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CORPORATE TAXATION AND THE QUALITY OF RESEARCH AND DEVELOPMENT

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Corporate Taxation and the Quality of Research and Development*

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Abstract

This paper examines the impact of tax incentives on corporate research and development (R&D) activity. Traditionally, R&D tax incentives have been provided in the form of special tax allowances and tax credits. In recent years, several countries moreover reduced their income tax rates on R&D output. Previous papers have shown that all three tax instruments are effective in raising the *quantity* of R&D related activity. We provide evidence that, beyond this quantity effect, corporate taxation also distorts the *quality* of R&D projects, i.e. their innovativeness and revenue potential. Using rich data on corporate patent applications to the European patent office, we find that a low tax rate on patent income is instrumental in attracting innovative projects with a high earnings potential and innovation level. The effect is statistically significant and economically relevant and prevails in a number of sensitivity checks. R&D tax credits and tax allowances are in turn not found to exert a statistically significant impact on project quality.

Keywords: corporate taxation, research and development, micro data

JEL Classification: H3, H7, J5

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1 Introduction

In recent decades, corporate tax policies related to research and development (R&D) have been high on governments' agendas in many countries. While, traditionally, tax incentives to foster R&D investment have been provided in the form of special tax allowances and tax credits, several countries recently also lowered their tax rates on patent income, including, among others, Luxembourg, the Netherlands and Belgium. The most recent addition to the list is the United Kingdom, which announced to reduce its tax rate on patent income from 28% to 10% in April 2013 with the intention 'to strengthen the incentives to invest in innovative industries and ensure [that] the UK remains an attractive location for innovation'.[1]

The welfare implications of these policy reforms are a priori ambiguous. Their success critically depends on the effect of tax incentives on R&D activities. If the effects are small, R&D incentives just generate windfall gains to the corporate sector as they subsidize R&D activities that would have been undertaken anyway. In recent years, a number of empirical studies have assessed the effect of special tax provisions on the quantity of R&D activities, commonly reporting significant and sizable effects for both, R&D tax allowances/credits and patent income tax rates (e.g. Hines and Jaffe, 2001, Bloom and Griffith, 2001, Griffith et al., 2011, Ernst and Spengel, 2011, Karkinsky and Riedel, 2012). While quantity effects are clearly important, the welfare benefits related to R&D activity likely also depend on project *quality*. Gains from technological spillovers are for example determined by the degree of innovativeness of an R&D project and corporate income tax payments hinge on the project's earnings potential (see Becker and Fuest, 2007, Fuest et al. 2012 for related arguments).

This paper argues that corporate tax incentives may also exert an effect on the quality of R&D projects. To receive guidance for the empirical analysis, the paper develops a simple theoretical model of a multinational group that operates affiliates in different countries and decides about the location of heterogeneous R&D projects. As R&D income becomes part of the local corporate tax base, the MNE has an incentive to distort the location of its projects in favor of low-tax affiliates (quantity effect). This incentive moreover turns out to be larger, the higher the technology's earnings potential. Low tax countries thus attract projects with an above average value and degree of innovativeness compared to high-tax locations (quality effect). Importantly, a similar quality effect is not derived for R&D tax credits and allowances as their

[1] See paragraph 4.40 of HM Treasury, Pre-Budget Report 2009, December 2009.

benefits are related to the size of R&D expenditures instead of (expected) earnings.

To test for these hypotheses, we exploit information on the universe of patent applications to the European Patent Office (EPO) between 1995 and 2007 which is drawn from the PATSTAT data base. Following previous studies, we exploit information on the host country of the patent inventor to proxy for the location of corporate R&D activity. The patent information is moreover linked to rich firm level data that provides detailed accounting and ownership information on multinational firms in Europe and allows us to control for observed and unobserved heterogeneity across patent inventing affiliates. To proxy for the earnings potential and innovativeness of R&D projects, we furthermore make use of factor analysis to derive a measure for patent quality as reflected by three indicators: the patent's number of forward citations, its family size (i.e. the number of countries in which the corporation filed for patent protection) and the number of industry classes stated on the patent.

This patent information is merged with detailed data on national R&D tax incentives. We include information on the effective patent income tax rate, which accounts for taxes levied on patent income in the royalty receiving country as well as for withholding taxes levied in the royalty paying country in case of cross-border royalty streams and the unilateral and bilateral method to avoid double taxation. Moreover, we follow the existing literature and construct a tax variable (the so-called B-index) that accounts for tax incentives provided through R&D tax allowances and R&D tax credits.

Our results suggest that patent income taxation exerts a significantly negative effect on patent quality. Quantitatively, we find that an increase in the patent income tax rate by 10 percentage points reduces patent quality by around 5.6%. This result prevails in a large number of specifications and sensitivity checks which control for observed and unobserved heterogeneity in patent quality across industries, countries and firms. In line with the theoretical presumption, we do not find a significant impact of corporate tax allowances and tax credits (as measured by the B-index) on patent quality though. As sketched above, this likely reflects that tax credits and tax allowances are designed to increase R&D *expenditures*, i.e. they are targeted to boost the input side of R&D activities, while patent quality, in turn, is directly related to the *output* of R&D investments.[2] Thus, while both, special tax allowances/credits and low patent income tax rates raise the level of R&D activity, our analysis finds that only patent income tax provisions are instrumental in raising the quality of corporate R&D projects.

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[2]R&D tax allowances and tax credits are not expected to exert an impact as long as the firm's pre-tax profits are large enough to ensure that tax allowances and tax credits can be fully exploited.

The paper contributes to several strands of the economic literature. Firstly, it directly relates to a small number of papers which assess the impact of R&D tax incentives on R&D expenditure. For the US, Hall (1993) and Hines (1994) study the responsiveness of corporate R&D to the Research and Experimentation Tax Credit and find significant R&D price elasticities. Similarly, Jaffe and Hines (2001) determine how US R&D expense deduction rules affect the location of R&D by US multinationals. Bloom et al. (2002) confirm a significantly positive effect of R&D tax credits on the level of R&D expenditures using macro data for major OECD countries (see also Hall and van Reenen (2000) and Arundel et al. (2008) for survey papers on the topic).[3]

Griffith et al. (2011), Ernst and Spengel (2011) and Karkinsky and Riedel (2012) moreover find a negative effect of patent income taxes on the number of corporate patent applications. As the authors focus on the location of the patent applicant (who is presumed to be the owner of the associated royalty income) and do not distinguish between patents where applicant and inventor are located in the same and different countries respectively, the findings may reflect both, responses in the quantity of corporate R&D activity to patent income taxation as well as the strategic location of mobile patent income in low-tax countries, e.g. through patent holding entities that are geographically separated from R&D locations. Boehm et al. (2012) find that geographical splits of patent applicant and inventor are in general rare events which are partly motivated by tax considerations though.[4] To avoid results that reflect multinational income shifting through geographical relocations of patents from R&D units, our analysis focuses on the location of the patent *inventor* and disregards patents where applicant and inventor are located in different countries.

