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Abstract

The paper discusses the effects of the corporate tax on local R&D expenditures by multinational enterprises (MNEs) when income from intellectual property (IP) may or may not benefit from a special IP regime. Our model shows that an increase of the standard corporate tax may have positive effects on the R&D expenditures in the country that carries out the corporate tax increase. The possible positive R&D effect results from a tax asymmetry: not all R&D returns are subject to the higher tax. First, since R&D creates a public good within the MNE, some of the R&D benefit is taxed at other countries' tax rates that are not subject to the tax increase. Second, some of the R&D benefits are taxed at a lower IP regime tax rate. Therefore, a higher corporate tax, which increases value of the cost deductibility of R&D, may actually foster R&D. This expectation is empirically supported by country-by-country R&D data of U.S.-owned subsidiaries for countries that have an IP regime.

Keywords: corporate income tax, R&D, intellectual property regimes, patent box, international profit shifting

JEL classification: H25, H26, O3

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1. Introduction

The taxation of income from intellectual property (IP) has received considerable research interest in recent years. Much of this interest has been stirred by new tax legislation and the political debate connected to it. In the last twenty years, many countries have moved to schedular taxation by introducing a special tax rate on intellectual property income that is below the standard corporate tax rate. Schemes that introduce such a schedularization of business taxation have been labelled as patent boxes, innovation boxes, IP boxes, or IP regimes (OECD, 2015; OECD, 2017).

Intangible assets are increasingly perceived to be important value-drivers within multinational enterprises (MNEs). From the perspective of an MNE, locating these assets in low-tax affiliates is an attractive tax-saving strategy. There is a large body of literature, more extensively reviewed in the next section, that indicates that IP boxes and taxes on income from intellectual property affect the location of patents. For example, Griffith *et al.* (2014) and Alstadsæter *et al.* (2018) provide evidence that a lower tax on IP income increases the number of patents that are registered in the respective jurisdiction.

While there is ample evidence that low tax rates attract the location of patents, empirical evidence on the effects of taxes on the location of actual research and development (R&D) activity is all but missing. An exception is Alstadsæter *et al.* (2018) who find that the tax advantage of IP boxes in a panel sample of large research-intensive multinationals is negatively rather than positively correlated with a variable designed to measure the shift of inventors to IP box countries.

One difficulty of identifying tax effects on the location of R&D activity is that country-level data on R&D expenditures of multinational companies is scarce. Most existing studies on IP boxes work with patent registration data. At the same time, the location of patent registration provides limited evidence on where the actual R&D activities take place and, in particular, on the size of local R&D expenditures. When it comes to patent registration data, evidence on the distinction of patent registration and the location of real R&D activity can only be derived from a gap between the country of registration and the residence country of the inventor. This leaves a potentially important research gap since the technological spillover effects of foreign direct investment and foreign know-how are expected to result from the size of real research activity, not so much from the mere registration of patents or the residence of single individuals. Within an MNE, the registration of patents may be influenced by the wish to shift profit into low-tax jurisdictions, without much connection to the location of research activity.

While corporate groups report aggregate R&D expenditures, the distribution across different subsidiaries is difficult to obtain in data bases that are readily available for researchers. The present paper adds empirical evidence on real R&D activity by looking at R&D expenditures of U.S. majority-owned subsidiaries abroad, data that is available on the country-year level from the Bureau of Economic Analysis (BEA).

Our empirical analysis is guided by a model of optimal R&D decisions. Within our model MNE, the benefits of R&D derive from royalty income and from increased productivity of the MNE as a whole. Since the increased productivity is not confined to the subsidiary that undertakes the R&D, research expenditures contribute towards a public good within the MNE.¹ This can have interesting and counter-intuitive implications for the role of corporate taxes if one country exogenously increases its corporate tax. An increase in the corporate tax of one country means that the value of the cost deductibility of R&D expenditures increases in this country. At the same time, due to the public goods characteristics, the additional benefits of a marginal unit of R&D occurs in other countries as well. As the tax rates of these other countries are constant, the average tax rate on R&D benefits across subsidiaries increases by less than the tax rate for the deduction of R&D expenditures. As a result, a corporate tax increase can increase local R&D of foreign subsidiaries. This cost shifting is a tax efficient reaction if, as it is assumed in the model, the subsidiary that increases its R&D costs reports positive taxable profits, which implies that transfer pricing strategies and other strategies of tax avoidance are insufficient to wipe out all taxable profits. Thus, in our study, we propound the possibly counter-intuitive idea that a higher statutory corporate income tax rate may have positive effects on the local R&D expenditures by MNEs.

The positive effect of the corporate tax on R&D expenditures may even be amplified by the existence of an IP regime. In this case, if the R&D in the tax-reform country increases, not only the profitability gains of affiliated subsidiaries in other countries are sheltered from the corporate tax increase. In addition, the IP regime allows to spare from the tax rise qualified IP income in the country that introduces the corporate tax increase.

