table 2a

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)	Within group (3)	All (4)	All (5)	Within group (6)
Buyer corporate tax rate	0.81	1.07	0.24	-1.02	-0.71	-1.34
	(1.28)	(1.33)	(1.83)	(1.25)	(1.28)	(1.59)
Buyer patent tax rate wedge in all years after introduction	-0.04			-0.29		
	(0.76)			(0.67)		
Buyer patent tax rate wedge in year of introduction		0.18	0.17		-0.12	-0.14
		(0.67)	(0.87)		(0.63)	(0.79)
Buyer patent tax rate wedge in year after introduction		1.07	1.59		0.83	1.41
		(1.40)	(1.53)		(1.35)	(1.41)
Buyer patent tax rate wedge two years after introduction		2.41*	3.41**		2.05*	3.07**
		(1.27)	(1.45)		(1.21)	(1.32)
Seller corporate tax rate	1.11	1.17	0.88	0.59	0.63	0.00
	(1.03)	(1.00)	(1.27)	(1.44)	(1.43)	(1.88)
Seller patent tax rate wedge	-1.52**	-1.43**	-2.01***	-1.38**	-1.33**	-2.09***
	(0.63)	(0.62)	(0.76)	(0.66)	(0.67)	(0.70)
Chi-squared	4191.5	4110.5	3139.6	4486.2	4473.0	12817.9
Degrees of freedom	92	94	94	102	104	104

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 4-6 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. Such an approach is already suggested by the nonsignificance of buyer corporate tax rate and some of the seller patent box variables in the previous models. Denoting the statutory corporate tax rate as τ and the tax rate on patent income as ρ, we define the following variables:

$$difftax = \tau_S - \tau_B$$
$$diffbox = (\tau_B - \rho_B) - (\tau_S - \rho_S) = (\rho_S - \rho_B) - (\tau_S - \tau_B)$$

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 2b shows the results of estimation with these variables, and additional results are shown in Appendix Table B3. 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 2b show the results for within-group transfers, as in Table 2a. 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 2b

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*	*group*	*All*	*All*	*All*	*group*
Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
Difference:	0.18	0.35	-0.31	0.29	0.80	0.79	0.70	0.94
seller corp tax-buyer corp tax	(0.88)	(0.90)	(0.95)	(1.24)	(0.98)	(0.97)	(0.98)	(1.30)
Difference:	0.60	1.35**	0.33	0.40	0.39	0.67	0.08	0.30
buyer-seller patent tax wedge	(0.49)	(0.63)	(0.55)	(0.74)	(0.49)	(0.59)	(0.56)	(0.69)
D (dev condition on use)*buyer-		-1.95*				-0.67		
seller patent tax wedge		(1.03)				(0.94)		
D (CFC rules apply to buyer)			-0.37**	-0.22			-0.40***	-0.27
			(0.17)	(0.27)			(0.15)	(0.21)
D (CFC) * seller-buyer corp			3.31***	1.20			2.40*	0.75
tax difference			(1.13)	(1.77)			(1.34)	(1.65)
D (CFC) * buyer-seller patent			1.27	2.22*			1.71*	2.47**
box difference			(1.04)	(1.26)			(0.99)	(1.18)
Chi-squared	4,054.3	4,072.5	4,175.9	3,095.2	4,342.6	4,359.7	4,470.2	11,753.1
Degrees of freedom	90	91	93	93	100	101	103	103

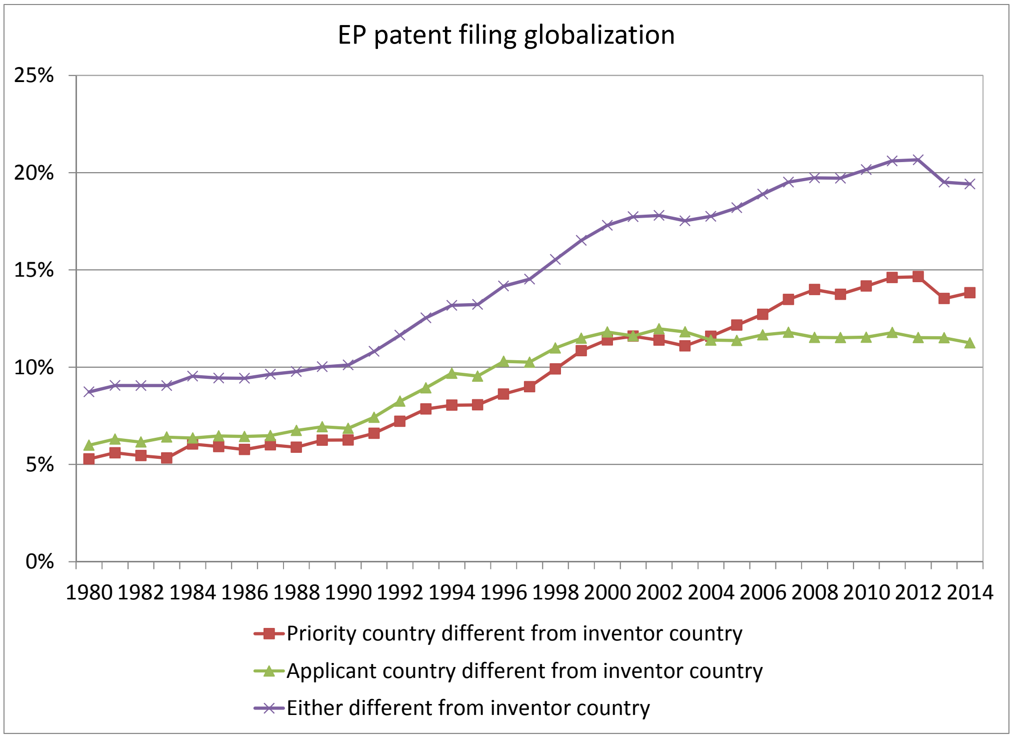
Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs.
19,980 observations on 1,332 country pairs, 2000-2014
Coefficient significance is denoted by * p<0.1, ** p<0.05, *** p<0.01.
All regressions include complete sets of dummies for the 37 buyer and seller 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 does seem to induce some transfers to the jurisdiction, albeit with a bit of lag. 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.