Our paper adds to the sketched literature by stressing that tax provisions for patent income may not only impact on the quantity of R&D and patent holdings but also on their quality. In this sense, the paper is related to recent contributions that emphasize the importance of quality aspects in assessing the welfare consequences of corporate

[3]In a recent paper, Ernst and Spengel (2011) report a faint impact of R&D tax incentives on the number of corporate patent applications. Buettner and Wamser (2009) find positive effects of R&D tax incentives on the volume of foreign direct investment (FDI) of German multinationals.

[4]Corporations may implement a geographical split between the location of R&D activities and patent income through advantageous cost sharing agreements or contract research schemes, where an R&D unit undertakes research for a group affiliate in a tax-haven country which finances the project and bears its risk. With contract research, the R&D unit earns a small fixed profit margin on its costs, while the residual income accrues with the contracting entity in the low-tax country. Mutti and Grubert (2008) present indirect evidence that US companies engage in advantageous cost sharing schemes in order to relocate royalty revenues to foreign subsidiaries in low-tax countries.

taxation. Becker and Fuest (2007) and Fuest et al. (2012) criticize that conventional studies solely focus on the effect of corporate taxes on the quantity of capital investment. The welfare effects of the investment, however, critically depend on the number of jobs created, the associated profit and tax revenue base, and the project's innovativeness. Our results confirm their argumentation as we find a negative effect of corporate taxation on patent quality, which is presumed to go along with lower patent income (i.e. a lower tax revenue base) and lower innovativeness.

The remainder of the paper is structured as follows: In Section 2, we present a simple theoretical model to motivate our empirical analysis. Sections 3 and 4 describe our data set and estimation methodology. The results are presented in Section 5. Section 6 concludes.

2 A Simple Theoretical Model

The following section presents a short theoretical model to motivate our empirical analysis. Consider a representative company which engages in R&D activities and may locate R&D projects in a country h or a country ℓ. The project success is risky and the company has to form expectations on the pre-tax earnings π_i of each project i. The expected value is denoted by $E(\pi_i)$.

Moreover, all R&D projects incur costs of C which are assumed to accrue at the beginning of the period and are therefore deterministic.[5] Both countries levy a tax rate on the return of the innovative project $[E(\pi_i) - C]$ denoted by t_k with $k \in \{h, \ell\}$. Without loss of generality, we assume that country h imposes a higher corporate tax rate than country ℓ, i.e. $t_h > t_\ell$.

Both countries are, moreover, assumed to provide an R&D tax credit which reduces the company's tax burden by τ_k cents for each Dollar invested in R&D ($k \in \{h, \ell\}$). If the company's profits exceed $\tau_k \cdot C$, the R&D tax credit reduces the corporate tax burden by the full amount of the credit $\tau_k \cdot C$. If the tax due is smaller than the value of the corporate tax credit, the actual tax reduction granted by the tax credit is smaller than $\tau_k \cdot C$ as tax authorities commonly do not pay out subsidies to loss-making firms.[6]

[5] Note that this assumption is not decisive for our results though.

[6] We abstract from loss offset opportunities where losses in one period may be consolidated with profits in later periods or profits of other firms that belong to the same corporate group. We also abstract from refund options for R&D tax credits that are granted in some countries like the United Kingdom, France and Austria. This is a reasonable simplification as the refund is often delayed or

Formally, the full tax credit is exploited if

$$t_k[\pi_i - C] \geq \tau_k C, \quad \Longleftrightarrow \quad \frac{\pi_i}{C} \geq \frac{\tau_k}{t_k} + 1 \tag{1}$$

Thus, the firm's corporate tax payment is reduced by the full amount $\tau_k \cdot C$ if the profit (or earnings) to costs ratio π_i/C of the project is large and the tax credit rate τ_k is small relative to the patent income tax t_k.

Moreover, we assume that the project's after-tax profit is affected by a set of factors which are not explicitly modeled and which are subsumed in the variable μ_{ik} with $k \in \{\ell, h\}$.[7] Factors that may determine an affiliate's suitability to host and run project i are, for example, the availability of high-skilled human capital or the access to technical equipment in the host country. The project's after-tax profit reads

$$\Pi_{ik} = (1 - t_k)\,[E(\pi_i) - C] + \gamma_{ik}\tau_k C + \mu_{ik}, \quad k \in \{\ell, h\} \tag{2}$$

where $\gamma_{ik} = \gamma_{ik}(E(\pi_i), t_k, \tau_k)$ takes on the value 1 if the expected earnings are above a critical threshold value $\widetilde{E(\pi_i)}$ which allows for full exploitation of the R&D tax credit, with $\frac{\widetilde{E(\pi_i)}}{C} = \frac{\tau_k}{t_k} + 1$. Otherwise, if $E(\pi_i) < \widetilde{E(\pi_i)}$, it holds that $0 < \gamma_{ik} < 1$, with $\partial\gamma_{ik}/\partial E(\pi_i) > 0$. Put differently, if expected corporate earnings fall below the critical threshold upon which corporate tax payments are larger than the value of the R&D tax credit, the tax credit cannot be fully exploited and the value of the credit increases in the expected corporate earnings. With $[E(\pi_i) - C] = 0$, it holds that $\gamma_{ik} = \gamma_{ik}\tau_k C = 0$.

The firm is assumed to maximize its after-tax profit and will thus locate the R&D project i in jurisdiction ℓ if

$$\phi = \Pi_{i\ell} - \Pi_{ih} = (t_h - t_\ell)[E(\pi_i) - C] + (\gamma_{i\ell}\tau_\ell - \gamma_{ih}\tau_h)C + (\mu_{i\ell} - \mu_{ih}) > 0 \tag{3}$$

Consequently, the attractiveness of location ℓ relative to location h increases in the tax rate differential $t_h - t_\ell$. Thus, the smaller the corporate tax burden of location ℓ relative to location h, the more attractive it is for the firm to locate the project in country ℓ. Formally, this reads

$$\frac{\partial\phi}{\partial(t_h - t_\ell)} = E(\pi_i) - C \tag{4}$$

Intuitively, the importance of the tax rate differential for the firm's location choice increases in the value of the expected earnings as higher expected earnings result in

subject to a significant discount from the original tax credit's value.