A priori, the role of IP regime for the way in which the corporate tax rate affects R&D expenditures, however, is not unambiguous. While it is true that a lower IP tax rate leaves more of the benefits of R&D to an innovating firm, the existence of an IP box may also reduce the tax rate

¹ Recent evidence that corporate R&D leads to productivity gains in other parts of a multinational is provided by Bilir and Morales (2020). The idea that knowledge is shared across locations within the firm dates back at least to Arrow (1975) and is consistent with recent studies emphasizing the transfer of intangible inputs within firm boundaries as a key motive for plant integration (Atalay *et al.*, 2014).

applicable when a subsidiary deducts its R&D expenditures. *De jure*, most international IP regimes are following the net income approach. In a net income approach, the preferential IP rate applies not only to the revenues earned on the IP. It should also be applied when deducting the cost incurred to produce the IP. If this approach is followed through, an increase in the headline corporate tax rate may not increase the value of the cost deductibility of R&D expenditures and their overall size. In practice, however, it should be difficult to tell apart all those cost from normal business expenses. In this case, for tax purposes, firms have a strong incentive to declare that facilities and most of the personnel are used for non-R&D related purposes.

A further reason why an IP box may not prevent that R&D expenditures are deducted against the standard corporate tax rate changes is the application of the gross income approach: a few countries officially allow all R&D costs to be deductible at the higher standard rate, while IP revenues still benefit from the preferential IP rate.

In the end, the question of whether an increase in the corporate tax rate has a higher or lower R&D effect in countries with an IP box is an empirical one. Our empirical analysis of R&D by U.S.-owned MNEs shows that the headline corporate tax has a positive, though insignificant, effect on R&D if there is no IP regime. The effect of a corporate tax increase on R&D expenditures is larger and significant in IP regime countries. This is compatible with the expectation that tax incentives are active and a large share of R&D deductions for tax purposes is channeled into the standard basket of deductions. We find no significant differences of corporate tax changes depending on whether an IP regime uses the gross or a net income approach.

The empirical result that a higher corporate tax rate tends to have a positive effect on R&D expenditures may not only come as a surprise to many policy makers, but, as to our best knowledge, is new to the literature on taxes and R&D.

When it comes to the effect of an IP regime, we find that given an IP regime is in place, a lower preferential rate on IP income significantly increases R&D expenditures. This suggests a positive effect of the tax preference on the attractiveness for R&D, while Alstadsæter *et al.* (2018, p. 165) found that, in their sample, the size of the tax advantage of patent boxes led to a surprising negative effect on the probability of moving inventors to the patent box country. At the same time, in our study, the introduction of an IP regime has only a small effect on R&D.

The remainder of the paper is as follows. Section 2 provides a literature review of previous studies that look at how taxes affect the international location of patents. Section 3 introduces a simple

model of an MNE's R&D decisions. Section 4 presents our data, Section 5 discusses the empirical results derived from U.S. MNE expenditures. Section 6 concludes.

2. Literature review

Evers *et al.*, (2015) and Bradley *et al.*, (2015) review several objectives that may motivate governments' decisions to introduce Intellectual Property regimes.³ Both papers suggest that governments that introduce IP regimes aim to reduce tax base erosion, which occurs when IP is shifted to tax havens or other tax law jurisdictions.

Against the background of our own study, the main interest is in existing papers that evaluate the link between taxes, IP regimes and the amount and location of R&D output.

Most prior studies have measured R&D output in terms of patents and suggest that low and preferential tax rates on IP income lead to more local R&D output. At the same time, the tax induced increase in patent applications seems associated with a significant increase of the share of patents whose inventors are located abroad. This leaves open whether an IP regime is able to attract also the underlying R&D activity.

Ernst and Spengel (2011) estimate that a decrease of the corporate income tax rate increases the average count of patent applications, the effect being 120% larger for inventions developed by foreign inventors. Griffith *et al.* (2011) and Griffith *et al.*, (2014) confirm that lowering a country's corporate tax increases the probability that a patent is registered for a firm in that jurisdiction. In addition, Griffith *et al.* (2011) document that the introduction of IP regimes in Benelux countries increased newly created patents in Benelux countries, but a fall elsewhere. Bradley *et al.*, (2015) suggest a roughly 3% increase in new patent applications for every one percentage point decrease in the tax rate on patent income. Unlike in Griffith *et al.* (2011), this effect appears to be confined to patents for which the inventors and patent owners are located in the same host country; there seemed no measurable impact on the number of patents owned and invented in different countries. Evers *et al.* (2015), Klemens (2016) and Liberini *et al.* (2018) provide further evidence that preferential tax rate regimes on IP income distort patent registration and lure income on intellectual property to countries that, apart from the IP regimes, are not necessarily perceived as low-tax countries.

³ Other objectives that may motivate governments' decisions to introduce Intellectual Property regimes might be: to foster domestic innovation and the creation of high-value jobs; to incentivize firms to increase investment in innovative activities; to attract or retain mobile investments that may be associated with high-skilled jobs and knowledge creation (Evers *et al.*, 2015; Bradley *et al.*, 2015).

