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## ABSTRACT

### Corporate taxes and the location of intellectual property\*

The literature suggests that tax rates on mobile activities should fall to zero. Intellectual property is very mobile and has grown in importance. Firms can use intellectual property to shift income offshore and reduce their corporate income tax liability. Yet most intellectual property is held in relatively high tax countries. We estimate the impact of corporate taxes on where firms hold patents. We consider domestic and international taxes, and control for the potential non-tax costs and benefits associated with different locations. We allow heterogeneity across industries, firm size and, most importantly, unobservable patent specific heterogeneity in the responsiveness of patent location to tax. Our results suggest that, on average, corporate tax rates have a negative impact on the likelihood of a firm choosing a location, and that there is substantial heterogeneity in responses. We simulate the impact of recent reforms that apply a lower tax rate to patent income, finding that they attract patent income but result in losses in government revenues.

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# 1 Introduction

The taxation of corporate income is an issue that has vexed academics and policymakers for some considerable time. There is a considerable theoretical literature that predicts that there should be downward pressure on taxes on mobile factors of production (see surveys in Wilson (1999) and Fuest et al (2005)). The growing importance of intellectual property as a factor in production<sup>1</sup> presents increased challenges; it is more difficult for governments to identify the tax liability on income associated with intellectual property and easier for firms to relocate taxable income. As noted by a tax lawyer quoted in the New York Times, “... *most of the assets that are going to be reallocated as part of a global repositioning are intellectual property ... that is where most of the profit is.*”<sup>2</sup>

However, firms do not by and large hold intellectual property in the lowest tax countries, and in fact relatively little intellectual property is held in tax havens.<sup>3</sup> In this paper we estimate the impact of corporate income tax on innovative European firms’ choices over where to hold patents, an important form of intellectual property. We take account of both the costs and benefits that a firm trades off when selecting where to hold its intellectual property. The country with the lowest tax rate will not always be chosen, for example, because anti-profit shifting rules may diminish the tax benefits of selecting a low tax location, while costs, such as those needed to establish a subsidiary to hold intellectual property, may make a higher tax country more attractive.

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<sup>1</sup> OECD (2006, p34) describes the growing significance of intellectual property and its simultaneous use by many different parts of a firm as “one of the most important commercial developments in recent decades”. NESTA (2009) estimates that in the UK knowledge investment overtook fixed capital investment in the mid-1990s and is now about 50% higher.

<sup>2</sup> See “Key Company Assets Moving Offshore,” New York Times, Nov. 22, 2002.

<sup>3</sup> See Appendix A, section A.1.

We expect there to be considerable heterogeneity in where patents are located and how responsive such choices are to tax. Our contribution is to estimate an empirical model of location choice of intellectual property that controls for observable firm and patent characteristics and location specific factors, and importantly also allows for unobservable heterogeneity in the responsiveness of location choices to tax. This allows us to estimate more realistic substitution patterns that do not exhibit the restrictive Independence of Irrelevant Alternatives (IIA) property present in standard multinomial logit models. The use of these models is now common in many areas of economics, for example, transport (McFadden (1974) and Train (2003)) and demand (Berry, Levinsohn and Pakes (1995, 2004), Nevo (2001)).<sup>4</sup> Our model yields estimates of both own and cross tax elasticities of location choice that are location specific and a function of the tax rates firms face in all locations. This extends the current empirical literature on firms' responsiveness to tax, which typically estimates more restrictive elasticities.<sup>5</sup>

We simulate the impact of recent reforms in several European countries that give preferential tax treatment to income arising from patents (Patent Boxes). We find that they are likely to have significant effects on the location of new intellectual property, and are likely to lead to substantial reductions in tax revenue.

A patent is a legal document that grants a firm the exclusive rights to use (or license) a novel technology for a specified period of time and thus confers the ability to earn income. While tax laws constrain the extent to which firms can lower their tax bill through location decisions, it is nonetheless possible for firms to hold patents at distance from their headquarters, to the location where the underlying technology was created and to the location

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<sup>4</sup> For a recent application of a discrete choice model to firms' location decisions see Cohen (2009).

<sup>5</sup> Most papers in the current empirical literature on capital mobility and location choice estimate (or use) a single estimate of the responsiveness of location choice (usually of capital) to tax that does not vary across countries and that is invariant to tax policy changes.

where it will be applied.<sup>6</sup> Indeed, the share of European Patent Office (EPO) patent applications that UK multinationals hold in offshore subsidiaries increased from 8% in 1985 to 30% by 2005. The location of the subsidiary in which a firm holds a patent will in part determine where the income from the patent is taxed, providing firms with an opportunity to reduce tax payments by holding a patent in a lower tax jurisdiction. For example, Microsoft reportedly saved at least \$500m in taxes by licensing its intellectual property from an Irish subsidiary.<sup>7</sup> There are also important interactions between tax jurisdictions as a result of anti-profit shifting rules that can reduce or remove the tax benefits of locating a patent in a lower tax country. For example, transfer pricing rules can limit the incentive to shift the income associated with a given patent.<sup>8</sup> In addition, many countries operate Controlled Foreign Company (CFC) regimes that aim to prevent some forms of tax motivated profit shifting; in some cases the income a firm holds in an offshore subsidiary can be liable for additional tax in the home country. Our measure of the tax rate that a firm faces explicitly accounts for the presence of CFC regimes.

We expect heterogeneity in the responsiveness of each individual patent location decision to tax. For instance, the responsiveness may vary across patents depending on the expected net present value of the patent. The benefit of a lower tax rate and therefore the incentives to achieve this by attempting to circumvent any anti-profit shifting rules, will be increasing in the expected net present pre-tax value of a patent. At the same time, there may be costs associated with locating a patent in a low tax jurisdiction, some of which may be related to the patent's expected net present value. For example, the higher a patent's expected net

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<sup>6</sup> Lipsey (2008) notes that, in multinational firms, intangible assets “have no clear geographical location, but only a nominal location determined by the parent company's tax or legal strategies”.

<sup>7</sup> Simpson, Glenn R. “Irish Subsidiary Lets Microsoft Slash Taxes in U.S. and Europe.” *The Wall Street Journal*, November 7, 2005, p.A1. Ireland has a substantially lower tax rate than other European countries.

<sup>8</sup> A firm may earn income from a patent in a higher tax country and make royalty payments to a subsidiary in a lower tax country. The payments made between subsidiaries are subject to transfer pricing rules, which aim to ensure that the prices of transactions between entities within the same group are those that would result from transactions between unrelated parties.

present value, the larger the incentive for tax authorities to enforce transfer pricing rules thereby potentially diminishing the firm's ability to transfer income to a lower tax country. These patent characteristics are unobservable to the econometrician.

Tax will not be the only factor influencing location choice. Firms may also incur both costs (in addition to their tax liability) and benefits depending on where a patent is held. That is, non-tax characteristics of countries can make a location a more or less attractive place to hold patent income. Such characteristics include, for example, the costs (both material and legal) of establishing and maintaining an entity to manage intellectual property (for example a subsidiary). This means that some firms may choose a higher tax location if they place a high value on the country's characteristics (for example public goods provision or institutions). Krautheim and Schmidt-Eisenlohr (2010) presents a model which implies that, when there are fixed costs (net of benefits) to locating patents offshore and profits differ across patents (either as a result of heterogeneous costs of creating patent income or heterogeneous patent values), it will only be beneficial for firms to locate some patents in low tax countries.

There are also important firm characteristics that affect the costs a firm faces when deciding where to locate a patent.<sup>9</sup> In particular, firms differ in their organisational structure (for example in their network of subsidiaries, the size and proficiency of their legal and tax departments, and existing relationships with tax authorities), in the strategies they employ (for example in relation to how they manage patent income for tax purposes), in the countries in which they are headquartered (which differ in the stringency of their tax rules and effectiveness with which they are applied) and in the markets in which they operate (which will be relevant if, for example, markets with many market-based transactions make it easier for tax authorities to enforce transfer prices that more closely reflect underlying value than if

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<sup>9</sup> A number of papers have emphasised the importance of incorporating heterogeneity in firms' decisions. See for example Melitz (2003), Bernard, Redding and Schott (2007a,b).



most trade is intra-firm). In addition, both firm size and industry have been highlighted as important in the context of firms making decisions over how to organise their offshore activities. For instance, Graham and Tucker (2006) shows that larger firms use tax haven operations more intensively. Desai, Foley, and Hines (2006) also find this and additionally highlight the importance of other characteristics, notably industry.<sup>10</sup> Indeed, the values of patents, the relative attractiveness of locations and firms' strategies and organisational structures are likely to vary across industries and, within industries, according to firm size. This variation is captured in both the observed and unobserved heterogeneity that we allow for.

Our paper is novel in directly considering the impact of taxes on the location of intellectual property.<sup>11</sup> Most of the literature on the impact of tax on firm location choices has focussed on real activity, notably the location of production, with a few considering the location of R&D.<sup>12</sup> The literature on income shifting by firms to minimise tax has tended to look at tangible capital, with less, and often only indirect, evidence on the importance of intangibles in firms' strategies, and in both cases almost exclusively providing evidence on US firms.<sup>13</sup> However, the existing evidence suggests a particularly important role for intangible assets. For example, Grubert (2003) formalises how intangible assets can be used to shift income

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<sup>10</sup> Desai, Foley, and Hines (2006) show that industries in which a large proportion of total sales are to related parties offshore have a higher presence of subsidiaries in tax havens.