[7]For simplicity reasons, we abstract from any tax-consequences of μ_{ik}. It may be considered to reflect additional or reduced volumes of equity finance and, hence, non-tax-deductible capital investment costs necessary for the project.

a larger corporate tax base and imply that differences in corporate tax rates exert a stronger influence on corporate tax payments. Formally,

$$\frac{\partial^2 \phi}{\partial(t_h - t_\ell)\partial E(\pi_i)} = 1 > 0 \tag{5}$$

Thus, the incentive of the firm to locate project i in low-tax country ℓ becomes larger the higher the expected earnings of the project. This induces a project selection across locations in the sense that projects with high (low) earnings tend to be located in the low-tax country ℓ (high-tax country h).

Analogous considerations apply for the tax credit rate τ. If tax payments before the tax credit $t_k[E(\pi_i) - C]$ are large enough to exploit the full tax credit, it holds that $\gamma_{i\ell} = \gamma_{ih} = 1$. Differences in the tax credit rates τ_k then affect the location choice as

$$\frac{\partial \phi}{\partial(\tau_h - \tau_\ell)} = -C \tag{6}$$

Thus, the larger the difference in the tax credit rate granted by country h and country ℓ, the lower is the probability that the project is located in country ℓ. Note that this effect is independent from the expected earnings of the project as the value of the tax credit is determined by the size of R&D spending only $(\partial^2\phi/\partial(\tau_h - \tau_\ell)\partial E(\pi_i) = 0)$. The latter result does not hold though if affiliate earnings fall short from the tax credit value $\tau \cdot C$ and $\gamma_{ik} = \gamma_{ik}(E(\pi_i)) < 1$. Then, the effect of a change in the tax credit rate in country h on the probability that the project is located in country ℓ reads

$$\frac{\partial \phi}{\partial \tau_h} = -C \cdot \gamma_{ih} \tag{7}$$

Increases in the earnings rate of the project now diminish the probability that the project is located in country ℓ as higher earnings now imply that a larger fraction of the increased tax credit in country h can be exploited. Formally,

$$\frac{\partial^2 \phi}{\partial \tau_h \partial E(\pi_i)} = -C \cdot \frac{\partial \gamma_{ih}}{\partial E(\pi_i)} < 0 \tag{8}$$

Summarizing, the considerations in this section suggest that the corporate incentive to locate R&D projects in countries with a small patent income tax rate increases in the expected earnings and profitability of the projects. In the contrary, high tax credit rates do not impact on the earnings potential of the attracted projects if project profits (and other affiliate earnings) are high enough to ensure that the firm can exploit the full amount of the tax credit. High tax credit rates are only instrumental in attracting projects with above average earnings in situations in which the earnings rate of the project and other affiliate taxable activities are too low to exploit the full amount of the tax credit. Consequently, we expect that countries with a low patent income tax rate attract R&D projects with above average returns, while the effect is less clear for countries which grant high tax credits on R&D expenditures. In the following, we will empirically assess these hypotheses using patent data from the European Patent Office's (EPO) Worldwide Patent Statistical Database (PATSTAT).

3 Data

Patent and Firm Data

The PATSTAT data contains information on all patent applications to the EPO, including information about the patent applicant and patent inventor, the technology of the patent and patent citations. The information is available for 1978 to 2007. The data comprises up to 60,000 patent applications per year filed by corporations in Europe. In the analysis, we will account for patent applications from 1995 onwards as our tax and firm accounting data is restricted to that period (see below).

Firms seeking patent protection in a number of European states may file an application directly at the EPO and designate the relevant national offices (among those covered by the EPO) in which protection is sought.[8] Filing a patent with the EPO firstly enables a firm to make a single application, which is cheaper than filing separately in each national office, and, secondly, allows the firm to delay the decision over which national states to further the application in. Thus, it is especially attractive to file the valuable patents, which a firm intends to exploit in several European markets with the EPO.

Following previous studies, we use information on the location of the patent inventor as a proxy for R&D activity. Note that in most cases (more than 90% of the patent applications), the patent inventor is also the applicant of the patent and thus the owner of the associated income stream (or, patent inventor and applicant are at least located in the same country). As recent papers suggest that the decision to geographically split the location of patent inventor and patent applicant may partly reflect tax-motivated international profit shifting (see e.g. Boehm et al., 2012), we drop the according patents from our analysis and thus focus on the 'standard' case where the patent inventing unit

[8]The EPO is not a body of the European Union and, as a result, the states which form part of the European Patent Convention (the legal basis for the EPO) are distinct from those in the European Union. See: http://www.epo.org/about-us/epo/member-states.html.

is also the patent owner or is at least located in the same country.[9]

Furthermore, we link the patent information to firm-level accounting and ownership data in the AMADEUS data base provided by Bureau van Dijk. The link between the data bases is achieved through standard name matching procedures. Following previous efforts (see e.g. Abramovsky et al., 2008), the name of the AMADEUS firm has been matched to the name of the applicant on the patent application. Success rates of that procedure are comparable to previous studies (see e.g. Thoma et al., 2010). On average around 67% of the patents in our data are matched over all sample years and countries.[10] The match rates for the five largest EU countries by population are, for example, 47% for Spain, 55% for France, 68% for Germany, 63% for Italy and 72% for the United Kingdom. The majority of patent applicants is located in large industrialized economies. In the following, we will restrict our sample to corporate patents filed by multinational firms in Europe. Table 1a presents host country statistics for the patent applications in our data.[11]

Construction of the Patent Quality Indicators

As described above, the purpose of this paper is to assess the effect of corporate taxation on the earnings potential and other quality aspects of R&D projects in a country. Patent applications are ideal for this purpose as they allow to construct information on the underlying value of the patent and, hence, the invented technology to the firm. This is especially important as it has been demonstrated by earlier research that the corporate value of patents strongly varies and exhibits a highly skewed value distribution (see e.g. Harhoff et al., 1999).

In the following, project quality is proxied by the quality of patents invented in a country (see Section 5 for a discussion of this approach). The patent quality measure used in this analysis is constructed on the basis of a factor analysis.[12] The factor model accounts for three separate indicators (forward citations, family size and the number of technical fields) of the patent's underlying, latent quality.[13] The estimates of the

[9]Note that the patent applicant is the legal owner of the technology at the time of the application (as only the legal owner may apply for patent protection) and is therefore also the relevant subject for taxation (e.g. Quick and Day, 2006; Ernst and Spengel, 2011).

[10]For more details on the matching procedure, see Ernst and Spengel (2011).

[11]Note that our data is restricted to granted patents which allow for the construction of patent quality indicators as sketched in the next section.

[12]See Hall et al. (2007). We are grateful to Grid Thoma for providing us with this data.

[13]Each indicator's variation is assumed to consist of a quality related and an idiosyncratic com-

factor model can be used to construct an estimator for patent quality conditional on the indicators. In the following, we will give a brief description of the information used to derive the quality index. See Lanjouw and Schankerman (2004) and Hall et al. (2007) for more details.