Schwab and Todtenhaupt (2017) and Gaessler *et al.*, 2018 investigate the role of restrictions on preferential regimes, with a particular focus on the “modified nexus approach”. IP boxes with nexus requirement effectively preclude tax benefits from the transfer of intangibles and, thus, seem to result in much smaller cross-border spillovers.

While most studies concentrate on the location of new patents, Alstadsæter *et al.* (2018) not only look at patent registration, but also on the location of researchers. Using patent applications to the EPO of world corporate R&D investors from 39 home countries in 33 different host countries over 2000-12, this paper suggests that patent boxes have a strong effect on patent registrations, especially when these regimes are generous and have a large coverage in terms of the types of IP covered. When it comes to real activity, the tax advantage linked to IP boxes is associated negatively with the annual growth in the number of inventors and also negatively with the probability that a MNE moves inventors from other affiliates to an affiliate in a patent box country.

As intellectual property is firm-specific in nature, arm’s length prices are difficult to obtain. This creates opportunities for MNEs to shift income to low-tax countries by mispricing intra-firm royalties and license fees. Papers looking for evidence on such profit shifting are part of a closely related strand of the literature. Dischinger and Riedel (2011) find that the lower a subsidiary’s corporate tax rate compared to all other affiliates of the same multinational group, including also the parent, the higher is its probability of holding intangible assets there. Karkinsky and Riedel (2012) show that the number of patent applications filed by multinational affiliates strongly responds to changes in corporate tax rate. The estimated semi-elasticity ranges between -3.5% and -3.8%. At the same time, there are no statistically significant negative effects on patent applications for purely domestic firms, which lack low-tax affiliates. Böhm *et al.* (2012) analyze the extent to which corporations use patents to transfer corporate income to tax favored locations within multinational groups. They provide evidence that low-tax countries are more likely to attract ownership of foreign-invented patents. Indeed, the majority of patents owned in tax-haven locations is invented in a foreign country. Griffith *et al.* (2014) suggests a negative and statistically significant marginal impact of tax on the payoff from placing legal ownership of a patent in a location, where the own-tax semi-elasticity of patent location choice varies between -0.5% and 3.9%. Dudar and Vogel (2016) conclude that companies seem to use intangible assets as an instrument of base erosion and profit shifting. Several other studies provide more direct evidence on the fact that IP ownership creates opportunities for strategic mispricing of intrafirm trade (e.g. Hebous and Johannesen, 2015; Liu *et al.*, 2017; Hopland *et al.*, 2018). Recently, Baumann *et al.* (2020) provide descriptive evidence on the negative correlation between a country’s patent income

tax rate and its fraction of foreign-invented patents, suggesting that the propensity to locate patent ownership in foreign tax haven economies increases in the inventor country's patent income tax rate.

A rich study on the tax effects on innovation and patents in the U.S. is Akcigit *et al.*, (2021). While it shows that the corporate tax has a significantly negative effect on patents, this comes “predominantly from mobility responses” (p. 4) suggesting that aggregate effects across U.S. states are zero-sum. This leaves open the effect of international tax rate differences. Knoll *et al.* (2021) consider multinational firms and their reactions to input-related R&D tax incentives such as tax credits, accelerated depreciation or super-deductions. The results suggest that MNEs respond to R&D tax incentives by relocating patent activity within the MNE rather than by increasing their aggregate patent activity.

3. A Model of R&D location within an MNE

This section studies the decision making on R&D expenditures in a simply model, in which an MNE consists of two subsidiaries in two different countries, labelled 1, 2. The main objective of the exercise is to show that the size of the standard corporate tax rate may have a positive effect on local R&D if (i) R&D cost are deductible against this standard rate and (ii) the benefits of R&D are partly taxed at some other rate, either at a foreign one or at a rate deriving from a preferential IP regime.

In our framework, R&D expenditures of one subsidiary increase the productivity of both subsidiaries. A further effect of R&D and the production of IP is that leads to royalties for the subsidiary that carries out the respective R&D, leading to an extra benefit for the R&D-conducting subsidiary. We distinguish two tax rates in both countries. t_i denotes the standard corporate tax rate in country $i = 1, 2$; τ_{IPi} is the rate on royalty income in country i , that may benefit from an IP regime, such that this rate may or may not fall short of t_i .

The IP, labelled P , within the MNE derives from the sum of IP of both subsidiaries, $P = P_1 + P_2$. Each subsidiary produces IP using a strictly concave research function, such that $P_i = P_i(R_i)$, $\frac{\partial P_i}{\partial R_i} > 0$, $\frac{\partial^2 P_i}{\partial R_i^2} < 0$ where R_i denotes the research expenditures of subsidiary i . Assuming the same cost of research across countries, it is also a measure of the amount of research undertaken. The profit in each subsidiary is then a strictly concave function of total IP, $f_i(P)$.