<sup>11</sup> Our work relates to the literature on the impact of tax when a project incurs costs and earns profits in the same location, in the Hall and Jorgenson (1967) tradition, including Auerbach (1979), Devereux and Griffith (2003).

<sup>12</sup> Devereux (2006) provides a survey of the empirical literature. See also, *inter alia*, Hall (1993), Devereux and Griffith (1998, 2000), and Bloom, Griffith and Van Reenen (2002). A recent exception, Karkinsky and Riedel (2009), considers the location of patents within a multinational group in a reduced form model.

<sup>13</sup> A review article, Hines (1996), sets out this body of work. See also Hines (1999). On tangible capital see Grubert and Mutti (1991), Hines and Rice (1994), Altshuler and Grubert (2006). Studies focusing on indirect evidence have looked at firms' relative profitability in low tax countries; the share of royalty payments associated with low tax countries; the tax liabilities of foreign affiliates.

and finds that about half of the income shifted from high-tax to low-tax countries by US manufacturing firms can be accounted for by income from R&D linked intangibles.<sup>14</sup>

We proceed in Section 2 by outlining a model of firms' decisions over where to hold patents that explicitly incorporates the tax rate firms will face in their chosen location (including the impact of CFC regimes), location specific fixed costs and unobserved firm and patent heterogeneity. In Section 3 we provide an overview of the data, which is discussed in detail in Appendix A. Section 4 presents the estimation results, including the own- and cross-tax elasticities between locations. Simulations of recent reforms that reduce the tax rate for patent income are presented in Section 5 and a final section summarises and concludes.

## **2 Model**

We model a firm's choice over where to hold a new patent for tax purposes. In the introduction we outlined a number of reasons why the responsiveness of patent location decisions to corporate tax is likely to vary both between firms and, within firms, across patents. We capture this heterogeneity in two ways. Firstly, we allow all coefficients in the model to vary according to firm size and industry classification of a patent. Secondly, and most importantly, we capture unobservable patent specific factors by including random coefficients which allow for variation in the impact of tax across individual patents. We account for the many non-tax factors that influence a firm's decision over where to hold a patent by allowing for fixed costs (and benefits) associated with locating in a country that are common across patents but can differ by country.

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<sup>14</sup>A recent paper, Dyreng, Lindsey and Thornock (2011), considers how tax rates and rules affect the state in which US subsidiaries incorporate. They find that firms hold intangible assets in Delaware (where they are untaxed) in order to make payments from high tax entities and thereby reduce tax payments.

## 2.1 Firm behaviour

Let  $i \in (1, \dots, I)$  index firms,  $t$  denote time,  $p \in (1, \dots, P) \equiv \Omega$  index patents, and  $j \in (1, \dots, J)$  index the location of a patent. Consider a firm,  $i$ , that at time  $t$  faces the decision of where to locate patent  $p$ , which has an expected net present pre-tax value  $\tilde{V}_p$ .  $\tilde{V}_p$  denotes the expected present value net of any patent specific costs. Let  $\tau_{ijt}$  denote the tax rate at time  $t$  levied on patent income attributed to a subsidiary in location  $j$  and associated with parent firm  $i$ . The inclusion of an  $i$  subscript on the tax rate captures the fact that the tax system in a firm's residence country may interact with that of the country in which the patent is held through operation of Controlled Foreign Company rules (see Appendix A.2.2 for details). We assume that when a firm chooses the location of a patent it makes its decision under the assumption that the current tax regime will remain unchanged.

We assume that for each patent location decision there is a cost that firm  $i$  incurs when locating the patent,  $C(\tilde{V}_p, X_i)$ . This includes, for instance, attempting to circumvent transfer pricing rules when locating patent  $p$ . The size of this cost can depend on the expected net present pre-tax value of the patent,  $\tilde{V}_p$  – the higher a patent's expected value, the larger the incentive for tax authorities to enforce transfer pricing rules and for the firm to attempt to get round them. It can also depend on a vector of firm characteristics,  $X_i$ , that influence the cost associated with locating a patent, including the firm's resident country – some countries operate more stringent or more effective transfer pricing rules; the firm's corporate and financial structure – some firms are organised in ways and have resources that are more conducive to locating a patent at a relatively low cost; the market that a firm operates in – transfer pricing rules may be stricter in markets with more market based transactions. We impose the restriction that  $C(\tilde{V}_p, X_i)$  does not vary across locations.

We also assume that there are some fixed costs (net of any benefits) to firm  $i$  of locating patent  $p$  (in year  $t$ ) in location  $j$ ,  $F_{ipjt}$ . This captures both location specific costs of locating in  $j$  – such as the legal costs associated with setting up a subsidiary – net of any location specific benefits – such as services provided from government tax revenues.

Hence the payoff to firm  $i$  of locating patent  $p$  in location  $j$  in year  $t$ , is given by:

$$\Pi_{ipjt}(\tilde{V}_p, X_i, \tau_{ijt}, F_{ipjt}) = (1 - \tau_{ijt})\tilde{V}_p - C(\tilde{V}_p, X_i) - F_{ipjt}$$

The firm will choose to locate the patent in location  $j$  if:

$$\Pi_{ipjt}(\tilde{V}_p, X_i, \tau_{ijt}, F_{ipjt}) \geq \Pi_{ipkt}(\tilde{V}_p, X_i, \tau_{ikt}, F_{ipkt}) \quad \forall k \neq j$$

Notice that without the location specific net fixed cost  $F_{ipjt}$  each firm would locate each of its patents in the location in which they face the lowest tax rate.<sup>15</sup> However, given the presence of the net fixed costs,  $F_{ipjt}$ , the location in which a patent is placed depends on both the after tax expected net present value of the patent and the importance of these fixed costs. For example, a firm may choose not to locate a patent in a location in which it would face the lowest tax rate (and instead to locate it in a higher tax location) if the expected net pre-tax value of the patent is relatively low and/or the net fixed cost associated with locating in the country is relatively high. The determinants of location choice are such that, within firms, not all patents will necessarily be held in the same location.

## 2.2 Empirical specification

From this description of behaviour we specify an empirical model that relates corporate income taxes to the location of patents. Firstly, we split the set of patents into three mutually exhaustive subsets  $\{R_r \subset \Omega: r \in \{1,2,3\}\}$ , such that patent  $p$  belongs to the subset  $R_r$  if it is

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<sup>15</sup> The country in which a firm faces the lowest tax rate may not be the country with the lowest statutory tax rate if the firm is subject to binding CFC rules.

classified in industry  $r$ , and we define a partition  $\{S_s \subset \Omega: s \in \{1,2\}\}$ , such that  $p \in S_s$  if parent firm  $i$ , which owns patent  $p$ , is of size  $s$ .

Secondly, we assume that net fixed costs take the form:

$$F_{ipjt} = \gamma_{rsj} + e_{ipjt}$$

where  $\gamma_{rsj}$  captures unobserved factors that influence the attractiveness of location  $j$  and are constrained to be common across patents within an industry-firm size grouping.  $e_{ipjt}$  is an idiosyncratic shock which we assume is distributed i.i.d. extreme value.

Thirdly, to allow the responsiveness of patent location to tax to depend on the expected net present value of the patent,  $\tilde{V}_p$ , which is unobservable to the econometrician, we include random coefficients on tax. In particular the responsiveness of patent location to tax is determined by  $\mu_{rs} + \sigma_{rs}\eta_p$ , where  $\mu_{rs}$  captures the mean responsiveness of patents in industry  $r$  and firm size grouping  $s$ ,  $\sigma_{rs}$  captures the standard deviation from this mean and  $\eta_p \sim N(0,1)$ . This specification allows the importance of tax in determining location choice to vary across patents in a flexible way; for  $p \in R_r \cap S_s$ , the random coefficient,  $\eta_p$ , allows for variation in responsiveness of location choice to tax along unobservable dimensions. We allow the distribution of responsiveness to differ for each subset of patents  $R_r \cap S_s \forall (r, s)$ .<sup>16</sup>

Together these assumptions imply the following empirical specification for (1):

$$\pi_{ipjt} = \varphi_{ipt} - (\mu_{rs} + \sigma_{rs}\eta_p)\tau_{ijt} - (\gamma_{rsj} + e_{ipjt}) \quad (2)$$

where:  $e_{ipjt} \sim i.i.d. \text{ extreme value}$  and  $\eta_p \sim N(0,1)$ .  $\varphi_{ipt}$  captures both the expected pre-tax net present value of the patent ( $\tilde{V}_p$ ) and the patent-firm fixed costs associated with locating

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<sup>16</sup> This means the random coefficient on the tax rate comprises six normal distributions. This allows the model to more flexibly capture underlying unobserved heterogeneity relative to the standard approach of using one parametric distribution. For further discussion see Burda et al (2008) and Fiebig et al (2010).

patent  $p$  ( $C(\cdot)$ ). As  $\varphi_{ipt}$  does not vary across locations it is not identified and differences out when comparisons are made across location. We estimate the model parameters,  $(\mu_{rs}, \sigma_{rs}, \gamma_{rsj}) \forall (r, s)$  and  $j$ , using maximum likelihood.<sup>17</sup>

It is possible to interact the tax variable with other observable characteristics, allowing the mean affect of tax on location choice to vary along other observable dimensions. However, the existing discrete choice literature (see Berry, Levinsohn and Pakes (2004)) has emphasised that accounting for unobservable heterogeneity through the inclusion of random coefficients is much more important when the objective is to realistically capture substitution patterns.