The first quality information used for the index construction is the patent's family size, i.e. the number of jurisdictions or countries in which the firm has filed for patent protection for a particular innovation. We consider family size to be a particularly good proxy for our purpose as the theoretical model predicts that corporate income taxation induces a systematic selection of R&D projects with different expected earnings potentials across countries. While expected earnings of an R&D project are unobservable to the researcher, the patent's family size may serve as a good proxy since filing for patent protection involves considerable costs (see e.g. Helfgott, 1993). Thus, it only pays for a firm to protect its innovation in many markets if the innovation's expected earnings potential is large. For the construction of the measure, note that PATSTAT also contains information on patent applications to the US patent office and all other major national patent offices. This information is used to identify equivalent applications filed outside of the EPO at an earlier time (priority applications). In a first step, all priorities for the EPO patents were identified. In a second step, all applications that report the EPO application as a priority were identified. After removing any double counting, the number of patent applications plus the patents from step 1 constitute the size of the patent family.

Additionally, the patent quality measure accounts for the number of forward citations received by a patent within the 5 year period from the publication date. Intuitively, a high number of forward citations indicates that the technology protected by the patent has served as a basis for several future inventions and thus indicates a high degree of innovativeness and, as innovativeness determines economic success, a high earnings potential. Forward citations have an important legal function in the sense that they limit the scope of property rights which are awarded to a patent. In the case of EPO patents, inventors are not required to cite prior technology used in the development of their patent but the references are added by patent examiners. On the one hand, this implies that not necessarily all innovations which draw on an existing patent in fact acknowledge the reference. On the other hand, an external patent examiner has the benefit of following a consistent and objective patent citation practice.[14]

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ponent. Estimation of the factor model exploits that variation in patent quality induces variation common to all indicators.

[14]Note that previous studies have also used backward citations as a measure for patent quality.

Last, the construction of the patent quality index accounts for the number of technological classes named on the patent which have been shown by previous research to be an indicator of technological quality (see Lerner, 1994). For the purpose of guaranteeing a reasonable level of precision, the construction of our quality measures accounts for an eight-digit IPC classification reported in the patent document.

In general, several authors have also stressed that the value of patents varies across industries and across time. To account for that, we follow previous studies (e.g. Hall et al., 2007) and use quality measures which control for technology and year fixed effects (i.e. determine deviations from the average patent quality in a technology class at a given point in time). Note that using quality measures which do not account for this type of normalization yields similar results to the ones reported in this paper, as our regressions account for year and technology fixed effects.

Descriptive statistics for the quality measures in our data are presented in Table 1b. The composite quality index accounts for all three quality dimensions (forward citations, family size and industry classes) and controls for technology and year fixed effects. The average index is approximately 0, varying strongly between -2.5 and $+7.3$ though. Quality indices which account for one of the quality dimensions only (forward citations and family size) exhibit a similar distribution.

Corporate Taxation

As described above, our analysis will assess the effect of the corporate tax system on patent applications, accounting for two types of tax incentive instruments: the (output-based) patent income tax rate and (input-based) tax credit and allowances measures.

Information on the patent income tax in the host country of the patent inventor is obtained from Ernst and Young's corporate tax guides, the International Bureau of Fiscal Documentation's country analyses and other sources. Most countries tax patent income at the same rate as other corporate income. In recent years, a growing number of countries have, however, introduced special low tax rates on patent income (e.g. Belgium, Luxembourg and the Netherlands). While many of these special provisions were introduced after 2007 and are, thus, not reflected in our data, our tax measure accounts

While some scholars have suggested that a large number of backward citations may, for example, reflect a more derivative nature of a patent and a lower degree of innovation (see e.g. Lanjouw and Schankerman, 2004), a large number of citations may also reflect an innovative combination of existing ideas. Consequently, the literature has provided mixed results regarding the correlation between backward citations and patent value (see e.g. Harhoff et al. 1999). Hence, following this argumentation, our patent quality indicators do not account for information on backward citations.

for special tax provisions where applicable (in France, Ireland and the Netherlands). The average tax rate applicable to the patents in our data is 41%, varying strongly between 10% and 59%. The high average rate reflects that many patents in our data are filed from large economies, like Germany, which also charged high tax rates on corporate income within our sample period.

Yet, using this statutory tax rate as a measure for the tax burden on patent income disregards that several countries additionally levy a so-called withholding tax on royalty payments from their border. In case of cross-border royalty streams, patent income is, thus, not only taxed in the country that receives the royalty income but may also be taxed in the royalty paying country. Royalty tax rates are commonly determined in bilateral double taxation agreements between countries. The according information is retrieved from recent and historic bilateral tax treaties and from Ernst and Young's corporate tax guides. To avoid double taxation, royalty receiving countries commonly grant a tax credit for withholding taxes paid on the royalty income.[15] Thus, the effective tax rate t_e on a cross-border royalty stream is the maximum of the royalty income tax rate t_k in the patentee's host country k and the royalty withholding rate tw_{jk} charged on royalty streams from country j to country k: $t_e = max(t_k, tw_{jk})$.

To determine the average tax on royalty income related to a particular patent, we have to make assumptions on the structure of the royalty streams. We pursue two strategies: Firstly, we assume that the patent owner receives royalty payments from all countries within EU25 for the patented technology whereas the relative size of the royalty streams corresponds to the country size distribution as measured by the country's relative GDP. This assumption reflects that production and sales activities are plausibly positively correlated with market size and, thus, trigger higher payments for the use of the protected innovation. Formally, the definition reads

$$t_e = \sum_{j=1}^{25} W_j \cdot max(t_k, tw_{jk}) \tag{9}$$

where j indicates the considered country within EU25, including the host country of the patentee, and tw_{jk} depicts the respective royalty withholding rate charged on royalty income paid from country j to the patentee's host country k.[16] W_j is a weighting matrix capturing the size of the country's GDP relative to all other EU 25 countries

[15]There were a few exceptions to the credit method. If no double tax treaty was in force for a specific country in a specific year (especially in the 1990ies) the unilateral method to avoid double taxation was applied to calculate the effective income tax rate, e.g. deduction of the foreign withholding tax.

[16]Note that $tw_{jk} = 0$ if $j = k$.

$(W_j = GDP_j / \sum_{j=1}^{25} GDP_j)$.