Choice of priority country

We now turn to the choice of where to file for a patent first (priority choice) and the question of which country will be chosen as the country of ownership. Obviously this latter question affects mainly multinational firms that have subsidiaries in several countries. Figure 3 illustrates the globalization trends in patent filing at the EPO. In 1980, the vast majority of filings were made from the country of the inventor residence, which is presumably the country in which the research leading to the invention was performed. There is a sustained rise in cases where the chosen priority country was different from that of the inventor, from 5 percent to almost 14 percent, and initial rise followed by a leveling off in cases where the country of the applicant (patent owner) was different from that of the inventor. We know that one of the reasons for these changes is the increasing globalization of patents, with an increase in the number of jurisdictions for which protection for an invention is desired (Fink et al., 2016). It may also be the case that firms increasingly include the location of its patent filings in its tax planning.

Figure 3



If this is the case, we would expect that the decision to file the priority (first) filing in a country other than that of inventor residence might depend on the presence of a patent box. Similarly, where the applicant location differs from the inventor location, it may be because the firm has located patent ownership in a more favorable jurisdiction for tax purposes. We explore these hypotheses in Table 3, using a similar model as in the previous section, but where the "seller" country is the inventor country and the "buyer" country is the priority or applicant country. For consistency with the remainder of this study, we confine the data to EP patent applications, which may have priority patents or applicants outside the countries that are member of the EPC.

The first three columns in Table 3 are for the inventor-priority combination and the next two are for the inventor-applicant combination. In each case we show Poisson estimates of the model where we do not include cases where the inventor country is the same as the priority patent or applicant country. Columns 1 and 4 control only for the tax differences between the two countries, while columns 2, 3, and 5 add the usual gravity model variables GDP and population, as well as two variables that are tailored to the setting here, R&D spending and patenting in the relevant countries.

Table 3

Inventor country to priority/applicant country flows 2000-2014

Dependent variable:	Number of patents from an inventor country with chosen priority country#			Number of patents from an inventor country with chosen applicant country#		
Difference in corp tax rate	-2.05***	-1.83***	0.36	0.13	0.17	-0.29
inventor less prior/app country	(0.56)	(0.46)	(0.40)	(0.43)	(0.31)	(0.33)
D (US priority) * diff in corp tax rate			-3.60***			1.66***
inventor less prior/app country			(0.78)			(0.58)
Difference in pat box wedge	0.09	0.34	0.44	-0.03	-0.09	-0.09
prior/app less inventor	(0.38)	(0.32)	(0.29)	(0.26)	-0.24	-0.22
Log patent apps per capita		0.52***	0.51***		0.47***	0.49***
in inventor country		(0.09)	(0.08)		-0.07	-0.07
Log patent apps per capita		0.54***	0.54***		0.56***	0.55***
in prior/app country		(0.09)	(0.08)		-0.07	-0.07
Log real GDP per capita		0.77**	0.54		0.03	0.07
in inventor country		(0.35)	(0.35)		-0.14	-0.13
Log real GDP per capita		-0.80**	-0.61*		-0.01	-0.04
in prior/app country		(0.35)	(0.35)		-0.14	-0.13
Log population (millions)		-0.44	-1.02*		0.43	0.55
in inventor country		(0.64)	(0.52)		-0.44	-0.44
Log population (millions)		1.26*	1.71***		0.63	0.54
in prior/app country		(0.69)	(0.57)		-0.45	-0.45
Log R&D researchers per M pop		0.34	0.38		-0.08	-0.09
inventor country		(0.31)	(0.31)		-0.14	-0.14
Log R&D researchers per M pop		-0.30	-0.34		0.07	0.08
prior/app country		(0.30)	(0.29)		-0.14	-0.14
Observations	19,980	19,980	19,980	20,535	20,535	20,535
Country pairs	1,332	1,332	1,332	1,369	1,369	1,369
Chi-squared	7,059.6	78,915.3	81,916.1	10,892.7	100,239.4	111,650.0
Number of coefficients	88	98	99	89	99	100

Poisson random effects panel regression with standard errors clustered on buyer-seller country pairs. * p<0.1, ** p<0.05, *** p<0.01.

The dependent variable is number of patents with the inventor country-priority/applicant country combination.

All regressions include complete sets of dummies for the 37 inventor and priority/applicant countries, and years 2000-2014. One country has no priority apps and is dropped in those regressions.