### 2.3 Elasticities

The coefficient estimates allow us to calculate own and cross tax elasticities of location choice. These are a function of tax rates in all countries and vary across patents, firms, locations and time. Denote the unconditional probability that firm  $i$  chooses to locate patent  $p$  (in year  $t$ ) in location  $j$  where it faces a tax rate  $\tau_{ijt}$  as

$$Pr_{ipjt} = \int L_{ipjt}(\tau_{ijt}, \theta_1, \theta_2) \phi(\theta_2) d\theta_2$$

where  $\theta_1$  is the vector of non-stochastic coefficients  $(\mu_{rs}, \sigma_{rs}, \gamma_{rsj})$  and  $\theta_2$  the vector of stochastic variables  $(\eta_p)$ .  $L_{ipjt}(\tau_{ijt}, \theta_1, \theta_2)$  is the probability that firm  $i$  chooses to locate patent  $p$  (in year  $t$ ) in location  $j$  conditional on  $\theta_2$ :

$$L_{ipjt}(\tau_{ijt}, \theta_1, \theta_2) = \frac{e^{\pi_{ipjt}(\tau_{ijt}, \theta_1, \theta_2)}}{\sum_k e^{\pi_{ipkt}(\tau_{ikt}, \theta_1, \theta_2)}}$$

where  $\pi_{ipjt}(\cdot)$  is the payoff function in (2).

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<sup>17</sup> Evaluation of the log-likelihood function requires numerical integration over the distribution of the random coefficients. We do this using a Gauss-Hermite quadrature rule.

The location  $j$  tax elasticity for firm  $i$ , patent  $p$ , in year  $t$  is given by:

$$\epsilon_{ipjt} = \frac{\partial Pr_{ipjt}}{\partial \tau_{ijt}} \frac{\tau_{ijt}}{Pr_{ipjt}}.$$

This contrasts with the standard multinomial logit elasticity, which is given by  $\mu_{rs}\tau_{ijt} (1 - L_{ipjt}(\tau_{ijt}, \theta_1))$ , where  $L_{ipjt}(\tau_{ijt}, \theta_1)$  is the *unconditional* probability of locating patent  $p$  in location  $j$ .<sup>18</sup> The multinomial logit model imposes that the elasticity is approximately proportional to the tax rate, while the random coefficients (or mixed logit) model that we estimate is much less restrictive and is able to capture variation in substitution patterns between countries.

The cross tax elasticity for location  $j$  with respect to the tax rate in location  $k$  for firm  $i$ , patent  $p$  at time  $t$  is given by

$$\epsilon_{ipjkt} = \frac{\partial Pr_{ipjt}}{\partial \tau_{ikt}} \frac{\tau_{ikt}}{Pr_{ipjt}},$$

Like the own tax elasticity, this is much more flexible than that implied by the standard multinomial logit model.<sup>19</sup> Aggregating these elasticities across patents yields the market level or aggregate elasticities.

### 3 Data

To estimate the model we need information on the location of firms' patent holdings and the tax rates they faced. We measure the location of firms' patent holdings using the legal address of the subsidiary that files the patent application. The tax liability on patent income will depend predominately on the tax rate in the country where the patent is held (the source

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<sup>18</sup> In this case the firm's payoff function is given by  $\pi_{ipjt}(\tau_{ijt}, \theta_1) = \varphi_{ipt} - \mu_{rs}\tau_{ijt} - (\gamma_{rsj} + e_{ipjt})$

<sup>19</sup> The cross tax elasticity in a multinomial logit model is given by  $\epsilon_{ipjkt} = \mu_{rs}\tau_{ikt}L_{ipkt}(\tau_{ikt}, \theta_1)$ . Notice that this does not vary with  $j$ .

country) and, potentially, on CFC rules operated by firms' home countries, both of which we measure. The data are described in detail in Appendix A.

### **3.1 Firms and patent location**

We measure where a patent is held for tax purposes using the country of residence of the applicant listed on the patent application. The applicant is the entity which legally holds the patent, and will therefore be liable for tax on associated income. We have matched the applicants from 14 European countries and the US to their European parent firms, as recorded in firm accounts data.

We classify patent applications into one or more of three broad industry groups – Chemical, Electrical and Engineering – based on the technology embodied in the patent as well the markets in which the technology has an application using Thomson's Derwent database. Within each industry we exclude firms that only patent infrequently (measured as those below the 20th percentile in terms of the number of patents per firm in their industry).

Our data include 639 parent firms that collectively have 4,740 patenting subsidiaries, which file 233,471 patent applications over the period 1985-2005. Appendix A Table A.1 describes the breakdown of firms, subsidiaries and patent applications by the country of the parent firm. Within each industry we distinguish *large firms* as those with a level of patenting above the 80th percentile of the distribution of number of patents per firm. The resulting numbers of patent applications and firms in each industry-firm size group are shown in Table 1.

**Table 1: Number of patent applications and firms by industry and firm size**

Industry	Large firms		Medium firms	
	Patent applications	Firms	Patent applications	Firms
Chemical	81,268	124	23,307	480
Electrical	93,473	125	22,335	490
Engineering	64,811	149	26,063	480

*Notes: The total number of patent applications sums to more than the 233,471 cited in the text because patents can be classified into multiple industries. Likewise, firms can operate in multiple industries. Large firm are those associated with a total number of patent applications above the 80th percentile in each industry.*



Appendix A Table A.2 further describes the numbers of patent applications in each industry-firm size group by country of the applicant.

### **3.2 Taxes**

Patent income is primarily taxed at the statutory corporate tax rate in the source country (the location of the subsidiary). Firms can subsequently sell a patent meaning the income will no longer be taxed in the country of the patent applicant; we assume that at the time of filing the application the firm does not expect to do this.<sup>20</sup>

There are important interactions between tax jurisdictions. Specifically, there can be additional tax levied in the parent firm's home country, as a result of Controlled Foreign Companies (CFC) rules, which aim to prevent firms locating income in lower tax countries in order to avoid taxation in their home country. CFC regimes differ across countries. Broadly they set out criteria for identifying subsidiaries that are located offshore but with income that has been artificially diverted and that therefore will be subject to tax in the parent firm's residence country (with a credit for foreign tax paid). One of the key criteria is that the subsidiary is located in a (source) country that is deemed to be 'low-tax' (as judged against home country specific thresholds). Further details on the operation of CFC regime and the thresholds for identifying 'low tax' countries are given in Appendix A section A.2.2.

For each residence country that operates a CFC regime we identify the source countries that would be deemed low tax. We then define the tax variable,  $\tau_{ijt}$ , at time  $t$  as equal to the source country tax rate or the residence country's statutory rate if a CFC regime is in place and the source country in which the patent is located is deemed a 'low tax' location. We consider the

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<sup>20</sup> There can be tax penalties involved in transferring patents to a different subsidiary. Selling a patent to a foreign subsidiary will generally attract an exit tax, which taxes the gain in value of the patent since it was originally acquired. Broadly, the value at the point of transfer should represent the net present value of the expected revenue stream from that point forward. This means that subsequently transferring a patent to a low tax location will not necessarily reduce the firm's tax liability.

tax regime in place at the time that the firm applies for the patent, thus assuming the firm expects this regime to remain unchanged in the future.

We use variation over time and across countries in the tax rate that firms face in different locations to identify both the mean effect of tax on location choice and the standard deviation of the random coefficient. There is variation in statutory tax rates across countries and over time, see Appendix A Table A.3. There is also variation in whether a residence country operates a CFC regime (some regimes are introduced during the period for which we have data) and in which source countries are deemed low tax (which differ over time when statutory rates change), see Appendix A Table A.4.

In recent years, some European countries have introduced Patent Boxes, which levy a lower rate of corporate tax on the income derived from patents. In 2007 Belgium introduced a Patent Box which entails a rate of 6.8% and the Netherlands introduced one with a 10% rate. In 2008 Luxembourg adopted a Patent Box which introduced a rate of 5.9% for patent income and in 2013 the UK will introduce a 10% rate.<sup>21</sup> Appendix A Table A.5 gives details of these policies. We use these Patent Box tax rates when simulating the effects of the introduction of Patent Boxes.

## **4 Results**

To estimate the affect of corporate tax on the location of patents, controlling for other potentially confounding observed and unobserved factors, we estimate a model of the form described in Section 2. To highlight the importance of unobserved heterogeneity we report results from a multinomial logit specification that does not include unobservable heterogeneity in the tax coefficient, alongside our main random coefficients (mixed logit)

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<sup>21</sup> For information on the UK's plan to introduce a Patent Box see HM Treasury (2010) and for the authors' response see Griffith and Miller (2010, 2011). For additional discussion of the forthcoming UK Patent Box in the context of the results from this paper see Griffith, Miller and O'Connell (2010).

specification. An observation is a single decision that a firm  $i$  made over where to hold the intellectual property for patent  $p$  in year  $t$ , choosing between locations  $j=1,\dots,J$ . We consider a firm's decision conditional on having made an innovative discovery. As described above, we estimate the model allowing all coefficients to vary according to which of the three industries (Chemical, Electrical and Engineering) and firm size group (large and medium) the patent is classified in.<sup>22</sup> This allows the mean and standard deviation of the tax random coefficient and the location specific factors to vary along these dimensions. As described in Section 2, the model controls for any firm or patent specific factors that directly influence location choice, but are constant across locations.<sup>23</sup>

Table 2 reports our estimates. Column (1) presents coefficient estimates from a multinomial logit model, including tax as the only regressor. We expect there may be other factors (both costs and benefits) that affect firms' location choice, which vary across countries and may be correlated with tax. For example, firms may be attracted by the services countries offer, some of which may be funded from taxation. Many of these non-tax factors are likely to be constant over time. Therefore we control for them through the addition of country fixed effects (which we allow to vary by industry-firm size group) in the regressions reported in columns (2) and (3). We find that the fixed effects are all statistically significant and that their relative size differs across firm size and industry, indicating the importance of allowing heterogeneity in these dimensions. In column (2) the tax coefficients become more negative, and are statistically significant suggesting that country characteristics are positively correlated with higher statutory tax rates and cause upward bias when not included.