An alternative way to construct the effective tax measure is to exploit information on the structure of multinational corporations in our data. Precisely, innovation protected by corporate patents is often exploited within the boundaries of the multinational firm only to avoid knowledge dissipation to competitors (Zuniqa and Guellec, 2009). Thus, our second strategy assumes that royalties are paid to the patentee from all other firms belonging to the multinational group. Ideally, following the above logic, one might want to weigh the information by affiliate size. As size information is missing for a relatively large number of cases in the AMADEUS data base though[17], we follow previous studies (see e.g. Dischinger and Riedel, 2011) and construct an unweighted average, which takes on the form

$$t_e = \sum_j \frac{1}{J} \cdot max(t_k, tw_{jk}) \tag{10}$$

where j indicates each of the J other affiliates within the multinational group (apart from the patenting affiliate), including the parent firm, and tw_{jk} again denotes the withholding tax rate charged by their host country on royalty payments to the patentee.

Moreover, to measure the effects of R&D tax credits and allowances on the quality of patents, we follow Warda (2001) and construct the so-called B-index which captures the tax component in the costs of an R&D investment (Guellec and van Pottelsberghe de la Potterie (2003)), accounting for special tax incentive regimes. The measure formally reads

$$B_k = \frac{1 - Z_k \cdot t_k}{1 - t_k} \tag{11}$$

where t_k stands for the corporate income tax rate in country k and Z_k represents a measure for the deductibility of R&D expenditures, including tax allowances or tax credits granted for R&D investments. The numerator reflects the after-tax cost of one unit of expenditure in R&D. If an R&D investment can be fully expensed in a fiscal year, the B-Index is equal to one since Z_k equals one. A tax incentive, granting for example an additional deduction on top of the normal deduction of R&D expenditures, reduces the value of B_k below one, as Z_k is then larger than one. Consequently, the lower the B-Index the more attractive is the tax system for R&D investments and vice versa. The B-Index information was obtained from Ernst and Spengel (2011).

[17] Note that AMADEUS contains ownership information on a worldwide basis. For most subsidiaries and parents outside Europe, accounting information which allows to proxy for subsidiary size is not available though.

Control Variables
Last, we augment our data by information on other country characteristics, like GDP per capita (as a proxy for economic development), the size of population (as a proxy for country size) and a corruption perception index obtained from the World Development Indicator Database and Transparency International respectively. We furthermore include information on the concomitant qualities of democratic and autocratic authority in a country's governing institutions using the so-called Polity2 Index. Note that Transparency International's corruption perception index ranges from 0 (high corruption) to 10 (absence of corruption), while the Polity 2 Index varies from -10 (strongly autocratic) to +10 (strongly democratic).

4 Estimation Strategy

As described above, the aim of our analysis is to identify whether the structure of the corporate tax system affects the quality of R&D projects undertaken in a country. To do so, we proxy for project quality by the patent quality indicators described in the previous section and estimate a model of the following form

$$q_{iat} = \beta_0 + \beta_1 \tau_{it} + \beta_2 X_{iat} + \phi_a + \mu_t + \epsilon_{iat} \qquad (12)$$

where q_{iat} indicates the quality of patent i filed at time t by affiliate a. The explanatory variable of main interest is τ_{it}, which is the vector of corporate tax parameters comprising the statutory tax rate on patent income levied by the host jurisdiction of the patenting firm, the effective tax rate on patent income and the B-Index capturing any tax incentive regimes for R&D investment. The theoretical considerations laid out above suggest that firms strategically select R&D projects across countries in the sense that patent quality is higher the smaller the statutory and effective tax rate on patent income, implying that we expect a negative coefficient estimate for the respective tax variables. The effect of the B-index on patent quality is less clear though. While, for low-profit firms, it may be attractive to locate high-value projects in countries with generous R&D tax allowances and tax credits to ensure that the reported earnings are high enough to exploit the full deduction value of the R&D tax incentives, this does not hold true for the standard case of firms which generate enough taxable earnings to account for the full R&D related tax deductions. For them, the deduction value of the R&D tax allowances and tax credits is independent from project quality and earnings and hence, we presume a zero effect for these entities.

To control for time-constant heterogeneity in average patent quality across firms and industries, we moreover include a full set of affiliate fixed effects and industry fixed effects (as determined by the first industry class named on the patent) in the estimation. The set of regressors is furthermore augmented by a full set of year fixed effects to absorb common shocks to patent quality which simultaneously affect all patents in the data. Additionally, we include time-varying country controls for market size (as measured by the host country's GDP), the degree of development (as measured by the host country's GDP per capita) and the country's political and governance situation (as measured by the Transparency International corruption index and the Polity2 Index). Last, we augment the vector of control variables by firm size information as measured by the number of employees to control for a potential systematic correlation between corporate taxation, firm size and patent quality.

5 Results

The estimation results are presented in Tables 2 to 5. The tables display the coefficient estimates and heteroscedasticity robust standard errors which are adjusted for clustering at the country-year level. In Specification (1) of Table 2, we regress the composite quality measure on the statutory tax rate levied on patent income in the host country of the patent applicant, simultaneously controlling for country and year fixed effects. The coefficient estimate is negative and statistically significant, suggesting that an increase in the patent income tax rate by 10 percentage points reduces the quality index by 0.025. Evaluated at the sample mean, this corresponds to a decline by 1.1%.[18]

Specifications (2) and (3) reestimate specification (1) augmenting the vector of regressors by a full set of industry fixed effects and time-varying country controls. While the inclusion of the additional control variables leaves the qualitative results unaffected, adding the set of time-varying country controls leads to a slight drop in the quantitative coefficient estimate for the statutory tax rate variable. Specification (4), furthermore, includes a full set of affiliate fixed effects which absorb any time-constant heterogeneity in the quality of R&D projects across patent inventing firms. Specification (5) adds the logarithm of the firm's number of employees as an additional control variable. Both specifications confirm our previous findings and suggest a significantly negative impact of the patent income tax rate on patent quality. Quantitatively, specification (5) in-

[18]As the composite quality index (CQI) may take on negative values, the semi-elasticity is evaluated at the sample average of the variable plus the absolute value of the variable's minimum: $|\min(\text{CQI})| + \text{avg}(\text{CQI}) = 2.5289 - 0.1958 = 2.3331$, cf. Table 1b. It follows that $0.025/2.3331 = 1.1\%$.

dicates that an increase in the statutory tax rate on patent income by 10 percentage points decreases the patent quality index by 0.13. Evaluated at the sample mean, this corresponds to a decline by 5.6%.

As a robustness check, we further reran the analysis using the patent's number of forward citations and family size as proxies for its degree of innovation and earnings potential. The results are presented in specifications (6) to (9). Similar to the previous estimates, we find that patent taxation reduces the quality measure. An increase in the tax rate by 10 percentage points lowers the family size index (the forward citation index) by 0.11 (0.06). Evaluated at the sample mean, this corresponds to a decrease by 6.4% (2.9%) (cf. specification (7) and specification (9) respectively). To the extent that the patent's family size and forward citations serve as a proxy for the earnings potential and the degree of innovation of the underlying R&D project, the estimates thus suggest a significant reduction in the two welfare components.