We looks first at the question of whether the choice of priority country depends on its tax rates relative to the tax rates in the country where the inventor is located. In columns 1 and 2, we find that higher tax rates in the inventor country relative to priority country depress the choice of priority country, which is contrary to one's intuition. However, column 3, where we estimate a separate effect for the United States, shows that this result is an artifact of the preference of EP applicants for the United States as a priority country, in spite of its high corporate tax rate during the period. We conclude that the presence or absence of a patent box has little impact on the priority country choice. However, other variables in the regression do matter for the inventor-priority choice: patenting per capita in both countries, the size of the priority country, the GDP per capita of the inventor country, and the GDP of the priority country (negatively). It is important to keep in mind that these variables are identified by changes over time, since there are a complete set of inventor and priority country dummies in the regressions.

Turning to the inventor-applicant combinations, recall that only applicants with a presence in multiple countries will be able to choose among them as a location from which to file, which may lead to somewhat weak effects in an aggregate regression that includes patent applications owned by all applicants. Indeed, we do find that the only significant predictors of the inventor-application choice are the patenting per capita in the two countries. When we add the US-corporate tax differential to the equation, we find that applicants have a significant preference for filing from the United States when the inventor country corporate tax rate is high.

The conclusion from these aggregate results is that there is little evidence that the location of patent filings is affected by the presence of a patent box, although there is fairly strong evidence that there exists a preference for the US as the locus of ownership and priority patenting in spite of the high statutory tax rate in that country (39 per cent in our time period).

Invention

The policy argument for the introduction of a patent box is that it should encourage invention and innovative activity in the relevant country. Although we do not (yet) have the data that would allow us to investigate innovative and R&D activity broadly, with the current data we can look at changes in the level of patented inventions in a country after a patent box is introduced. We first show the simple trends around accession time for the 12 countries in our dataset that have introduced a patent box. Given the wide range of patenting activity across countries, we show two figures, one for the 6 larger countries, and another for the 6 smaller countries (note that the scales differ by a factor of 50).

Figure 4a

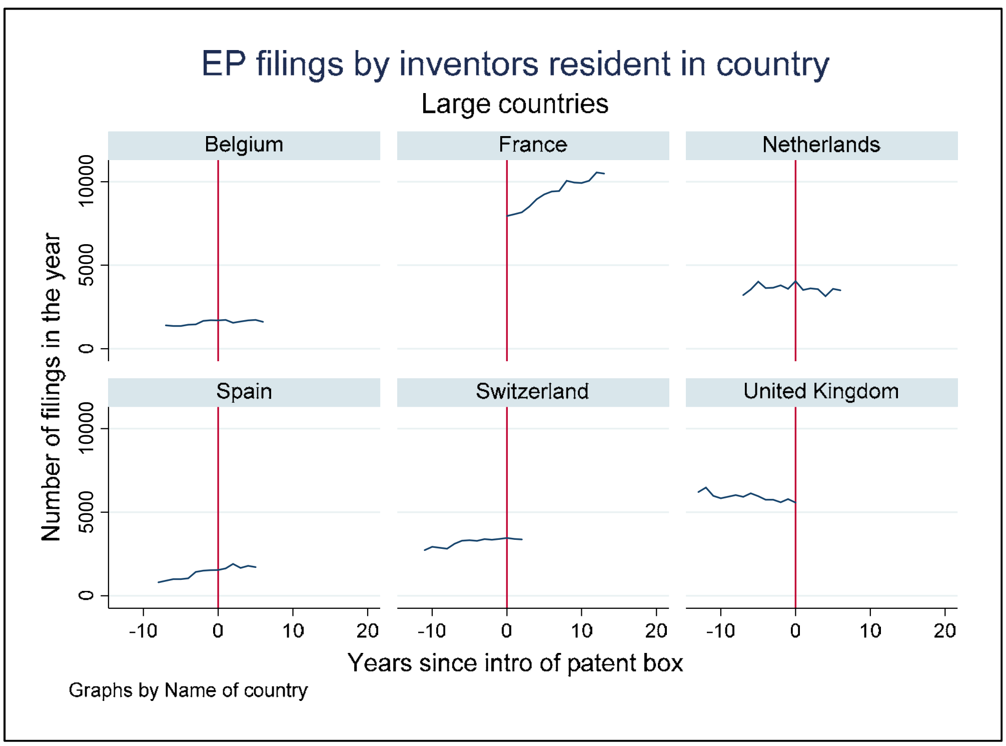
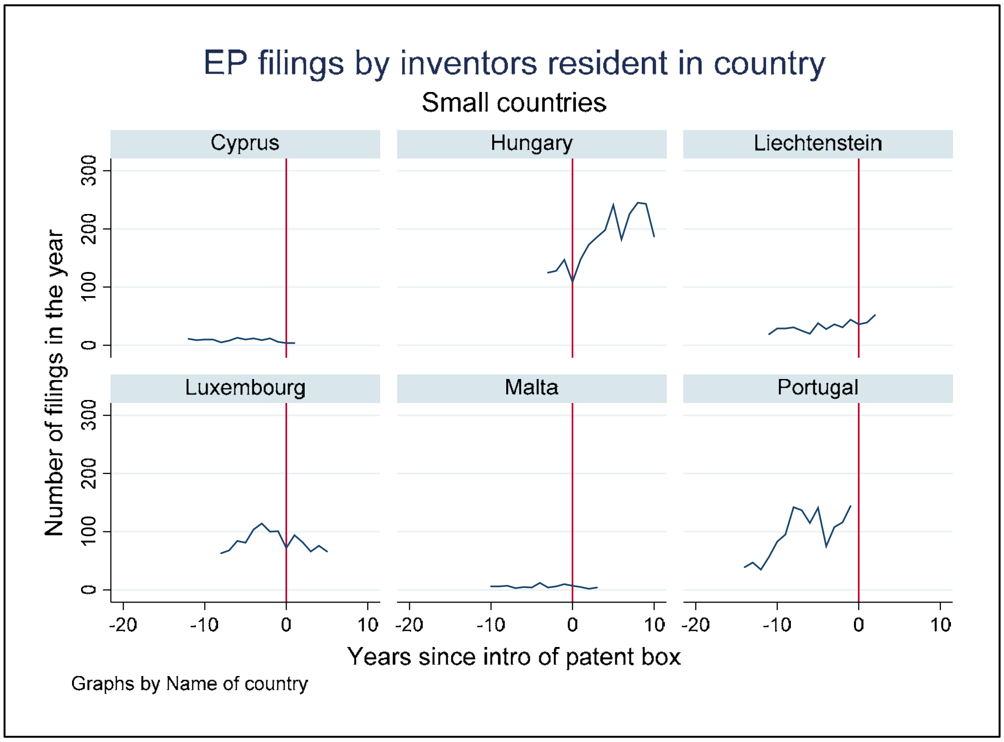