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<sup>22</sup> This is equivalent to estimating 6 separate regressions; one for each industry-firm size grouping.

<sup>23</sup> As these factors do not vary across location, they difference out when comparisons are made across locations and are therefore are not identified.

**Table 2: Estimated parameters**

	<i>Multinomial logit</i>	<i>Multinomial logit</i>	<i>Random coeff. logit</i>
	(1)	(2)	(3)
<i>Chemical Industry</i>			
<i>Large firms</i>			
Tax rate, Mean	-0.04 (0.04)	-1.42 (0.09)**	-4.00 (0.14)**
Tax rate, Std Dev	-	-	8.85 (0.20)**
<i>Medium firms</i>			
Tax rate, Mean	-0.55 (0.08)**	-2.67 (0.18)**	-3.30 (0.22)**
Tax rate, Std Dev	-	-	4.06 (0.39)**
<i>Electrical Industry</i>			
<i>Large firms</i>			
Tax rate, Mean	0.59 (0.04)**	-3.17 (0.09)**	-5.01 (0.12)**
Tax rate, Std Dev	-	-	6.80 (0.16)**
<i>Medium firms</i>			
Tax rate, Mean	-1.11 (.08)**	-4.48 (0.19)**	-5.17 (0.27)**
Tax rate, Std Dev	-	-	3.52 (0.51)**
<i>Engineering industry</i>			
<i>Large firms</i>			
Tax rate, Mean	0.44 (0.05)**	-1.80 (0.11)**	-2.60 (0.13)**
Tax rate, Std Dev	-	-	4.66 (0.23)**
<i>Medium firms</i>			
Tax rate, Mean	-0.15 (0.07)*	-2.98 (0.16)**	-3.76 (0.21)**
Tax rate, Std Dev	-	-	4.20 (0.39)**
Industry-firm size specific			
country fixed effects	no	yes	yes

Notes: Estimation is conducted using 311,257 observations. Standard errors in parentheses; \* significant at 5%; \*\* significant at 1%. Large firm are those associated with a total number of patent applications above the 80th percentile in each industry. The numbers of observations in each of the industry-firm size groupings is reported in Table 1. Country fixed effects – which vary by industry-firm size grouping – are not reported, but are available on request.

The multinomial logit specification imposes that the responsiveness of location choice to tax is the same across all patents in the industry–firm size group, creating very restrictive substitution patterns. However, we expect different firms and, within firms, different patents

to respond heterogeneously to tax, depending on unobserved factors. Column (3) reports results when we allow for unobserved heterogeneity through the inclusion of random coefficients. The estimated mean effects of tax increase in absolute terms compared to the multinomial logit. The standard deviations for the random coefficients are large and statistically significant.

The estimates of the main random coefficients specification suggest substantial variation in the responsiveness of location choice to tax, which is not captured by observable characteristics. Considering the six random coefficients together we calculate that a marginal increase in the tax rate faced by firms in a location will lead to a reduction in the probability of locating there (*ceteris paribus*) for 75% of the patents in our data.<sup>24</sup> This varies by firm size and industry. The overall effect of a change in the tax rate on the probability of choosing a location is captured by the elasticities, which, as shown below, are negative for all locations.

We use the coefficient estimates from the random coefficients logit model to calculate the own and cross tax elasticities of location choice with respect to tax for all patents, as outlined in Section 2.3. Aggregating over the patent specific elasticities we obtain market level or aggregate elasticities.

Table 3 presents market elasticities for the most recent year in our data – 2005. Each cell shows the change in the share of patents located in the country indicated in column 1 when the tax rate set by countries indicated in row 1 changes. Cells on the diagonal (in bold) are the own tax elasticities; as expected, these are negative. For the majority of countries they are greater than one, indicating that a 1% increase in the rate of tax faced by firms in a particular location will induce a (slightly) greater than 1% reduction in the share of patents locating

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<sup>24</sup> Within each industry-firm size group we use the estimated parameters for the normally distributed random coefficient to calculate the proportion of patents with a negative response to tax. We compute the total proportion of all patents with negative responsiveness as the average across the six distribution (one from each industry-firm size group), weighted by the proportion of patents in that group.

there. The off-diagonal cells contain the cross tax elasticities, the majority of which are positive, indicating that the different locations are substitutes as one would expect.<sup>25</sup> When we measure the tax rate and compute the elasticities in Table 3 we account for the presence of CFC regimes. Not doing so is akin to incorrectly assuming that all firms face the statutory tax rate in the source country. However, if a country deemed to be ‘low-tax’ by CFC regimes, for instance Ireland, were to reduce its statutory tax rate we would not expect firms subject to a CFC regime to respond: UK resident firms will still face the UK statutory rate if they locate in Ireland. Not including the effect of CFC regimes in the calculation of the elasticity would result in higher reported elasticities for those countries that are deemed ‘low tax’ in other countries’ CFC regimes, and since the elasticities of each country are a function of taxes in all other countries, would also alter the calculated elasticities of other countries.

#### ***4.1 Importance of including unobserved heterogeneity***

A key strength of our model is that we allow unobservable characteristics to affect how responsive the location of patents are to tax, meaning that our model generates more realistic substitution patterns than standard multinomial models. In contrast, the multinomial logit model imposes restrictive substitution patterns. To highlight this, Table 4 presents the market elasticities generated through estimating a standard multinomial logit model on all the patents in our data, with tax and fixed effects as right-hand side variables (i.e. the equivalent column (2) in Table 2 but imposing common coefficients across industry and size class). To accentuate the point we have also shut off the CFC regimes.<sup>26</sup>

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<sup>25</sup> There are five cross-tax elasticities which are negative, but very close to zero.

<sup>26</sup> Incorporating CFC regimes into the computation of the multinomial logit elasticities would introduce a limited amount of heterogeneity. In particular the cross tax elasticities for a change in the tax rate in Ireland (or Switzerland) would differ across countries depending on whether they operated a CFC regime that deemed Ireland (or Switzerland) a ‘low tax’ location, or not.

**Table 3: Own and cross tax elasticities; random coefficients model, accounting for CFC regimes**

<i>Location country</i>	<i>Country changing tax rate</i>														
	Belgium	Denmark	Finland	France	Germany	Ireland	Italy	Luxembourg	Netherlands	Norway	Spain	Sweden	Switzerland	UK	US
Belgium	<b>-1.006</b>	0.031	0.051	0.171	0.026	0.001	0.042	0.006	0.168	0.006	0.004	0.080	0.111	0.143	-0.012
Denmark	0.064	<b>-1.375</b>	0.056	0.261	0.076	0.001	0.089	0.011	0.228	0.011	0.007	0.109	0.193	0.257	0.038
Finland	0.055	0.030	<b>-1.568</b>	0.471	0.112	0.001	0.062	0.005	0.486	0.006	0.004	0.193	0.147	0.202	0.054
France	0.030	0.023	0.077	<b>-0.917</b>	0.035	0.000	0.031	0.003	0.232	0.004	0.002	0.097	0.095	0.124	0.000
Germany	0.011	0.016	0.046	0.087	<b>-0.642</b>	0.000	0.016	0.003	0.109	0.004	0.002	0.060	0.069	0.080	-0.053
Ireland	0.082	0.081	0.083	0.311	0.094	<b>-0.768</b>	0.129	0.017	0.252	0.016	0.014	0.136	0.461	0.318	0.053
Italy	0.028	0.029	0.038	0.117	0.025	0.001	<b>-0.842</b>	0.008	0.089	0.008	0.005	0.064	0.091	0.132	-0.014
Luxembourg	0.058	0.056	0.045	0.194	0.074	0.001	0.124	<b>-1.299</b>	0.129	0.013	0.010	0.089	0.160	0.242	0.028
Netherlands	0.038	0.025	0.103	0.301	0.056	0.000	0.030	0.003	<b>-1.067</b>	0.004	0.002	0.124	0.116	0.148	0.018
Norway	0.061	0.055	0.056	0.249	0.085	0.001	0.115	0.013	0.183	<b>-1.340</b>	0.008	0.105	0.168	0.242	0.039
Spain	0.043	0.041	0.040	0.148	0.052	0.001	0.097	0.012	0.090	0.010	<b>-1.081</b>	0.068	0.099	0.171	0.018
Sweden	0.052	0.035	0.119	0.365	0.090	0.001	0.063	0.006	0.359	0.007	0.004	<b>-1.405</b>	0.146	0.196	0.043
Switzerland	0.069	0.061	0.085	0.336	0.094	0.002	0.087	0.010	0.316	0.011	0.005	0.140	<b>-0.857</b>	0.276	0.052
UK	0.052	0.046	0.069	0.258	0.067	0.001	0.073	0.008	0.239	0.009	0.005	0.109	0.160	<b>-1.181</b>	0.026
US	-0.007	0.012	0.031	-0.001	-0.075	0.000	-0.013	0.002	0.048	0.002	0.001	0.040	0.058	0.044	<b>-0.266</b>