Royalty incomes for the subsidiaries in country 1 and 2 are simply modelled as $sP_1(R_1)$ and $sP_2(R_2)$, where s may be thought of as the share of IP that cannot only be used to increase MNE productivity but can also be sold on the market. Net of tax, the global MNE profit derives as:

$$\begin{aligned} \Pi = & (1 - t_1)\{f_1(P) - R_1\} + (1 - \tau_{IP1})\{sP_1(R_1)\} \\ & + (1 - t_2)\{f_2(P) - R_2\} + (1 - \tau_{IP2})\{sP_2(R_2)\}. \end{aligned} \quad (1)$$

The Lagrangian of the profit maximization problem can be written as $L = \Pi + \mu_1 R_1 + \mu_2 R_2$, where μ_1 and μ_2 represent Kuhn-Tucker multipliers for the non-negativity constraints on local research expenditures. The two first-order conditions for a profit maximum are:

$$\begin{aligned} (1 - t_i) \left\{ \frac{\partial f_i}{\partial P} \frac{\partial P_i}{\partial R_i} - 1 \right\} + (1 - \tau_{IPi}) s \frac{\partial P_i}{\partial R_i} \\ + (1 - t_j) \left\{ \frac{\partial f_j}{\partial P} \frac{\partial P_j}{\partial R_i} \right\} + \mu_i = 0 \text{ for } i, j = 1, 2; i \neq j. \end{aligned} \quad (2)$$

Consider a special case, which is particularly easy to analyze, where just one subsidiary, say in country 1, conducts research ($\mu_1 = 0; R_1 > 0$) and the other subsidiary is in a corner solution with ($\mu_2 > 0; R_2 = 0$). In this case, a marginal change dt_i or $d\tau_{IP1}$ leaves constant R_2 . This, in the following, will be assumed for ease of presentation.

A change in the corporate tax rate of country 1, may have different effects, depending on whether an IP regime is in place or not. The effect of a corporate tax rate change in the presence of an IP regime can be derived by marginally changing t_1 , but leaving the rate on IP income (royalties) constant ($d\tau_{IP1} = 0$). By total differentiation of the first-order condition we receive for $dR_2 = 0$:

$$\frac{dR_1}{dt_1} = \frac{\frac{\partial f_1}{\partial P} \frac{\partial P_1}{\partial R_1} - 1}{(1 - \tau_{IP1}) s \frac{\partial^2 P_1}{\partial R_1^2} + A(1 - t_1) + B(1 - t_2)} > 0, \quad (3)$$

where

$$A \equiv \frac{\partial^2 f_1}{\partial P^2} \left(\frac{\partial P_1}{\partial R_1} \right)^2 + \frac{\partial f_1}{\partial P} \frac{\partial^2 P_1}{\partial R_1^2} < 0; B \equiv \frac{\partial^2 f_2}{\partial P^2} \left(\frac{\partial P_1}{\partial R_1} \right)^2 + \frac{\partial f_2}{\partial P} \frac{\partial^2 P_1}{\partial R_1^2} < 0.$$

The positive sign of $\frac{dR_1}{dt_1}$ in equation (3) results as, due to our concavity assumptions, all three terms in the denominator are negative and, at the same time, the numerator is negative from the first order condition. It establishes a somewhat counter-intuitive result according to which a corporate tax increase can positively affect local R&D.

If country 1 changes its corporate tax rate without having an IP regime in place, the effect on R_1 needs modification as $dt_1 = d\tau_{IP1}$ and the effect of a corporate tax increase derives as:

$$\left. \frac{dR_1}{dt_1} \right|_{dt_1=d\tau_{IP1}} = \frac{\frac{\partial f_1}{\partial P} \frac{\partial P_1}{\partial R_1} - 1 + s \frac{\partial P_1}{\partial R_1}}{(1-\tau_{IP1})s \frac{\partial^2 P_1}{\partial R_1^2} + A(1-t_1) + B(1-t_2)} > 0. \quad (4)$$

With $t_1 = \tau_{IP1}$, the numerator (as the denominator) continues to be negative, but the positive term $s \frac{\partial P_1}{\partial R_1}$ tends to dampen the positive effect of an increase in t_1 . Evaluating equation (3) and (4) for

the same set of initial tax rates yields $\left. \frac{dR_1}{dt_1} \right|_{dt_1=d\tau_{IP1}} > \left. \frac{dR_1}{dt_1} \right|_{dt_1=d\tau_{IP1}} > 0$.

Next, consider a marginal change in τ_{IP1} assuming an IP regime is present and $dt_1 = 0$. From differentiating the first-order condition, we now get

$$\left. \frac{dR_1}{d\tau_{IP1}} \right|_{dt_1=0} = \frac{s \frac{\partial P_1}{\partial R_1}}{(1-\tau_{IP1})s \frac{\partial^2 P_1}{\partial R_1^2} + A(1-t_1) + B(1-t_2)} < 0. \quad (5)$$

This leads to the formulation of the following hypotheses, which are empirically testable.