Figure 4b



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 and the figures show clearly that for some countries (notably the UK, Switzerland, Cyprus, and Portugal), there is almost no time after the patent box is introduced so the power of any tests will be weak. In the case of France, there is no pre-patent box data. But the main finding in these graphs is a strong upward trend in EP patent filings overall which shows little signs of change around the date when the patent box is introduced.

To confirm the visual evidence, 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 R&D-GDP ratio of the country, and a set of country and year dummies. In this case, the method of estimation 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 Table 4. They are fairly clear: inventor filings depend positively GDP per capita and R&D intensity and insignificantly negatively on the country's corporate tax rate. The two patent box variables are slightly significant, but with the wrong sign: if anything, the presence of a patent box *reduces* patentable invention in the country.

As mentioned earlier, Altstadsaeter 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 4, 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 Altstadsaeter 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 Altstasaeter et al. on large R&D-doing firms only, most of which are multi-nationals.

Table 4

Inventor filings by country

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

	(1)	(2)	(3)	(4)	(5)	(6)
D (patent box)	-0.20*	-0.13*				
in all years after introduction	(0.10)	(0.06)				
Patent tax rate wedge			-0.48*	-0.41	-0.07	-0.63*
in all years after introduction			(0.24)	(0.57)	(0.46)	(0.27)
D (excluding existing patents)				-0.10		
* patent tax wedge				(0.61)		
D (excluding acquired patents)					-0.72	
* patent tax wedge					(0.51)	
D (development restriction)						0.29
* patent tax wedge						(0.51)
Corporate tax rate	-0.38	-1.47	-1.44	-1.43	-1.36	-1.40
	(1.47)	(1.09)	(1.10)	(1.11)	(1.11)	(1.12)
Log population		-0.94	-0.97	-0.97	-0.98	-0.92
		(1.18)	(1.20)	(1.21)	(1.19)	(1.21)
Log GDP per capita		1.54***	1.51***	1.50***	1.52***	1.51***
		(0.34)	(0.35)	(0.35)	(0.35)	(0.35)
Log R&D expenditure over GDP		0.70***	0.72***	0.72***	0.72***	0.71***
		(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
Std. error	0.31	0.25	0.25	0.25	0.25	0.25
Log-likelihood	-107.7	23.2	21.5	21.5	23.1	21.7

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).