Moreover, the effective tax burden on patent income does not only depend on the statutory tax on patent income charged by the host country of the royalty recipient but may, in case of cross-border payments, be equally determined by royalty withholding taxes charged by the royalty paying country. As laid out in Section 3, we account for this by constructing an effective tax rate on patent income which takes both rates into account. The results are presented in Table 3. Specifications (1) to (6) employ an effective tax rate measure which is constructed based on the assumption that the patentee receives royalty payments from all countries within EU25 and that the relative size of the royalty streams matches partner country size (see Section 3, equation (9)). Specifications (7) to (12) employ an effective tax rate measure which is constructed based on the assumption that the patentee receives royalties from all other affiliates within the same multinational group (see Section 3, equation (10)). The results confirm our qualitative and quantitative baseline findings for the statutory patent income tax rate, irrespective of whether the composite patent quality index is used as the dependent variable or the indices reflecting forward citations or patent family size.

Note, moreover, that our results are robust to clustering standard errors at different levels. While our baseline specifications report standard errors that allow for correlation of residuals in the same country and year cell, we reran our specifications calculating standard errors that account for correlation within country clusters and industry clusters respectively. Table 4 presents the results of specifications which reestimate the models presented in columns (7) to (12) of Table 3. The modification leaves the statistical significance of the coefficient estimates for the tax variable (the effective tax measure calculated based on multinational group structure information) unaltered.

Finally, Table 5 tests for a potential link between R&D tax allowances and tax credits as measured by the B-index and patent quality. Specifications (1) and (2) regress the composite patent quality index on the B-index as well as the effective tax measure calculated based on group structure information. The coefficient estimate for the effective tax rate on patent income, again, shows a negative sign, indicating a statistically significant and economically relevant impact of patent income taxes on patent quality. Quantitatively, an increase in the tax rate by 10 percentage points reduces patent quality by 0.18 or 7.7%. The coefficient estimate for the B-index is in turn quantitatively small and statistically insignificant, confirming the notion laid out in Section 2 that R&D tax provisions do not impact on the quality and earnings potential of R&D projects undertaken in a country as their tax saving value is only related to R&D costs but not to expected earnings. Again, we reran the regressions using the patent's forward citations (cf. specifications (3) and (4)) and its family size (cf. specifications (5) and (6)) as proxies for patent quality which yields comparable results. As a robustness check, we furthermore also ran specifications which included the B-index as the only tax measure, which does not change our results.

To sum up, our findings are in line with the notion that firms strategically select their R&D projects across borders in response to corporate tax incentives. Proxying for the projects' earnings potential and degree of innovation by patent quality indicators, we find that high-value projects tend to be located in countries with a low effective patent income tax rate, while low-value projects tend to be located in high-tax countries. In line with our theoretical considerations, we find no statistically significant impact of R&D tax incentives, like tax allowances and tax credits, on project quality.

Note again that these findings are unlikely to reflect tax-motivated international profit shifting as we focus on the location of the patent inventing unit and drop patents where the patent applicant (i.e. the owner) and the patent inventor are located in different countries. Another issue that merits discussion is the use of the patent quality measure to proxy for the quality of R&D projects. In particular, strategic patenting may involve that different subparts of one innovation are protected by a number of interconnected patents. This directly implies that increases in the quality of an R&D project may partly show up through increases in the number of patents filed by a corporation. Using the number of patent applications as the main regressand, like done in previous research (see e.g. Ernst and Spengel, 2011, Griffith et al., 2011, Karkinsky and Riedel, 2012), might thus capture both, responses in the quality and quantity of R&D projects to corporate taxation. The merit of our approach is in turn that it allows for an isolated identification of the quality effect by investigating the impact of patent income taxation and R&D tax incentives on the quality of patents filed by a corporation, conditional on the number of patent applications.

6 Conclusion

In recent years, a large and growing empirical literature has shown that corporate taxation negatively impacts on corporate investment behavior at the extensive and intensive margin. Most existing papers, however, restrict their view on testing for corporate tax effects on investment *quantity*. The welfare implications of corporate taxation in turn critically depend on the effects of corporate taxation on investment *quality*, e.g. the number of jobs created, the size of corporate tax payments and the innovations resulting from R&D activity (see Fuest et al., 2012).

The aim of this paper was to assess the effect of the design of the corporate tax system on the quality of innovations resulting from R&D activity. While a number of existing papers assess the effect of corporate taxation on quantitative R&D levels as measured by R&D spending and the number of corporate patent applications, our analysis stresses that tax instruments may also exert an effect on the quality of R&D activities, i.e. on their earnings potential (and consequently the company's corporate tax payments) and degree of innovation. The paper sets up a simple theoretical model to derive empirically testable hypotheses. The main insight from the theoretical analysis is that while low income tax rates on the output from R&D activities raise the quality of attracted R&D projects, the same does not hold true for R&D tax incentives, like tax allowances and tax credits, whose benefits for the corporation are related to the size of its R&D expenditures instead of expected earnings (at least as long as corporate profits are high enough to fully exploit the tax deduction value related to the incentives).

To assess this hypothesis, we use rich data on patent applications to the EPO between 1995 and 2007 which is linked with firm level information. Proxying for a project's earnings potential and innovativeness by patent quality measures constructed from information on the patent's family size, its number of forward citations and the number of industry classes, we find that, in line with our theoretical expectations, low tax rates on patent income tend to increase the quality of patents filed from a country. The effect also turns out to be economically relevant. An increase in the patent income tax rate by 10 percentage points reduces patent quality by around 5.6%. The empirical findings furthermore confirm the theoretical notion that tax allowances and tax credits for R&D investment do not exert a significant impact on observed project quality.

These results may have important implications for the design of tax instruments related to innovation policy. In recent years, several governments in Europe significanlty reduced their tax rates on patent income. Most academic observers interpreted these policy adjustments to target mobile international patent income. Policy makers in turn justified the tax adjustment with the aim to foster and attract innovative R&D activities (see e.g. the UK Pre-Budget Report 2009, footnote 1). Our findings confirm the latter notion and suggest that low patent income tax rates are indeed instrumental in attracting R&D projects with an above average earnings potential and innovativeness. Interestingly, we do not find an analogous effect for R&D tax subsidies, like R&D tax allowances and R&D tax credits as their deduction value is unrelated to project quality. Thus, while both tax policy measures may help to attract and increase the size of R&D projects (i.e. R&D quantity), only low patent income taxes are found to exert a positive effect on project quality, i.e. its earnings potential and innovativeness.