- H1. *An increase in the corporate tax rate of a country increases the local R&D expenditures of MNEs.*
- H2. *The increase in local R&D expenditures of MNEs upon an increase in the corporate tax rate is higher if IP income in the respective country is subject to a separate tax rate (IP regime) than if this is not the case.*
- H3. *If there is an IP regime in place, an increase of the local tax rate on IP income will decrease local R&D.*

Clearly, the above model introduced a very simple framework. Several limitations come to mind and may or may not be important factors in practice.

The corporate tax modeled above resembles a pure profits tax, as all costs are tax deductible. Real world corporate taxes differ and usually disallow deduction of some cost, for example, the opportunity cost of equity. Therefore, high real-world taxes, unlike the corporate tax in the above model, may induce the MNE to exit a country or enter a different one. This would have a negative effect on R&D in high-tax countries, possibly negatively affecting the empirical support for H1 and H2. Despite this possibility, the mechanism described above would work against such a reduction of R&D and cushion the effect of a corporate tax increase.

Another caveat applies to the implicit assumption of the model that tax rates indeed are relevant as all subsidiaries have positive taxable profits. In so far, as some real-world MNEs have

sufficiently powerful tax avoidance instruments that already wipe out taxes, the above mechanisms would have reduced predictive power.

Another possible concern is that the model does not explicitly allow for contract R&D. Within an MNE, a low-tax subsidiary could pay a high-tax subsidiary to conduct R&D services on behalf of the low-tax subsidiary (Griffith *et al.*, 2014, p.14). While this has not been explicitly modelled, the possibility of such schemes should reinforce the expectation that the cost deductibility of R&D expenditures is an argument to conduct real R&D activity in high-tax countries, given that the MNE wishes to be present in those countries.

4. Data

The empirical part of the paper uses aggregated data, although the above model discussed the decision problem of a single MNE. Unfortunately, company accounts data does not typically distinguish the geographical location of firm's R&D activities and multinationals report R&D expenditures at consolidated level. Therefore, we use data on R&D expenditures of majority-owned foreign affiliates of U.S. MNEs, reported at country level. We obtain the data from the Bureau of Economic Analysis (BEA) homepage. To the best of our knowledge, this is the first study using the BEA's direct investment data for investigating tax policy effects on real research activity.

The BEA database contains the R&D expenditures of U.S. majority-owned foreign affiliates as performed by the relevant foreign affiliates. Should one affiliate pay a second affiliate within the same MNE to conduct R&D, then the R&D expenditure would be attributed to that second affiliate; no R&D cost are recorded for the first, merely contracting U.S. affiliate.⁴ This accounting convention is adequate for our purpose, as our main interest is in where the actual research activities take place and how these activities are affected by taxation.⁵

⁴ According to the BEA data description, R&D expenditures refer to expenditures for the planned, systematic pursuit of new knowledge or understanding toward general application (basic research); the acquisition of knowledge or understanding to meet a specific, recognized need (applied research); and the application of knowledge or understanding toward the production or improvement of a product, service, process, or method (development). It excludes quality control, routine product testing, market research, sales promotion, sales service and other nontechnical activities; routine technical services; geological and geophysical exploration activities, and advertising programs to promote or demonstrate new products or processes. Also excluded are capital expenditures, expenditures for tests and evaluations once a prototype becomes a production model, patent expenses, and income taxes and interest.

⁵ The R&D expenditures reported in our data are attributed to the affiliate that conducts the real research activity. Therefore, any income from the patent(s) associated with the R&D expenditures reported in the respective country and year would satisfy the nexus requirement, if in place in that country. Consequently, we do not control for the nexus requirement.

Our sample includes seventy-five countries where U.S. multinationals have reported R&D expenditures for at least one year during the period under analysis, 2009-2017.⁶ In total, the sample includes 621 country-year observations, resulting in a slightly unbalanced panel with only 54 missing country-year entries.

The presence of an IP regime in the host country in a certain year constitutes the first variable of interest in our empirical analysis. Table A3 in Appendix A reports information on the existence of an IP regime in each country-year, the year of enactment and the preferential tax rate on IP income. For the construction of this variable, we rely on the OECD (2015) Final Report and OECD (2017). Further sources used for identifying IP regimes were data from multinational professional services networks such as KPMG, PwC, Deloitte, as well as from national websites, and previous working papers.

A second variable of main interest is the tax rate on IP income. As in the model of Section 3, it equals the preferential IP tax rate for countries that run an IP regime. For countries that do not run an IP regime, the tax rate on IP income equals the statutory corporate income tax rate. We take the information on the statutory corporate income tax rate from the OECD Statistics Database, KPMG, and Eurostat. For the preferential corporate income tax rates on IP income, the sources of information are significantly broader and coincide with the ones used for data collection on the presence of IP regimes in each country.⁷