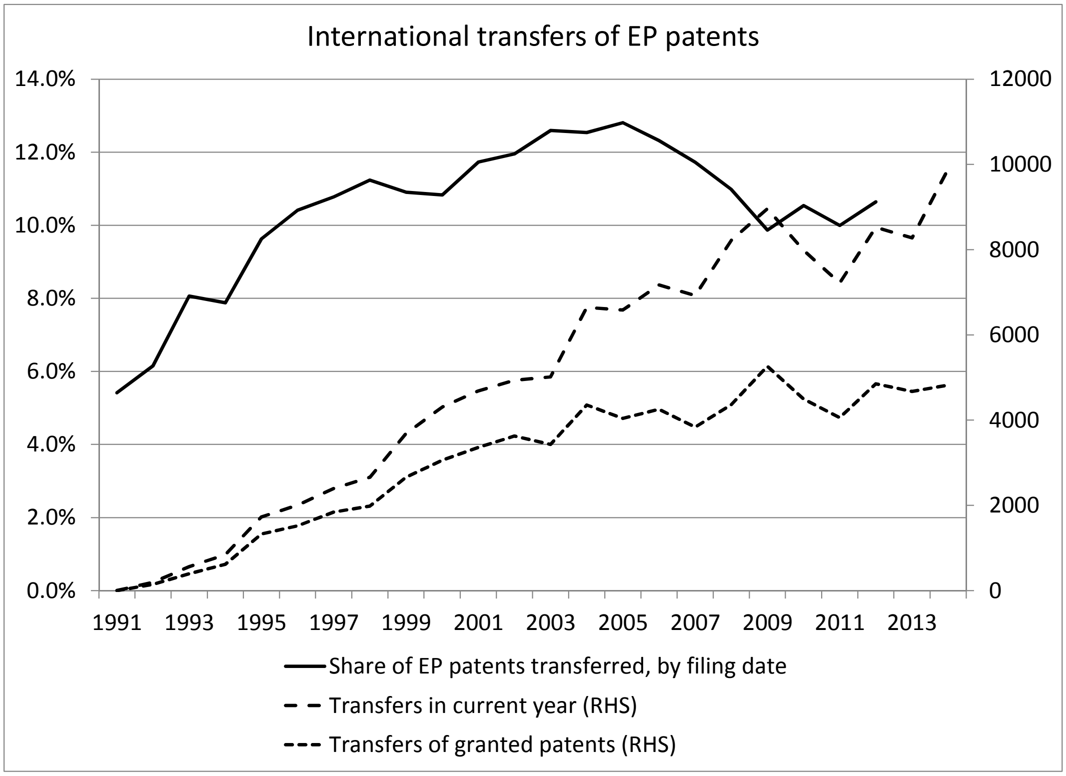
Method of estimation is least squares with robust standard errors.

Significance levels using standard errors clustered by country: * p<0.1, ** p<0.05, *** p<0.01.

7. Patent level analysis

We now turn to an analysis of the choice of patents to transfer. Our sample is the approximately 1,200,000 EP patents filed between 2000 and 2012 that have been granted as of 2014, of these patents 5.6 percent were subject to an ownership transfer across countries.[20] We focus on the first time that the patent is transferred, dropping 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, for both applications and granted patents. We use the 2000-2014 period because there were very few patent box countries prior to those dates.

Figure 5



We model the decision to transfer a patent using logit probability models. This approach has the advantage that it allows us to easily incorporate the choice of estimation of different types (within group or not, to a tax haven or not). As control variables, we include both the characteristics of the patent to be transferred and also those of the patent owner, which we expect to influence both its tax status and the costs of transfer. The patent characteristics we include are those that have been shown in previous work to be associated with patent value:

[20] Not all patent applications in the recent years that will eventually be granted have been granted by 2014, of course. Year of application dummies are included in all models to control for any differences in transfer due to this fact.

- 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 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.
- Number of patent owners (applicants) – however, often multinationals apply under both their own name and the name of their local affiliate, which means that this variable may in some cases proxy for multinational ownership.

To these we add the age of the patent. We have a limited number of applicant characteristics, 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.
- An MNC dummy for whether the applicant is research active in more than one country (as indicated by patenting from that country at least once during the entire period).
- A dummy for whether the applicant 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 (with the exception of patent age) are non-time-varying, which makes estimation straightforward and allows us to use a multinomial logit model to investigate the type of transfer. In some of the estimation, we also include dummies for the applicant country, the technology area of the patent at the 34 area level, and year effects for the patent application year. Testing revealed that the country dummies were the most important of these predictors, while the technology area dummies were less important, with the exception that they weakened the significance of the claims and forward citation coefficients, reflecting the fact that these variables vary by technology area.

Simple statistics for these variables are shown in Appendix Table A3. Using a non-parametric rank sum test, we find that in all cases the distribution of the variables for the patents that are transferred is significantly to the right of that for patents that are not transferred. The transferred patents are clearly different, in ways that we might expect if they are more highly valued. 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 A4, 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, and the dummies reduce them slightly.

The results of estimating a simple logit model for the international transfers of all EPO patents applied for 2000-2012 that are granted by 2014 are shown in Table 5. 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. King and Zeng (2001), among others, shows 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:

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

where $\hat{\beta}_0$ is the estimated intercept, ψ is the population share of transferred patents, and $\bar{y}$ is the share of the transferred patents in the sample. For our 10 per cent sample, this correction factor is equal to 2.3.[21] Note that for rare events, the correction factor is approximately equal to the log of the oversampling probability.

Table 5 shows the marginal impact (in percentage terms) on the probability of a transfer for each variable, which is more interpretable than the coefficients. This quantity does require correction for the bias in the intercept estimate, as can be seen the equation below, where *F(.)* is the logit probability:

$$\frac{\partial F(x\beta)}{\partial x_k} = \frac{\beta}{(1+\exp(x\beta))(1+\exp(-x\beta))}$$

Table 5 shows the average of this quantity for each variable x_k. Each column adds another set of dummies: none, country dummies only, country and year dummies, and country, year, and technology area dummies. Results do not change much as dummies are added, although the effects weaken somewhat. The results on patent value largely support the idea that higher value patents are transferred, with positive coefficients for family size, number of claims, forward citations, and number of inventors. What does predict more strongly that a patent will be transferred is its ownership: whether the owner has patenting activity in multiple countries, and whether the firm is a corporation, even if it is not a corporation doing multinational research. Patents that are part of larger portfolios are slightly less likely to be transferred, which is plausible, as many of these patents will be part of a patent portfolio strategy that depends on quantity rather than quality.