*Notes: Each cell contains the elasticity of the share of patents in the country indicated in column 1 when the tax rate changes in the country in row 1. Elasticities are derived from the full random coefficients model and incorporate the presence of CFC regimes.*

**Table 4: Own and cross tax elasticities; multinomial logit model, not accounting for CFC regimes**

<i>Location country</i>	<i>Country changing tax rate</i>														
	Belgium	Denmark	Finland	France	Germany	Ireland	Italy	Luxembourg	Netherlands	Norway	Spain	Sweden	Switzerland	UK	US
Belgium	<b>-0.816</b>	0.015	0.027	0.173	0.090	0.001	0.049	0.003	0.130	0.003	0.003	0.049	0.070	0.090	0.048
Denmark	0.031	<b>-0.683</b>	0.027	0.173	0.090	0.001	0.049	0.003	0.130	0.003	0.003	0.049	0.070	0.090	0.048
Finland	0.031	0.015	<b>-0.622</b>	0.173	0.090	0.001	0.049	0.003	0.130	0.003	0.003	0.049	0.070	0.090	0.048
France	0.031	0.015	0.027	<b>-0.671</b>	0.090	0.001	0.049	0.003	0.130	0.003	0.003	0.049	0.070	0.090	0.048
Germany	0.031	0.015	0.027	0.173	<b>-0.865</b>	0.001	0.049	0.003	0.130	0.003	0.003	0.049	0.070	0.090	0.048
Ireland	0.031	0.015	0.027	0.173	0.090	<b>-0.311</b>	0.049	0.003	0.130	0.003	0.003	0.049	0.070	0.090	0.048
Italy	0.031	0.015	0.027	0.173	0.090	0.001	<b>-0.879</b>	0.003	0.130	0.003	0.003	0.049	0.070	0.090	0.048
Luxembourg	0.031	0.015	0.027	0.173	0.090	0.001	0.049	<b>-0.755</b>	0.130	0.003	0.003	0.049	0.070	0.090	0.048
Netherlands	0.031	0.015	0.027	0.173	0.090	0.001	0.049	0.003	<b>-0.656</b>	0.003	0.003	0.049	0.070	0.090	0.048
Norway	0.031	0.015	0.027	0.173	0.090	0.001	0.049	0.003	0.130	<b>-0.695</b>	0.003	0.049	0.070	0.090	0.048
Spain	0.031	0.015	0.027	0.173	0.090	0.001	0.049	0.003	0.130	0.003	<b>-0.870</b>	0.049	0.070	0.090	0.048
Sweden	0.031	0.015	0.027	0.173	0.090	0.001	0.049	0.003	0.130	0.003	0.003	<b>-0.649</b>	0.070	0.090	0.048
Switzerland	0.031	0.015	0.027	0.173	0.090	0.001	0.049	0.003	0.130	0.003	0.003	0.049	<b>-0.461</b>	0.090	0.048
UK	0.031	0.015	0.027	0.173	0.090	0.001	0.049	0.003	0.130	0.003	0.003	0.049	0.070	<b>-0.658</b>	0.048
US	0.031	0.015	0.027	0.173	0.090	0.001	0.049	0.003	0.130	0.003	0.003	0.049	0.070	0.090	<b>-0.950</b>

*Notes: Each cell contains the elasticity of the share of patents in the country indicated in column 1 when the tax rate changes in the country in row 1. Elasticities are derived from a multinomial logit model and do not incorporate the presence of CFC regimes.*



In Table 4 the cross tax elasticities are the same within each column: cross tax elasticities in the multinomial logit model are a function of the tax rate in the country that is adjusting its tax rate, the share of patents in that country and the coefficient on the tax rate only. In contrast, in the random coefficients model the cross tax elasticities vary across countries, and are functions of the both the countries' characteristics and how close they are to one another. Countries that have more similar characteristics will be seen as closer substitutes by firms, and therefore the cross tax elasticity will be higher.

## 5 Policy Simulations

### 5.1 *The effects of Patent Boxes*

We use the estimates from the random coefficients logit model to simulate how the share of newly created patents in each of the 15 locations will respond to the introduction of the Benelux Patent Boxes and the planned UK Patent Box<sup>27</sup> and consider alternative assumptions about how Patent Boxes might interact with CFC regimes. Specifically, we explore how the results would change if countries operating CFC regimes were to classify countries as 'low tax' for the purposes of their CFC regulations based on the Patent Box tax rates.

Table 5 sets out these simulations.<sup>28</sup> Column (1) shows the predicted share of newly created patents across countries in 2005, the last year in our data. Columns (2) and (3) report the simulated proportional change in shares, and the resulting level, when the Benelux Patent Boxes are introduced. Here we assume that countries operating CFC

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<sup>27</sup> Existing Patent Boxes regimes apply only to patents issued after the policy's introduction. Therefore, we do not expect firms to relocate pre-existing patents in response. The shares we report can be interpreted as flows – the share of newly created patents that are held in a location.

<sup>28</sup> Some caution is needed here as the policy simulations are at tax rates that are outside the observed range of taxes in our data.

regimes do not use Patent Box rates to determine whether the Benelux countries are subject to CFC rules. The share of new patents locating in the Benelux countries increases, with the proportional increase being largest in Belgium and Luxembourg and the absolute increase largest in the Netherlands. The shares elsewhere fall.

The use of a random coefficients logit model allows for correlation in unobservables across choices and thereby captures any tendency firms have to perceive countries with similar characteristics as closer substitutes. This means that when a Patent Box is introduced, the greatest substitution is away from other low tax countries; the firms that substitute towards the Benelux countries when Patent Boxes are introduced are those with ‘preferences’ which favour low tax countries and, as a result, it is low tax countries that lose the greatest share (proportionately).<sup>29</sup>

In Column (4) we assume that countries that operate CFC regimes use Patent Box tax rates to determine whether activity in the Benelux countries is captured by CFC rules.<sup>30</sup> This dampens the effects of Benelux Patent Boxes, because firms from countries operating a CFC regime have a reduced incentive to substitute towards these countries. The remaining columns of Table 5 describe the introduction of a UK Patent Box into a world where the Benelux Patent Boxes are operating. Column (5) shows the proportional change in the share for each country (compared to column (3)) and column (6) the resulting level. The UK share more than doubles to 16.81%, which offsets the loss in share which occurred following the introduction of the Benelux Patent Boxes. The shares in Belgium, Luxembourg and the Netherlands decline, but remain higher than initially.

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<sup>29</sup> Note that in a standard multinomial logit model the change in share is proportional to the initial share of the country that changes its tax rate, meaning that the proportional change in share is the same across all other countries. That is, had we used the multinomial logit results, by assumption the proportional changes (column (2)) would have been the same for the 12 countries that did not introduce a Patent Box.

<sup>30</sup> This means, for example, that under the UK CFC rules a subsidiary of a UK parent firm operating in the Netherlands would be subject to the UK tax rate of 28% and not the Dutch Patent Box rate.

**Table 5: Impact of introducing a Patent Box on firm location**

Country	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Initial share	Patent Box introduced in Belgium, Luxembourg and the Netherlands			Patent Box also introduced in UK			
		% change in share from (1)	Share	<i>Benelux countries low tax in CFC regimes</i>	% change in share from (3)	Share	<i>UK low tax in CFC regimes</i>	<i>(7) plus remove the UK CFC regime</i>
Belgium	3.72%	+157.97%	9.60%	6.82%	-17.97%	7.88%	5.82%	6.01%
Denmark	2.21%	-31.10%	1.52%	1.90%	-9.24%	1.38%	1.75%	1.67%
Finland	4.77%	-43.01%	2.72%	3.96%	-7.05%	2.53%	3.79%	3.69%
France	21.79%	-25.20%	16.30%	19.56%	-3.53%	15.72%	18.99%	18.65%
Germany	7.64%	-15.88%	6.42%	7.14%	-1.96%	6.30%	6.99%	6.92%
Ireland	0.09%	-16.92%	0.07%	0.06%	-16.90%	0.06%	0.05%	0.06%
Italy	5.03%	-16.61%	4.19%	4.66%	-5.53%	3.96%	4.45%	4.33%
Luxembourg	0.39%	+157.14%	1.00%	0.70%	-23.14%	0.77%	0.57%	0.60%
Netherlands	18.35%	+78.35%	32.72%	25.00%	-12.71%	28.56%	22.67%	23.19%
Norway	0.44%	-28.20%	0.32%	0.39%	-10.56%	0.29%	0.36%	0.34%
Spain	0.29%	-18.38%	0.24%	0.27%	-8.05%	0.22%	0.25%	0.24%
Sweden	7.00%	-36.05%	4.47%	5.97%	-6.82%	4.17%	5.68%	7.52%
Switzerland	11.51%	-33.49%	7.66%	8.54%	-11.82%	6.75%	7.80%	8.54%
UK	11.59%	-29.64%	8.15%	10.08%	+106.13%	16.81%	15.93%	13.33%
US	5.18%	-11.22%	4.60%	4.94%	0.08%	4.60%	4.90%	4.89%

Notes: Column (1) shows predicted patent shares from the random coefficients model using 2005 statutory tax rates. The shares refer to the share of patent applications made in 2005. Column (2) shows the proportional change in predicted shares and column (3) the resulting shares when the Benelux countries introduce Patent Boxes (Belgium at 6.8%, Luxembourg at 5.9%, Netherlands at 10%)/ Column (4) shows predicted shares when the Benelux countries introduce Patent Boxes and it is assumed that income located there may be captured by the CFC regimes of other countries (which may classify Benelux countries as low tax). Columns (5), (6) and (7) repeat (2), (3) and (4) when the UK also introduces a Patent Box at rate 10%. Column (8) removes the UK's CFC regime.