Finally, we add control variables on non-tax country characteristics. We refer to prior literature (Böhm *et al.*, 2015; Dudar and Voget, 2016; Karkinsky and Riedel, 2012; Alstadsaeter *et al.*, 2018; Baumann *et al.*, 2020; Mukherjee *et al.*, 2017; Becker *et al.*, 2020), for the choice of the control variables in the baseline regression and for the two additional control variables used in the robustness checks analysis. We include LN (GDP) to control for market size, which measures the log of GDP in purchasing power parities. Since tax rates and country sizes have been found to be systematically correlated, inclusion of this size measure prevents the tax rate from picking up size effects (Weichenrieder, 2005; Ruf and Weichenrieder, 2012). In order to control for the country's degree of development and living standards, the logarithm of GDP per capita is included. In line with Dischinger and Riedel (2012), as a proxy for the country's economic situation, we include the unemployment rate. The Corruption Perception Index (CPI) represents the Transparency

⁶ Among the 163 countries listed in the database, R&D expenditures of U.S. MNEs are greater than 0, for at least one year between 2009-2017 in only 75 countries. For the rest of countries, data on R&D expenditures is missing for all the years or reported as 0 only for one or two years.

⁷ See table A2 in Appendix A, for the definition of all variables used and the list of the data sources for each of them.

International corruption index, which is constructed with higher values of the index indicating lower corruption, in order to capture perceptions of the public sector corruption, the quality of public services, the quality of policy formulation and implementation and the credibility of the governments' commitment to such policies. Table A1 in Appendix A reports summary statistics of all variables used. As a robustness check (Appendix B1, Table B1) we also included a Property Rights Index as included in several studies (Becker *et al.*, 2020; Alstadsæter *et al.*, 2018; Karkinsky and Riedel, 2012; Griffith *et al.*, 2014; Bradley *et al.*, 2015) and trade openness (Trade) as in Ernst and Spengel (2011). We excluded these consistently insignificant variables in the regressions of Table 1. Appendix B, Table 3 includes an (insignificant) variable that captures the availability of input related R&D tax credits.

Figure 1 visualizes the R&D expenditures in the top-10 host countries in absolute and relative terms. Germany, a high-tax country, leads the top-10 countries where U.S. multinationals locate their R&D expenditures, accounting for between 6,700 and 9,200 million dollar or between 14% and 20% of total foreign R&D expenditures. Germany is followed by United Kingdom and Canada until 2012 (Switzerland after 2012). Among the top-10 countries, four of them, Germany, Canada, Switzerland⁹ and Japan, fail to have a preferential tax rate regime during the period under consideration. The first three of them lead the top-10 list. The statutory corporate tax rate in Japan is the highest among all countries where U.S. majority-owned subsidiaries invest in R&D, with a range between 30.89% in 2017 and 40.69% in 2009. India as well offered one of the highest statutory corporate income tax rates hovering around 34% and 35% between 2009 and 2017, but it implemented an IP box regime in 2016 with a preferential tax rate on IP income of about 10%. China, that enacted an IP regime in 2008 and France, which has an IP regime since 1971, have the highest preferential tax rate (15%) among the rest of the six countries that run an IP regime. The United Kingdom, after the 2013 enactment of an IP box introduced a preferential tax rate of 10%. In the year of IP box enactment, the tax advantage was about 13%. It decreased to 9% after a year-by-year decrease of the statutory corporate income tax rate (19% in 2017).

A country with frequent changes is Israel. Its statutory corporate income tax rate ranges between 24% and 26% and its preferential tax rate within the period changes from 10% to 7%, then again to 9% and in the last two years 2016, 2017 it decreases to 6%. Ireland, which provided the lowest

⁹ In 2011, the Canton of Nidwalden in Switzerland introduced a License Box Regime, which provided exemption at the cantonal level, but not at the federal level, equal to 80% of eligible income. Given that the tax advantage was not given at the federal level, in the regressions below, Switzerland is considered as a country without IP regime (Guenther, 2017, p.9). Switzerland recently introduced a patent box regime going into effect in 2020, which covers all of Switzerland. The regime will provide a maximum tax base reduction of 90% on income from patents and similar rights developed in Switzerland. Cantons can opt for a lower reduction.

tax rate on IP income, 2.5% for 2009 and 2010, abolished its IP regime in 2010 and re-introduced it in 2016 with a preferential tax rate of 6.5%.

Figure 2, for each of the 22 countries with IP regimes, compares the mean corporate tax rate and the mean preferential IP rate across the years when an IP-regime was in place. The largest difference between the two mean rates is in Uruguay, Colombia and Macau, the smallest difference applies to the Republic of Korea.

Fig. 1. R&D Expenditures of U.S. wholly - owned subsidiaries by top-10 host countries in (a) millions of dollars and (b) as a fraction of total foreign R&D expenditures.