Appendix: Tables

Table 1a: Country Statistics	
Country	*Number of Patents*
Austria	3,127
Belgium	2,217
Bulgaria	9
Switzerland	8,495
Czech Republic	75
Germany	74,620
Denmark	2,536
Spain	1,453
Finland	3,788
France	23,842
Great Britain	12,145
Greece	60
Hungary	166
Ireland	331
Italy	11,886
Lithuania	1
Netherlands	8,080
Norway	969
Poland	53
Portugal	70
Romania	2
Sweden	6,805
Slovenia	50
Slovakia	10
Sum	160,790

Table 1b: Descriptive Statistics					
Variable	*Obs.*	*Mean*	*Median*	*Min.*	*Max.*
Composite Quality Index	160,790	-.1958	-.2494	-2.5289	7.2887
Quality Index - Forward Citations	160,790	-.2769	-.3026	-2.3566	7.2058
Quality Index - Family Size	160,790	-.0801	-.1349	-1.7970	5.2683
Patent Income Tax	160,790	.4061	.3836	.1	.59
Effective Patent Income Tax (GDP weighted)	159,821	.4057	.3890	.1011	.5680
Effective Patent Income Tax (group structure)	86,284	.4065	.3890	.1	.5680
B-Index	112,058	.9944	.0724	.428	1.069
GDP	160,790	1.55e+12	1.80e+12	1.27e+10	2.90e+12
GDP pC	160,790	26,128.32	25,913.16	5,365.83	51,862.42
Polity2	160,790	9.8513	10	8	10
TPI Corruption Index	160,790	7.6987	7.9	2.9	10
Log Employees	23,056	6.8880	6.8690	0	12.6863

Notes:
The Composite Quality Index is a measure for patent quality derived from a factor model accounting for the patent's forward citations, its family size and the number of industry classes (conditional on industry and year fixed effects). The Forward Citations (Family Size) Index is an analogous measure which accounts for the number of forward citations (family size) of the patent only. Patent Income Tax stands for the statutory tax rate on patent income, the Effective Patent Income Tax (GDP weighted) additionally accounts for withholding tax rates on cross-border royalty streams charged by the royalty paying country. Its construction assumes that the patent owner receives royalties from all EU25 countries and that the composition of the royalty stream corresponds to the relative size of the countries. The construction of the Effective Patent Income Tax (group structure) exploits ownership information from the Amadeus database to identify multinational affiliates within the same multinational group and assumes that the patent owner receives royalty payments from all other group affiliates (unweighted average). See Section 3 for details. The construction of the B-index follows Equation (11) in Section 3. GDP and GDP pC depict the host country's gross domestic product and gross domestic product per capita respectively in US dollars. The polity2 index captures information on concomitant qualities of democratic and autocratic authority in governing institutions. The Polity 2 Index varies from -10 (strongly autocratic) to +10 (strongly democratic). TPI Corruption Index stands for the Transparency International corruption perception index which ranges from 0 (high corruption) to 10 (absence of corruption). Log Employees stands for the natural logarithm of the number of workers employeed by the patent-filing firm.

Table 2: Patent Income Tax and Patent Quality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Composite Quality Index					Family Size		Forward Citation	
Patent Income Tax	-.249***	-.289***	-.190**	-.435***	-1.304***	-.096	-1.122***	-.222***	-.616*
	(.074)	(.074)	(.083)	(.110)	(.284)	(.066)	(.219)	(.084)	(.321)
$GDP/10^{12}$			.063***	.006	.202***	.051***	.178***	.059**	.112**
			(.023)	(.022)	(.043)	(.018)	(.037)	(.026)	(.053)
$GDP\ pC/10^3$			-.014***	-.015**	.200**	-.006	.019**	-.020***	.015
			(.005)	(.006)	(.010)	(.004)	(.008)	(.005)	(.011)
Polity 2			-.005*	.118	.050	.084	.118**	-.213*	-.163
			(.079)	(.083)	(.072)	(.074)	(.053)	(.113)	(.126)
TPI Corruption Index			.000*	.000	.049**	-.003	.034*	.004	.041
			(.009)	(.012)	(.022)	(.007)	(.019)	(.013)	(.026)
Log Employees					.023		.019*		.021
					(.016)		(.011)		(.018)
Industry Fixed Effects		√	√	√	√	√	√	√	√
Country Fixed Effects	√	√	√			√		√	
Affiliate Fixed Effects				√	√		√		√
# Observations	160,790	160,790	160,790	128,101	23,056	160,790	23,056	160,790	23,056
R Squared	0.0718	0.1296	0.1298	0.4250	0.4874	0.1659	0.5895	0.0463	0.3437

Notes:

*, **, *** indicate significance at the 10%, 5% and 1% level. Heteroscedasticity robust standard errors adjusted for country-year clusters in parentheses. The observational unit is the patent application whereas the sample is restricted to patent applications where inventor and patent applicant are located in the same country. The dependent variable is the composite patent quality index (specifications (1) to (5)) and the family size and forward citations index respectively (specifications (6) to (9)). For details on the variable definition, see the notes to Table 1b. All specifications include a full set of year fixed effects.

Table 3: Effective Patent Income Tax and Patent Quality

	Effective Patent Income Tax - GDP weighted						Effective Patent Income Tax - Group Structure					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Comp. Qual. Index		Family Size		Forward Citation		Comp. Qual. Index		Family Size		Forward Citation	
Effective Patent Income Tax	-.152*	-1.32***	-.078	-1.14***	-.180**	-.618*	-.383***	-1.806***	-.275***	-1.421***	-.455***	-1.25***
	(.091)	(.279)	(.073)	(.217)	(.087)	(.317)	(.119)	(.421)	(.100)	(.363)	(.123)	(.376)
GDP/10^{12}	.066***	.210***	.049**	.184***	.071***	.116**	.046	.134**	.018	.152***	.072*	.005
	(.023)	(.043)	(.019)	(.038)	(.026)	(.054)	(.031)	(.059)	(.026)	(.047)	(.039)	(.080)
GDP pC/10^3	-.017***	.027	-.005	.025**	-.026***	.018	-.012*	.045***	.001	.043***	-.025***	.020
	(.006)	(.011)	(.005)	(.010)	(.006)	(.012)	(.007)	(.017)	(.006)	(.014)	(.008)	(.019)
Polity 2	-.009	-.045	.084	.112**	-.219*	-.163	.081*	.049*	.166***	.100	-.268*	-.133
	(.080)	(.072)	(.074)	(.053)	(.114)	(.125)	(.041)	(.079)	(.047)	(.063)	(.149)	(.137)
TPI Corruption Index	-.002	.045**	-.005	.029	.002	.039	.001*	.064**	-.001	.047*	.004	.051
	(.009)	(.022)	(.007)	(.019)	(.013)	(.026)	(.013)	(.029)	(.009)	(.024)	(.016)	(.037)
Log Employees		.023		.019*		.023		-.014**		.008		.031
		(.016)		(.014)		(.019)		(.022)		(.016)		(.029)
Industry Fixed Effects	√	√	√	√	√	√	√	√	√	√	√	√
Country Fixed Effects	√		√		√		√		√		√	
Affiliate Fixed Effects		√		√		√		√		√		√
# Observations	159,821	22,801	159,821	22,801	159,821	22,801	86,284	15,214	86,284	15,214	86,284	15,214
R Squared	0.1296	0.4851	0.1644	0.5870	0.0463	0.3404	0.1358	0.4895	0.1819	0.5948	0.0507	0.3400