It is worth noting that these regressions have very little explanatory power, as the pseudo R-squares are all less than 0.06, even when we include country, year, and technology dummies. So there remain a number of factors that affect the choice of which patents to transfer that are unknown. Nevertheless, the combined impact of increasing the various patent characteristics by one standard deviation is to raise the probability that a patent is transferred by 0.11% on a base of 0.31%, an increase of one-third. A patent owned by a multinational that is research active in multiple jurisdictions is much more likely to be transferred with an increase in probability of 0.26%, nearly double the average.

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

Table 5

Probability of international patent transfer 2000-2014

Dependent variable: Dummy for first International transfer of patent (mean = 3.07%)

Variable	*(1)*	*(2)*	*(3)*	*(4)*
Patent family size (docdb)	0.086	0.063	0.063	0.067
	(0.001)	(0.001)	(0.001)	(0.002)
Number of claims	0.036	0.021	0.022	0.016
	(0.001)	(0.001)	(0.001)	(0.001)
Number of forward citations (5yrs)	0.009	0.010	0.011	0.005
	(0.001)	(0.001)	(0.001)	(0.001)
Number of inventors	0.026	0.040	0.040	0.039
	(0.002)	(0.002)	(0.002)	(0.002)
Number of patent holders	-0.069	-0.039	-0.040	-0.030
	(0.008)	(0.008)	(0.008)	(0.008)
Age of the patent	-0.141	-0.139	-0.139	-0.137
	(0.001)	(0.001)	(0.001)	(0.001)
Applicant's patent portfolio size	-0.056	-0.040	-0.040	-0.044
	(0.000)	(0.001)	(0.001)	(0.001)
Multinational research activity	0.330	0.270	0.271	0.260
(countries per applicant >1)	(0.002)	(0.003)	(0.003)	(0.003)
Patent holder a corporation,	-0.038	-0.021	-0.022	-0.024
but not an MNC	(0.003)	(0.003)	(0.003)	(0.003)
Applicant country dummies	no	yes	yes	yes
Year dummies	no	no	yes	yes
Technology area dummies	no	no	no	yes
Log likelihood	-454,600.7	-447,887.5	-447,489.5	-445,836.4
Chi-squared	62,462.0	77,041.4	78,537.5	84,702.0
Degrees of freedom	9	44	57	90
Pseudo R-squared	0.034	0.048	0.049	0.052

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

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.

3,428,110 observations on 343,154 patents; 104,664 transfers

Estimates shown are the average marginal impact on the probability in percentage terms. Standard errors are clustered by patent. * p<0.1, ** p<0.05, *** p<0.01.

Table 6 explores the variation across the different types of transfers. We define intra-group transfers those that are dependent or hierarchical in Gaessler and Harhoff (2018), and tax-motivated transfers as those that are either to the 14 tax haven countries, or to countries that have implemented a patent box. These two variables are then interacted to produce 4 possible transfer types, and a multinomial logit model is estimated for the choice of type (the left-out category is no transfer). The model is estimated with country and year dummies, but without technology area dummies, and we find that its explanatory power is slightly higher than the models in Table 5.

There are some differences in the patent valuation coefficients across the different types of transfers, but nothing terribly systematic, although patent value indicators seem to matter less for the non-group tax-motivated transfers. Within group transfers also tend to be of much younger patents than the others. The number of patent holders is quite negative for all the transfers, possibly because large numbers impede the pursuit of tax strategies involving patents, due to coordination failure between multiple independent entities when trying to sell the patent. Restricting to intra-group tax-motivated transfers changes the sign of the coefficient: these transfers are positively associated with the number of patent holders. This may be because such patents tend to be held by several members of the group, even though they are under control of a single ultimate entity. Related to this is the non-MNC corporation effect, which predicts intra-group tax-motivated transfers, but not other international transfers. These transfers are those within a group, where the group is not necessarily research-active in more than one location (hence the MNC dummy is zero).

Table 6

Type of international patent transfer 2000-2014

Dependent variable: type of first International transfer of patent (1-4)

	Multinomial Logit Estimation			
Variable	*Not a group, no tax*	*Group, no tax*	*Not a group, tax*	*Group, tax*
Patent family size (docdb)	0.200	0.183	0.176	0.220
	(0.009)	(0.008)	(0.016)	(0.012)
Number of claims	0.141	0.086	-0.078	0.030
	(0.009)	(0.008)	(0.015)	(0.009)
Number of forward citations (5yrs)	0.047	0.033	0.004	0.032
	(0.007)	(0.006)	(0.012)	(0.009)
Number of inventors	0.064	0.292	0.033	-0.055
	(0.012)	(0.010)	(0.022)	(0.016)
Number of patent holders	-1.047	-0.695	-1.158	1.547
	(0.060)	(0.051)	(0.117)	(0.032)
Age of the patent	-0.090	-0.622	-0.117	-0.766
	(0.005)	(0.004)	(0.009)	(0.005)
Applicant's patent portfolio size	-0.154	-0.085	-0.128	-0.177
	(0.003)	(0.003)	(0.006)	(0.004)
Multinational research activity	0.454	0.947	0.681	1.515
(countries per applicant >1)	(0.016)	(0.015)	(0.027)	(0.022)
Patent holder a corporation,	-0.117	-0.272	-0.097	0.708
but not an MNC	(0.016)	(0.017)	(0.033)	(0.039)
Log likelihood	-566,537.2			
Chi-squared	144,019.7			
Degrees of freedom	224			
Pseudo R-squared	0.064			

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 or tax haven country. The left-out category is no transfer

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

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.