Column (7) considers the case where Patent Box rates in each of the four countries are used to determine whether activity located there is captured by other countries' CFC rules. For the UK this has two effects. First, the move away from the UK is dampened because UK firms cannot access the low taxes offered in the Benelux countries (without being captured by the CFC regime and taxed at the UK rate). Second, the shift in patents towards the UK is dampened by the reduced incentive for firms from other countries that operate CFC rules to locate in the UK. In this scenario the UK share increases to 15.93%. This is lower than when no CFC-Patent Box interactions are considered, implying that the lower propensity of UK firms to substitute out of the UK is more than offset by the lower propensity of firms based in other countries operating CFC regimes to come to the UK.

It is unclear how the UK CFC regime will treat offshore patent income when the UK also operates a Patent Box. In column (7) we assumed that the UK continues to operate a CFC regime, where the threshold is based on the full statutory corporate rate, and the full rate (not the Patent Box rate) is applied to any foreign income captured by the CFC regime. Alternatively, the UK may choose to exempt patent income from their CFC regime.<sup>31</sup> Column (8) therefore effectively removes the UK CFC regime for patent income.<sup>32</sup> We see that the UK share is now 13.33%; higher than initially (column (4)) but lower than when either Patent Box rates are never considered by CFC regimes (column (6)) or all CFC regimes consider Patent Box rates (column (7)). This is because, with no UK CFC regime in place, UK firms face greater incentives to locate

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<sup>31</sup> This is not an issue for the Benelux countries since they do not operate CFC regimes.

<sup>32</sup> An alternative assumption, and one which gives almost identical results, would be to apply the current rules, where low tax is defined as a rate less than 75% of the UK rate, to the 10% tax rate. This gives a threshold of 7.5% which will be binding only for the Patent Boxes of Belgium and Luxembourg and result in only a small amount of additional tax being levied on UK firms that locate there.

patents in low tax countries. The Benelux countries capture an increased share of new patents as a result.

In summary, there are potentially important interactions between CFC regimes and Patent Boxes. The extent to which governments operate CFC regimes that effectively capture patent income held in Patent Box countries greatly affects the distribution of patent income across countries.

## ***5.2 The impact on tax revenue***

We consider the impact that the introduction of Patent Boxes is likely to have on government tax revenue from patent income. Revenue is a function of the share of patent income held in a country and the tax rate; since a Patent Box leads the first to increase and the second to decrease it is not immediately clear what the net effect will be.<sup>33</sup> For this exercise we assume that when Patent Boxes are introduced, CFC regimes continue to operate as they do now, based on the statutory tax rates, so that Patent Box countries are not deemed ‘low tax’ destinations for the purposes of CFC rules. This is the scenario shown in columns (3) and (6) of Table 5.

Table 6 shows the effect of introducing Patent Boxes on government tax revenues from new patent applications.<sup>34</sup> We assume that the introduction of Patent Boxes does not affect the expected income from each patent, and that the number of new patent applications is not affected. In this sense we are estimating a short-run impact. In the long-run the lower tax rate may lead firms to invest more in research and discovery, leading to either more patent applications or more valuable patents. However, given the

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<sup>33</sup> The own tax elasticities reported in Table 3 tell us the impact on government revenue of a *marginal* change in the tax rate (evaluated at the vector of tax observed in the data). This means that for those countries with an own tax elasticity greater than one (in absolute terms) a small reduction in the tax rate would increase revenue. However, the elasticity itself is a function of all tax rates, meaning the elasticities differ when evaluated at a different vector of tax rates.

<sup>34</sup> Like the shares presented earlier, we report government revenue raised from the taxation of newly created patents. Patent Boxes do not apply to pre-existing patents.

long timeline from research inception to commercialisation the effects of this will take some considerable time to feed through to tax revenue.

We index revenue prior to the introduction of any Patent Boxes to 100 (column (1)). Column (2) shows how revenue changes when Patent Boxes are introduced in the Benelux countries.<sup>35</sup> Revenue is reduced in all countries. In non-Benelux countries this is driven by the reduction in the share of patent income. In the Benelux countries the increase in share of income is outweighed by the lower tax rate applied to income.

**Table 6: Government revenue from new patents as Patent Boxes are introduced**

Country	(1) Initial	(2) Patent Box introduced in Belgium, Luxembourg and the Netherlands	(3) Patent Box also introduced in the UK (on top of col (2))
Belgium	100	51.6	42.3
Denmark	100	68.9	62.5
Finland	100	57.0	53.0
France	100	74.8	72.2
Germany	100	84.1	82.5
Ireland	100	83.1	69.0
Italy	100	83.4	78.8
Luxembourg	100	49.9	38.4
Netherlands	100	56.6	49.4
Norway	100	71.8	64.2
Spain	100	81.6	75.1
Sweden	100	63.9	59.6
Switzerland	100	66.5	54.3
UK	100	70.4	48.3
US	100	88.8	88.8
<i>Total</i>	<i>100</i>	<i>70.1</i>	<i>63.7</i>

*Notes: Government tax revenue equals the tax rate times the share of patents. We normalise that to 100 in the base year. Columns (2) and (3) show revenue relative to column (1). Shares used are those reported in Columns (3) and (6) of Table 5.*

<sup>35</sup> These figures are based on revenue from patents held in the country and do not include revenue from imposing the CFC regime on income held by home firms offshore in low tax countries. However, this revenue would be small; fewer than 0.5% of firms' location choices are of countries deemed 'low tax' by the home countries' CFC regimes.

Column (3) shows indexed revenue when the UK additionally introduces a Patent Box. UK revenue falls because the affect of the lower tax rate (10%) on all income outweighs any income gained from an increased share of patent income. UK revenue from income associated with new patents is halved when all four Patent Boxes are in place compared to its initial level with no Patent Boxes.

Recall that we have assumed that the UK does not consider the Benelux Patent Boxes as low tax for the purposes of its CFC regime, and that other countries do not consider the UK Patent Box as low tax for the purposes of their CFC regimes. As shown in Table 5, alternative assumptions about the interaction of Patent Boxes and CFC regimes further reduce the UK share and would therefore lead to further reductions in UK revenue. Indeed, under all assumptions, revenue falls in all countries.

The revenue losses would be mitigated to some extent if the introduction of Patent Boxes leads to an increase in patenting activity. Assuming the UK's share of patent income remains as given in column (6) of Table 5, the aggregate value of patenting activity in the 15 countries considered would have to increase *as a consequence of the introduction of Patent Boxes* by 45% for the UK's revenue to recover to the pre-UK Patent Box level or by over 100% to recover to the level before Benelux Patent Boxes are introduced.

### ***5.3 The effects of further Patent Boxes***

It seems unlikely that the UK will be the last country to introduce a favourable tax regime for patent income. There is a considerable literature relating the reduction in corporate tax rates over the 1980s and 1990s to tax competition between countries.<sup>36</sup>

What would the consequences be of other countries also deciding to introduce Patent Boxes? In Table 7 we simulate the effect on both the shares of patents across countries and tax revenues of the introduction of a Patent Box by Sweden or France (separately).<sup>37</sup> We assume that when Patent Boxes are introduced CFC regimes continue to operate based on the existing statutory tax rates. Column (1) shows the shares of new patents across countries when the Benelux countries and the UK operate Patent Boxes (a repeat of column (6) in Table 5).

Columns (2) and (3) show the proportional change in shares and the resulting share if Sweden introduces a 10% Patent Box. Columns (4) and (5) do the same in the case where France introduces a 10% Patent Box. We see that both countries experience large gains in shares. The UK loses share, particularly when France introduces a Patent Box: the UK share falls from 16.81% to 13.42%.

Columns (6) and (7) show the effect on government revenue from patent income (derived from new patents). Each shows the additional revenue effects on top of the impact of the Patent Boxes in the Benelux countries and the UK, and is therefore comparable to column (3) in Table 6. In each case the UK loses both share and revenue.

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<sup>36</sup> See Devereux, Lockwood and Redoano (2008) for a recent discussion of the literature and empirical evidence.

<sup>37</sup> France and Sweden were chosen for illustration, not because there is any suggestion that they are proposing Patent Boxes.