Notes:

*, **, *** indicate significance at the 10%, 5% and 1% level. Heteroscedasticity robust standard errors adjusted for country-year clusters in parentheses. The observational unit is the patent application whereas the sample is restricted to patent applications where inventor and patent applicant are located in the same country. The dependent variable is the composite patent quality index (specifications (1)-(2), (7)-(8)) and the family size (specifications (3)-(4) and (9)-(10)) and forward citations index respectively (specifications (5)-(6) and (11)-(12)). For details on the variable definition, see the notes to Table 1b. All specifications include a full set of year fixed effects.

Table 4: Clustering of Standard Errors at Different Levels

	Comp. Qual. Index				Family Size				Forward Citation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Country Cl.		Industry Cl.		Country Cl.		Industry Cl.		Country Cl.		Industry Cl.	
Effective Patent Income Tax	-.280	-1.806**	-.280**	-1.806***	-.275	-1.421**	-.275***	-1.421***	-.455***	-1.252**	-.455***	-1.252 *
	(.173)	(.685)	(.137)	(.494)	(.167)	(.565)	(.073)	(.386)	(.133)	(.503)	(.165)	(.744)
GDP/10^{12}	-.031	.134*	-.031	.134	.018	.152*	.018	.152**	.072*	.005	.072	.005
	(.036)	(.078)	(.020)	(.093)	(.041)	(.079)	(.029)	(.070)	(.039)	(.067)	(.045)	(.101)
GDP pC/10^3	-.022*	.045*	-.022***	.045**	.001	.043*	.001	.043***	-.025***	.020	-.025***	.020
	(.012)	(.023)	(.006)	(.022)	(.011)	(.022)	(.004)	(.016)	(.007)	(.014)	(.009)	(.027)
Polity 2	-.052	.049	.052	.049	.166***	.100	.166***	.100	-.268	-.133	-.268	-.133
	(.065)	(.115)	(.055)	(.078)	(.038)	(.086)	(.059)	(.068)	(.212)	(.151)	(.196)	(.112)
TPI Corruption Index	-.004	.064	-.004	.064**	-.001	.047	-.001	.047**	.004	.051	.004	.051
	(017)	(.043)	(.011)	(.032)	(.009)	(.031)	(.008)	(.019)	(.015)	(.049)	(.013)	(.048)
Log Employees		.014		.014		.008		.008		.031		.031
		(.023)		(.027)		(.019)		(.018)		(.024)		(.044)
Industry Fixed Effects	√	√	√	√	√	√	√	√	√	√	√	√
Country Fixed Effects	√		√		√		√		√		√	
Affiliate Fixed Effects		√		√		√		√		√		√
# Observations	86,284	15,214	86,284	15,214	86,284	15,214	86,284	15,214	86,284	15,214	86,284	15,214
R Squared	0.4090	0.4895	0.4090	0.4895	0.1819	0.5948	0.1819	0.5948	0.0507	0.1275	0.0507	0.3400

Notes:

*, **, *** indicate significance at the 10%, 5% and 1% level. Heteroscedasticity robust standard errors adjusted for country clusters (specifications (1)-(2), (5)-(6), (9)-(10)) and industry clusters (specifications (3)-(4), (7)-(8), (11)-(12)) respectively in parentheses. The observational unit is the patent application whereas the sample is restricted to patent applications where inventor and patent applicant are located in the same country. The dependent variable is the composite patent quality index (specifications (1)-(4)) and the family size (specifications (5)-(8)) and forward citations index respectively (specifications (9)-(12)). For details on the variable definition, see the notes to Table 1b. All specifications include a full set of year fixed effects.

Table 5: B-Index and Patent Quality						
	(1)	(2)	(3)	(4)	(5)	(6)
	Comp. Qual. Index		Family Size		Forward Citation	
Effective Patent Income Tax	$-.390^{***}$	-1.819^{***}	$-.291^{***}$	-1.435^{***}	$-.445^{***}$	-1.266^{***}
	(.126)	(.426)	(.084)	(.354)	(.171)	(.399)
B-Index	.014	.189	.143	.309	-.016	-.032
	(.191)	(.304)	(.138)	(.274)	(.244)	(453)
GDP/10^{12}	$.089^{**}$	$.144^{**}$	$.054^{*}$	$.167^{**}$	.081	-.021
	(.040)	(.068)	(.029)	(.053)	(.058)	(.099)
GDP pC/10^{3}	$-.023^{***}$	$.041^{***}$	$-.010^{*}$	$.036^{**}$	$-.037^{***}$	.023
	(.008)	(.015)	(.006)	(.013)	(.009)	(.020)
Polity2	.076	.034	$.148^{***}$	.075	$-.260^{*}$	-.136
	(.051)	(.086)	(.045)	(.069)	(157)	(.143)
TPI Corruption Index	$.058^{***}$	$.065^{**}$	$.039^{**}$	$.046^{*}$	$.061^{**}$	.056
	(.019)	(.030)	(.014)	(.024)	(.027)	(.038)
Log Employees		.015		.011		.027
		(.022)		(.016)		(031)
Industry Fixed Effects	√	√	√	√	√	√
Country Fixed Effects	√		√		√	
Affiliate Fixed Effects		√		√		√
# Observations	59,197	15,083	59,197	15,083	59,197	15,083
R Squared	0.1306	0.4912	0.1844	0.5977	0.0531	0.3415

Notes:

*, **, *** indicate significance at the 10%, 5% and 1% level. Heteroscedasticity robust standard errors adjusted for country-year clusters in parentheses. The observational unit is the patent application whereas the sample is restricted to patent applications where inventor and patent applicant are located in the same country. The dependent variable is the composite patent quality index (specifications (1)-(2)) and the family size (specifications (3)-(4)) and forward citations index respectively (specifications (5)-(6)). For details on the variable definition, see the notes to Table 1b. All specifications include a full set of year fixed effects.

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