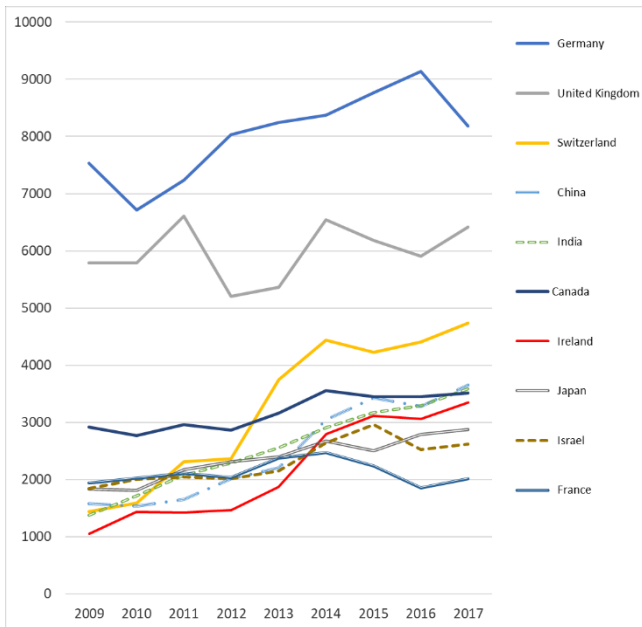


Fig.1 (a). R&D Expenditures of U.S. Wholly-Owned Subsidiaries abroad by Top-10 Host Countries (in million US dollars)

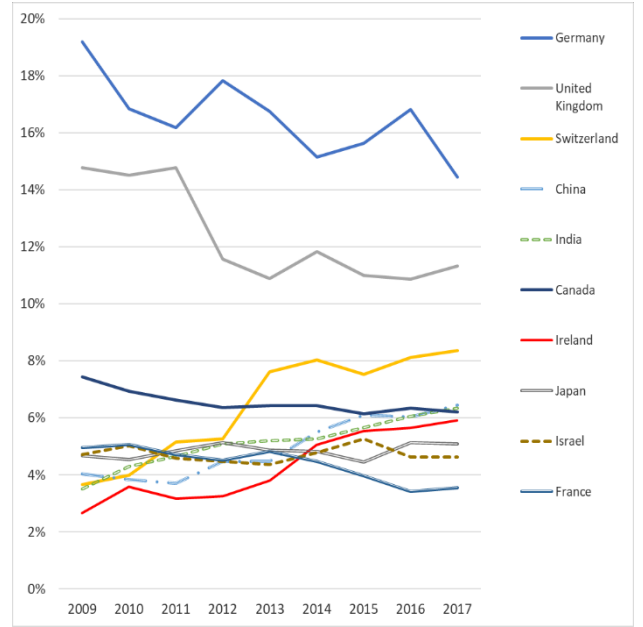
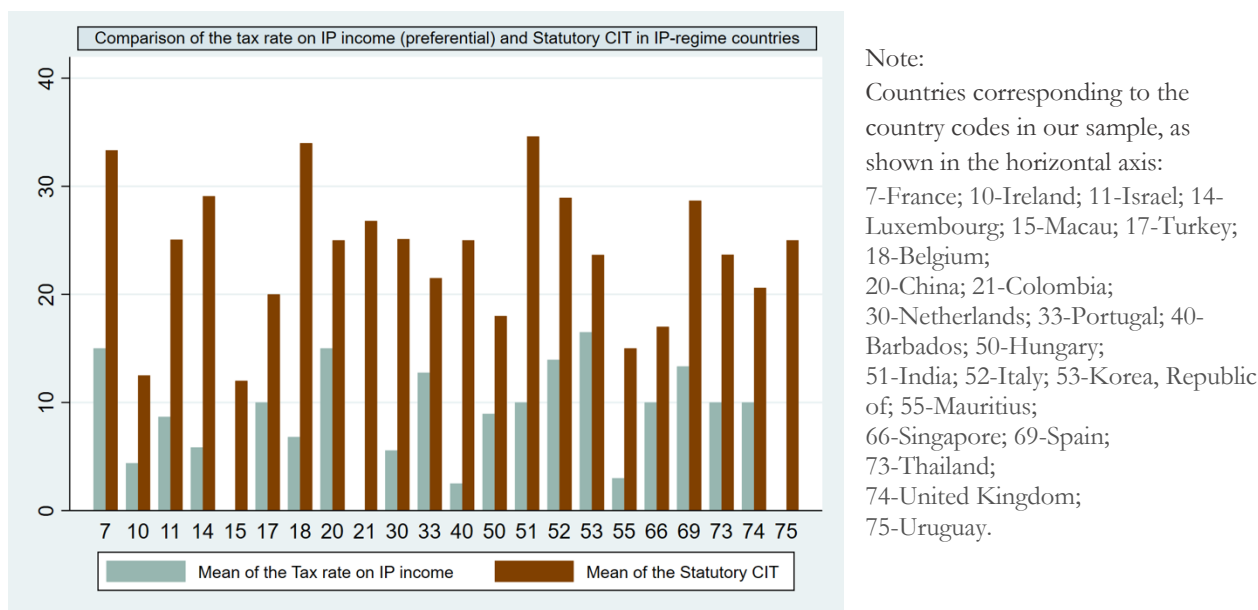


Fig.1 (b). R&D Expenditures of U.S. Wholly-Owned Subsidiaries abroad by Top-10 Host Countries (fraction of total foreign expenditures)

Source: Bureau of Economic Analysis (BEA)

Fig. 2. Comparing the preferential tax rate on IP income and statutory corporate income tax rate in IP-regime countries.