**Table 7: Impact of other countries introducing a Patent Box on firm location and government revenue**

Country	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Initial share (col. 6, Table 5)	10% Patent Box in Sweden		10% Patent Box in France		Government revenue	
		Proportional change in share from (1)	share	Proportional change in share from (1)	share	Sweden has Patent Box	France has Patent Box
Belgium	7.88%	-6.74%	7.34%	-22.74%	6.08%	39.5	32.7
Denmark	1.38%	-2.50%	1.35%	-5.51%	1.31%	61.0	59.1
Finland	2.53%	-3.74%	2.43%	-9.20%	2.30%	51.0	48.1
France	15.72%	-1.46%	15.49%	+80.43%	28.37%	71.1	38.5
Germany	6.30%	-0.52%	6.26%	+7.63%	6.78%	82.0	88.8
Ireland	0.06%	-4.77%	0.06%	-14.93%	0.05%	39.4	35.2
Italy	3.96%	-1.37%	3.91%	+1.19%	4.01%	77.7	79.7
Luxembourg	0.77%	-6.12%	0.72%	-18.44%	0.63%	36.0	31.3
Netherlands	28.56%	-7.20%	26.51%	-24.51%	21.56%	45.9	37.3
Norway	0.29%	-2.92%	0.28%	-7.11%	0.27%	62.3	59.7
Spain	0.22%	-1.92%	0.22%	-3.48%	0.21%	73.6	72.4
Sweden	4.17%	+105.05%	8.55%	-6.24%	3.91%	43.6	55.9
Switzerland	6.75%	-3.93%	6.49%	-11.76%	5.96%	52.2	47.9
UK	16.81%	-6.09%	15.79%	-20.18%	13.42%	45.4	38.6
US	4.60%	+0.15%	4.61%	+12.02%	5.16%	89.0	99.5

Notes: See notes to Table 5 and 6. Column 1 repeats column 3, Table 5. Columns 2 and 4 both show the proportional change in share with respect to column 1. Patent Boxes at 10% are added to Sweden or France. Columns 6 and 7 show an index of government revenue. Both show revenue relative to the case in which the UK and Benelux countries have Patent Boxes and can both be compared to column 3 in Table 6.

## **6 Summary and concluding comments**

The literature has emphasised the downward pressure on corporate income tax rates that arises from factor mobility. There is also a large literature that discusses the strategies firms use to shift income for tax purposes (and to avoid anti-avoidance rules) and that highlights an important role for intangibles. However, we know relatively little about how the location of intangible assets respond to tax, and what evidence there is on the impact if tax on the location of capital more generally has tended to suffer from the imposition of restrictive a priori assumptions on the underlying model of firm behaviour. From a policy perspective it is clearly important to understand how responsive the income from intangibles is to corporate income taxes.

Firms can use intangible assets, including intellectual property, to shift income with a view to minimising their tax liability. Notably, firms can hold patents separately from other activities and in a country with an attractive corporate tax regime in order to reduce the tax liability on associated royalty payments. This practice is likely to have become more prevalent as the importance of intangible capital has grown and the associated income has become more mobile.

In this paper, we estimate a model of firms' decisions over where to locate patents, and find that tax is an important determinant of location choice. Our model also highlights that other non-tax factors influence patent location. Indeed, such factors are the reason why we do not see firms choosing to hold all patent income in the lowest tax jurisdictions.

We contribute to the literature on firm location choice in a number of ways. We explicitly consider the impact of corporate taxes on where firms choose to hold their intellectual property. In doing so we account for important interactions between source

and residence tax jurisdictions that arise through the operation of CFC regimes. Our strategy is to estimate a model of firm behaviour which, in addition to controlling for observable firm characteristics and location specific factors, is able to capture unobservable patent specific factors which affect the responsiveness of location decisions to tax. Our estimates suggest that the extent of this heterogeneity is significant. Using the estimates from our model we compute elasticities of location choice with respect to tax. Unlike many elasticities estimated in the literature to date, these vary across location and are functions of the tax rates firms face in all potential locations.

In a recent policy development several European countries have introduced, or are planning to introduce, Patent Boxes, which provide preferential tax treatment for patent income. We use our model to simulate the introduction of Patent Boxes and show that, while they will succeed in attracting patent income, they also will result in a reduction in tax revenue from patent income. The introduction of Patent Boxes by several European countries in a relatively short space of time has given rise to concerns that countries are engaging in tax competition for patent income. We find that if another European country were to introduce a Patent Box all countries could expect to see a reduction in tax revenues from patent income. In future work we will consider what the revenue maximising tax rates is for intellectual property in a context where governments strategically set a separate tax rate for patent income.

## Appendix A

### *A.1 Firm and patent location data*

We measure where firms hold patents using data contained in patent applications made to the European Patents Office (EPO) and recorded in the EPO's Worldwide Patent Statistical Database (PATSTAT).<sup>38</sup> EPO patent applications include (by law) the name and residential address of the entity filing the patent (the applicant). The patent application also includes the name and address of the inventors which created the underlying technology.<sup>39</sup> The applicant is the entity which legally holds the intellectual property and therefore will be the recipient of any resulting income and liable for any associated tax.<sup>40</sup> Its location can be distinct from both where the inventors are located and where legal protection is sought (i.e. the countries in which the patent will be protected).<sup>41</sup>

The patents data does not record the parent (headquarter) company of the patent applicant. To obtain information on firms' ownership structure we have matched the corporate applicants (i.e. excluding individuals, universities and research institutions) of EPO patent applications from 14 European countries and the US to firms listed in Bureau van Dijk's Amadeus and Icarus databases. These data are described in detail in Abramovsky et al (2008). The result is a mapping between European parent firms and their European and US subsidiaries that file patent applications.<sup>42</sup> We do not include

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<sup>38</sup> We use all EPO patent *applications*, not only those that are granted.

<sup>39</sup> Note that, in contrast, patent applications made to the US Patent and Trademark Office (USPTO) list the inventors (i.e. the individuals which created the technology) as 'applicants'.

<sup>40</sup> A handful of patents are held by multiple applicants in multiple locations. In this case we randomly select one of these subsidiaries.

<sup>41</sup> For more information on the distinctions between the different locations contained in an EPO patent document see section 2.5 of Abramovsky et al (2008).

<sup>42</sup> We use information on firms headquartered in thirteen European countries: Belgium, Denmark, Finland, France, Ireland, Italy, Luxembourg, Netherlands, Norway, Spain, Sweden, Switzerland and UK and their subsidiaries located in these countries, as well as in Germany and the US.

applicants resident in the set of small countries that are often considered as tax havens. However, in the EPO data over the period 2001-2005, we observe that fewer than 0.5% of EPO applications are filed from such countries<sup>43</sup> and many of the applicants are unrelated to European firms.

We classify patent applications into industry groups using the Derwent Innovation Index which is compiled, for commercial purposes, by Thompson and classifies patent applications according to the industries in which the technology has an application. We use the following three broad industry groups: Chemical, which includes pharmaceuticals; Electrical, which includes communications and computing; Engineering which includes machinery, vehicles, and construction.<sup>44</sup> An individual patent application can be classified into multiple industries. In such cases we allow the patent application to enter the estimation for each relevant industry group. Within each industry we exclude firms that are below the 20th percentile in terms of the number of patents applied for in their industry.

We use data on 639 firms that collectively have 4,740 patenting subsidiaries that file 233,471 patent applications over the period 1985-2005. A breakdown of these figures by the country of the parent firm (residence country) is described in Table A.1. Column (1) shows the number of firms headquartered in each country, column (2) the number of subsidiaries associated with these firms, and column (3) the number of patent applications these subsidiaries filed. Columns (4)-(6) show the proportion of patents in column (3) that are in each of the three industries. Since patents can be in multiple industries, the percentages do not sum to 100 within rows.

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<sup>43</sup> The figure based on the patent applications of applicants in Bahamas, Barbados, Bermuda, Cayman Islands, Gibraltar, Hong Kong, Liechtenstein, Malta, Monaco, Netherlands Antilles, Panama or Singapore.

<sup>44</sup> For more information and the precise industry definitions, see Section 5 of Abramovsky et al (2008).

**Table A.1: Number of firms, subsidiaries and patents, by residence country**

Residence country	Firms (1)	Associated subsidiaries (2)	Patent applications (3)	% in		
				Chemicals (4)	Electrical (5)	Engineering (6)
Belgium	28	208	8229	73.3	35.7	53.1
Denmark	27	193	6686	72.8	19.1	35.3
Finland	25	107	10112	16.5	79.6	24.5
France	108	1212	58015	36.4	55.7	42.1
Ireland	4	15	511	94.1	10.8	28.0
Italy	77	297	11153	43.3	40.2	57.8
Luxembourg	8	47	1505	31.0	66.4	39.6
Netherlands	58	330	47084	37.1	65.1	31.9
Norway	7	50	1128	53.4	35.4	52.3
Spain	8	43	697	54.9	18.2	43.6
Sweden	48	456	16560	17.2	67.8	44.5
Switzerland	106	729	37260	60.6	30.9	38.7
UK	135	1053	34531	41.9	52.3	39.5
<b>Total</b>	<b>639</b>	<b>4740</b>	<b>233471</b>	<b>44.8</b>	<b>49.6</b>	<b>38.9</b>

*Notes: The residence country refers to the country in which a firm is headquartered. Column 1 shows the number of firms headquartered in each country and column 2 the number of patent application filing subsidiaries that are associated with these firms. Column 3 reports the number of patent applications made by these firms. All figures refer to the period 1985-2005.*

We allow behaviour to vary by firm size. In each industry we identify *large* firms as those patenting above the 80th percentile in terms of the number of patent applications filed over the period 1985-2005. Table A.2 shows the number of patents in each industry and firm size category by source country.

## **A.2 Taxes**

We consider the impact of statutory tax rates in the source country (the location of the applicant) and of Controlled Foreign Companies (CFC) rules operated in the home (residence) country of the parent firm. We use variation in the statutory tax rate over time and across countries and in whether the CFC regime is binding (which can differ as a result of changes in the tax rules or in tax rates) to identify the sensitivity of firms' location decisions to changes in the tax rate.