3,428,110 observations on 343,154 patents; 104,664 transfers

Coefficient estimates are shown. Standard errors are clustered by patent. * p<0.1, ** p<0.05, *** p<0.01.

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

Our not very surprising conclusion from examining the patent level decision to transfer ownership internationally is that more valuable patents (by conventional measures) are more likely to be transferred, regardless of whether the transfer is tax-motivated or not.

8. 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, when the majority of these tax incentives were introduced. 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. The choice of priority or applicant country was unaffected, and patented inventions did not increase in the countries offering a patent box. This last result is 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. 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. 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: Simple statistics

Table A1

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 A2

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 A3

EPO patents applied for 2000-2014: Simple statistics

Variable	*Mean#*	*St.dev.*	*Median*	*IQ range*	*Min*	*Max*
			Internationally transferred patents (N=105,328)			
Family size	8.196	0.639	8	1.83	2	236
Number of claims	14.655	0.616	15	1.82	1	593
5-year forward cites	2.314	0.816	2	4.00	1	142
Number of inventors	3.340	0.431	3	2.00	1	63
Number of applicants	2.018	0.114	2	1.00	2	10
Cumulative applicant patents*	79.8	2.7	83.0	83.12	2	28,370
MNC (multi-country researcher)	0.560	0.496	1	1	0	1
Corporation, not MNC	0.345	0.475	0	1	0	1
			Patents that are not internationally transferred (N=237,826)@			
Family size	6.567	0.621	6	1.80	2	428
Number of claims	12.685	0.615	14	1.80	1	488
5-year forward cites	1.931	0.776	2	3.00	1	972
Number of inventors	3.250	0.435	3	2.00	1	54
Number of applicants	2.024	0.108	2	1.00	2	18
Cumulative applicant patents*	124.7	2.6	139.0	105.82	2	31,451
MNC (multi-country researcher)	0.435	0.496	0	1	0	1
Corporation, not MNC	0.466	0.499	0	1	0	1

	Diff	*s.e.*	*T-stat*	*Ranksum test - chisq(1)*
Family size	1.629	0.002	694.8	109.9
Number of claims	1.970	0.002	864.1	52.9
5-year forward cites	0.382	0.003	128.5	62.8
Number of inventors	0.091	0.002	56.6	18.3
Number of applicants	-0.007	0.000	-15.9	-15.6
Cumulative applicant patents	-44.839	0.010	-4572.5	-38.6
MNC (multi-country researcher)	0.125	0.002	68.2	71.9
Corporation, not MNC	-0.121	0.002	-67.8	-67.9

The geometric mean is shown for all variables except the MNC and corporation 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.

Table A4

All EPO patents applied for 2000-2014: 343,154 observations#

Correlation matrix								
Family size	1.000							
Number of claims	0.091	1.000						
5-year forward cites	0.355	0.188	1.000					
Number of inventors	0.165	0.087	0.169	1.000				
Number of applicants	0.000	0.007	0.008	0.113	1.000			
Cumulative applicant patents	0.001	-0.051	0.037	0.174	-0.079	1.000		
MNC (multi-country researcher)	0.064	-0.001	0.061	0.129	-0.062	0.736	1.000	
Corporation, not MNC	-0.045	-0.011	-0.043	-0.085	-0.064	-0.572	-0.807	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	0.306	0.150	1.000					
Number of inventors	0.113	0.062	0.130	1.000				
Number of applicants	-0.008	0.009	0.008	0.109	1.000			
Cumulative applicant patents	0.030	-0.038	0.033	0.134	-0.074	1.000		
MNC (multi-country researcher)	0.059	-0.017	0.039	0.101	-0.043	0.721	1.000	
Corporation, not MNC	-0.022	0.012	-0.015	-0.052	-0.078	-0.569	-0.799	1.000