**Table A.2: Patent applications, by industry, size and source country**

Industry:	Chemicals		Electrical		Engineering	
Firm size:	Large	Medium	Large	Medium	Large	Medium
Source country						
Belgium	3546	1244	1969	828	2597	1080
Denmark	2216	1142	367	737	1216	725
Finland	1050	869	7270	763	1461	779
France	13690	3553	25461	3233	16645	3484
Germany	7651	1088	7178	1329	5228	1878
Ireland	167	162	35	24	69	58
Italy	2571	2453	1753	2624	2852	3369
Luxembourg	254	305	13	276	49	265
Netherlands	12690	1838	23949	1030	11007	1689
Norway	286	270	76	327	351	205
Spain	47	431	57	185	88	261
Sweden	3698	1228	8517	1492	5031	2216
Switzerland	14042	3251	5466	4018	8299	4483
UK	12728	4582	6813	4650	6538	4644
US	6632	891	4549	819	3380	927
<b>Total</b>	<b>81,268</b>	<b>23,307</b>	<b>93,473</b>	<b>22,335</b>	<b>64,811</b>	<b>26,063</b>

*Notes: The source country refers to the location of the subsidiary that applied for the patent, i.e. the country in which the patent is held.*

### **A.2.1 Statutory tax rates**

Statutory tax rates have varied differentially across countries over time. In most countries the statutory rate has fallen over the last two decades, but there is variation in both the trajectories and the levels, as described in Table A.3. The general downward trend in statutory tax rates does not pose a problem in estimation, as we model firms' decision over where to locate each of its patents at a given point in time. This decision depends on the cross-sectional variation in the tax rates the firm faces at that point in time in each location.

**Table A.3: Statutory corporate tax rates, 1985-2005**

Source country	Statutory tax rate			Number of changes
	min	max	mean	
Belgium	0.340	0.450	0.400	5
Denmark	0.280	0.500	0.368	7
Finland	0.250	0.602	0.364	7
France	0.333	0.500	0.378	13
Germany	0.383	0.617	0.534	15
Ireland	0.100	0.125	0.104	1
Italy	0.373	0.532	0.455	7
Luxembourg	0.304	0.394	0.373	6
Netherlands	0.315	0.430	0.361	4
Norway	0.280	0.508	0.356	1
Spain	0.350	0.353	0.351	1
Sweden	0.280	0.520	0.351	2
Switzerland	0.213	0.285	0.270	6
UK	0.300	0.400	0.327	5
US	0.340	0.495	0.393	5

*Notes: This table shows the minimum, maximum and mean of the statutory corporate tax rates across the period 1985-2005 as well as how many times the rate changed. The rates reflect the corporate income tax rate adjusted to account for surcharges, local taxes, and additional taxes levied on tax bases that are similar to the corporate income tax where such things exist.*

## **A.2.2 International tax considerations**

There are important interactions between tax jurisdictions which mean that the overall tax liability a firm faces may depend on the tax regime in the parent firm's home country of residence as well as that in the country where a patent is held. Many (but not all) governments operate anti-avoidance legislation, in the form of Controlled Foreign Company (CFC) rules, which aim to prevent firms locating income in low tax countries in order to avoid taxation in their home country and, in so doing make, realising the tax benefits of locating in lower tax jurisdictions more difficult.<sup>45</sup> CFC legislation defines the set of subsidiaries that are located offshore with income subject to tax in the parent

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<sup>45</sup> Firms' location choices may also be affected by withholding taxes and transfer pricing rules. Withholding taxes are levied on royalty payments between some countries. Between the European countries and in the years we consider, these taxes are low and in most cases zero.



firm's residence country (with a credit for foreign tax paid). The precise form of CFC regimes varies across countries. Broadly, CFC regimes apply when:

- (i) the parent firm owns a sufficiently large share of an offshore subsidiary, and
- (ii) a sufficiently high proportion of the subsidiaries' income arises from 'passive sources' (i.e. income from non-commercial activities, mainly investment income such as interest, dividends and patent royalties), and
- (iii) the subsidiary is located in a country deemed to be a low tax country.

Under these circumstances, the passive income of the subsidiary will be taxed at the statutory corporate tax rate of the residence country, with a credit given for any tax already paid in the source country. This affects the tax liability on income earned in an offshore subsidiary. We assume that the foreign patenting subsidiaries in our data satisfy condition (i) and, since we are considering the location of patents, that a subsidiary's income would be considered passive and therefore fulfil (ii). We use the rules set out in countries CFC regimes to define which source countries would be deemed 'low tax'.<sup>46</sup> That is, for each residence country that operates a CFC regime we identify the source countries that would be deemed low tax. We assume that, in these cases, patent income earned in the source country would be subject to the statutory tax rate in the residence country (i.e. the tax liability comprises taxes paid in the source country plus the additional tax which accrues in the residence country). Denmark, Finland, France, Italy, Norway, Spain, Sweden and the UK operate CFC regimes; see Table A.4 for details.

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<sup>46</sup> Most countries that operate a CFC regime set a threshold tax rate below which a source country is deemed 'low tax'. This is either an absolute rate, or a proportion of the resident country's rate. Alternatively, some countries use a (black) list which explicitly sets out low-tax countries.

**Table 4: Controlled Foreign Company (CFC) regimes**

Residence country	Year introduced	Threshold	Threshold rate	Source countries for which CFC ever binds (no. of years*)
	(1)	(2)	(3)	(4)
Belgium	-	-	-	-
Denmark	1995	Relative	0.75	FI (1 year), IE (all years)
Finland	1995	Relative	0.60	IE (11 years)
France	1980	Relative	0.66	CH (6 years), IE (all years)
Ireland	-	-	-	-
Italy	2002	Blacklist <sup>†</sup>	-	-
Luxembourg	-	-	-	-
Netherlands	-	-	-	-
Norway	1992	Relative	0.66	IE (14 years)
			0.75	CH (7 years), FI (2 years), IE (all years)
Spain	1996	Relative		
Sweden	1990	Relative	0.55	CH (1 year), IE (11 years)
Switzerland	-	-	-	-
UK	1984	Relative	0.75	CH (2 years), IE (all years)

*Notes: The country refers to the country in which a firm is headquartered, the residence country. In column 1, '-' indicates that no CFC regime is in operation. In cases where the CFC regime was introduced during the period 1985-2005, there is no CFC regime before the year of introduction. Column 2 shows the type of threshold in operation and column 3 the rate of the threshold. Column 4 shows that total number of source countries for which the CFC regime is binding. Country codes refer to countries as follows: CH, Switzerland; FI, Finland; IE, Ireland.*

<sup>†</sup>Italy operates a blacklist which sets out the countries deemed low tax.

\*This is the number of years for which the CFC regime binds between 1985-200.

In summary, we define the tax variable,  $\tau_{ijt}$ , as equal to the source country tax rate unless the residence country (of firm  $i$ ) operates a CFC regime and the source country ( $j$ ) is deemed low tax, in which case  $\tau_{ijt}$  is equal to the residence country's statutory rate.<sup>47</sup>

<sup>47</sup> Our measure of tax does not account for whether the home country operates a credit or exemption system for the taxation of income earned in offshore subsidiaries (foreign source income). Many European countries operate exemption systems in which foreign source income is not taxed in the home country. Some, including the UK before 2009, operate credit systems in which foreign source income is liable for corporation tax when remitted to the home country (with a credit for any tax paid in the source country). For firms whose residence country operates a credit system, we assume that the home country tax rate does not apply to foreign source income (unless the CFC regime binds). This could result either because income is not remitted (therefore the credit system operates like an exemption system for retained earnings) or because the firm structures income in such a way to avoid home country taxation. See section 10.5.2 of Griffith, Hines and Sørensen (2010) for further discussion.

### A.2.3 Patent Boxes

In recent years, some European countries, including Belgium, Luxembourg and the Netherlands, have introduced 'Patent Boxes', under which income from patents is taxed at a lower corporate tax rate. The UK has announced that it will introduce a Patent Box in 2013 which will reduce the rate of corporation tax for the income from patents to 10%. These four Patent Box regimes are described in Table A.5.

**Table A.5: Patent Boxes**

Country	Year effective from	Patent Box	Rate
Belgium	2007	80% of patent income (net of development costs) is exempt from corporate tax;	6.8%
Netherlands	2007	Net (of development costs) patent income is taxed at a rate of 10%. Extended to 'Innovation Box' with wider scope in 2010.	10%
Luxembourg	2008	80% of patent income (net of development costs) is exempt from corporate tax	5.9%
UK	Planned for 2013	Net (of development costs) patent income is taxed at a rate of 10%.	10%

*Notes: We do not include Ireland or Spain. Ireland operates a system whereby certain patent royalties are tax exempt and qualifying patents are required to have had an element of the underlying research or processing carried out in Ireland. Spain introduced a Patent Box in 2008 (applied retrospectively to patents for 2007) whereby 50% of revenues from patents are tax exempt with development costs being deducted from the part of revenue that is not tax exempt (which is different to other Patent Boxes that have tax exemptions for revenue net of costs). The Patent Box schemes in Belgium, the Netherlands and Luxembourg are also associated with criteria that define which patents are eligible and thresholds for the total amount of income that can be exempted from tax. The legislation which will finalise the precise details of the UK Patent Box is due to be introduced in 2011.*

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