All variables are in logs except the MNC and corporation dummies

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

Table A5

Variable means by type of transfer#

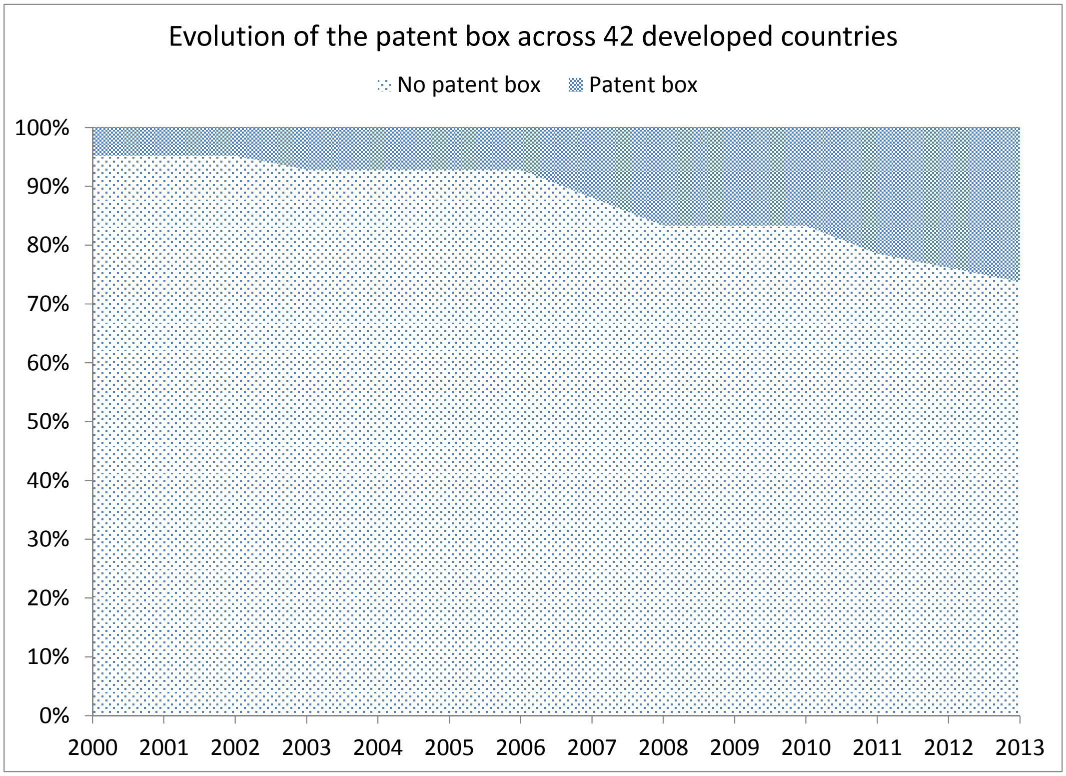
	no transfer@	*non-group, non-tax*	*group, non-tax*	*non-group, tax-related*	*group, tax-related*
Observations	237,826	34,220	40,951	11,318	18,839
Family size	6.57	8.09	8.41	7.98	8.15
Number of claims	12.69	14.70	14.77	14.11	14.72
5-year forward cites	1.93	2.27	2.36	2.26	2.34
Number of inventors	3.27	3.22	3.52	3.29	3.42
Number of applicants	2.05	2.03	2.04	2.03	2.11
Cumulative applicant patents*	120.3	44.3	113.4	75.4	120.3
MNC (multi-country researcher)	1.54	1.53	1.86	1.69	2.02
Corporation, not MNC	2.44	2.38	2.46	2.45	2.60

The geometric mean is shown for all variables except the MNC and corporation 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.

Figure A1



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 B: Additional estimates

Table B1

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)*	*All* *(4)*	*Within group* *(5)*
Buyer corporate tax rate	0.82	0.98	1.11	1.19	0.40
	(1.24)	(1.22)	(1.26)	(1.26)	(1.74)
D (buyer patent box)	-0.04				
in all years after introduction	(0.15)				
D (buyer patent box)			0.00		
in year of introduction			(0.11)		
D (buyer patent box)			0.17		
in year after introduction			(0.22)		
D (buyer patent box)			0.39*		
two years after introduction			(0.23)		
Buyer patent tax rate wedge		0.12			
in all years after introduction		(0.74)			
Buyer patent tax rate wedge				0.18	0.20
in year of introduction				(0.64)	(0.84)
Buyer patent tax rate wedge				1.14	1.68
in year after introduction				(1.39)	(1.52)
Buyer patent tax rate wedge				2.28*	3.19**
two years after introduction				(1.25)	(1.42)
Seller corporate tax rate	0.90	1.03	0.98	1.08	0.93
	(1.15)	(1.13)	(1.13)	(1.11)	(1.39)
D (seller patent box)	-0.28**		-0.26**		
	(0.13)		(0.13)		
Seller patent tax rate wedge		-1.32**		-1.26*	-1.88**
		(0.65)		(0.64)	(0.80)
Chi-squared	12829.9	11975.8	11957.8	11956.1	11028.3
Degrees of freedom	92	92	94	94	94

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 B2

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)*	*All* *(4)*	*All* *(5)*	*Within group* *(6)*	*Within group* *(7)*
Difference:	0.05	0.05	0.22	0.20	-0.37	0.61	0.27
seller corp tax-buyer corp tax	(0.84)	(0.85)	(0.86)	(0.86)	(0.94)	(1.08)	(1.23)
Difference:	0.62	0.83	0.19	1.33**	0.34	1.85**	0.47
buyer-seller patent tax wedge	(0.49)	(0.64)	(0.56)	(0.61)	(0.55)	(0.84)	(0.73)
D (existing patents) * buyer- seller patent tax wedge		-0.38					
D (acqired patents) * buyer- seller patent tax wedge			1.54				
D (dev condition on use)*buyer-				-1.88*		-2.29*	
seller patent tax wedge				(1.03)		(1.29)	
D (CFC rules apply to buyer)					-0.25		-0.14
					(0.19)		(0.25)
D (CFC) * seller-buyer corp					2.30*		0.58
tax difference					(1.29)		(1.60)
D (CFC) * buyer-seller patent					1.30		2.17*
box difference					(1.02)		(1.24)
Chi-squared	11777.7	11585.1	12474.6	12401.3	11447.9	10061.1	9920.0
Degrees of freedom	90	91	91	91	93	91	93

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 B3

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.

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:

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

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*. We use the semi-parametric Cox model for *h(t)*.