Keen (2001) and others have argued that preferential tax regimes may allow for higher standard corporate tax rates since, with such a special regime, parts of the most mobile tax base are taken out of the high-taxed base. We checked whether this is reflected in our sample. 12 out of 22 IP-regime countries had the regime in place during all of our sample years; 10 countries had years with and without IP regimes. For these 10 countries, the mean statutory corporate tax rate in years without an IP regime (24.6%) is almost identical to the average rate in years with an IP regime (23.2%). Controlling for country and time-fixed effects, we found an insignificant negative correlation between an IP regime dummy and the rate of the statutory corporate tax rate. This finding does not support the idea that countries introduce a preferential regime to be able to increase their rates on the remaining tax base.

Among the 22 countries, Ireland, Israel, Netherlands, Portugal, Hungary, Italy, Korea and Spain had different rates of the preferential tax rate on IP across the years in which a regime had been in place. For the rest, the tax rate on IP income did not change.

5. Estimations

In this section, we exploit our panel data to regress country-level R&D expenditures of US-owned subsidiaries on country characteristics that capture R&D-friendliness from a tax and non-tax perspective. Based on the model in Section 3, our main interest is in the corporate tax rate, the

availability of a preferred patent box regime, and the interaction between tax rates and regimes. This leads us to the following empirical model.

$$\begin{aligned} \text{LN(R\&D)}_{it} = \\ \alpha_0 + \beta_1 \text{ipr}_{it} + \beta_2 \tau_{\text{IP}_{it}} + \beta_3 \text{Stat_CIT}_{it} + \delta_1 \text{Stat_CIT}_{it} * \text{ipr}_{it} + \beta_4 \mathbf{X}_{it} + \varphi_i + \gamma_t + u_{it} \end{aligned} \quad (6)$$

Our left-hand variable, LN (R\&D)_{it} , represents the natural log of R&D expenditures by U.S. majority-owned subsidiaries in country i in year t .¹⁰ In each country there are two, possibly distinct, tax rates: the standard statutory corporate income tax rate applying to all kinds of deductions and sales revenues (Stat_CIT_{it}), and the tax rate as it applies specifically to income from intellectual property ($\tau_{\text{IP}_{it}}$). Although these rates may be identical if the country under consideration does not offer a patent box regime, this separation allows to account for regime changes over time and a lower rate on income from intellectual property. The dummy variable ipr_{it} takes on the value one if in country i in year t there is an IP regime in place, and zero otherwise. The interaction term $\text{Stat_CIT}_{it} * \text{ipr}_{it}$ captures the possibly different effect of the statutory corporate income tax rate on R&D expenditures if an IP box is in place. In this case, an increase in the corporate tax may increase the value of the tax deductibility of research expenditures, but would *ceteris paribus* not increase the tax on IP income. For this reason, we expect a positive coefficient for this interaction that captures a difference in the marginal effect of the statutory corporate income tax rate between countries with an IP-regime in place and countries that do not offer a preferential tax treatment for IP income. \mathbf{X}_{it} is a vector including the four country-specific control variables, described in the previous section. The variable φ_i represents country-fixed effects, capturing a country's unobserved characteristics that are time-invariant.¹¹ The variable γ_t captures year-fixed effects that may affect all host countries alike.

While OLS is easy to interpret, a logarithmic or semi logarithmic OLS model may be biased if the data is heteroscedastic (Silva and Tenreyo, 2006). Another possible concern is that OLS does not account for the fact that the dependent variable is restricted to positive values (Karkinsky and Riedel, 2012; Alstadsæter *et al.*, 2018). Moreover, country-years with zero R&D are dropped by taking the log. In order to account for these concerns, we also use a negative binomial (NB) fixed effects model. We follow Allison and Waterman (2002) and Greene (2007), suggesting a simple

¹⁰ By taking the natural logarithm of R&D expenditures in millions of dollars, we lose only 33 observations. A robustness check in Appendix B estimates equation (1) by using an Inverse Hyperbolic Sine transformation of our dependent variable that keeps these observations. Table B2 in Appendix B reports very similar results to Table 1 and Table 2, although some coefficients of interest are slightly higher.

¹¹ A Hausman test suggested that the fixed-effects model is more appropriate than a random-effects model.

approach which jointly estimates the parameters, fixed effects and the over-dispersion model in a standard NB model with a full set of country specific dummy variables.¹²

A further potential issue are endogeneity problems. For example, countries could be tempted to introduce an IP regime in years in which R&D expenditures of local U.S. are particularly low. This produced a problem of reverse causality. This is a general problem of the IP regime literature, which according to our knowledge has not been addressed fully convincingly in previous studies. See the discussion in Alstadsæter *et al.* (2018, p. 150). This said, we want to note that a main interest of this study is to evaluate the role of the general corporate tax rate on R&D. Compared to the introduction of IP regimes, this general rate should be less susceptible of being set as an intentional instrument of R&D policy. If true, this should reduce the problem of endogeneity compared to the papers on IP regimes reviewed in Section 2. A potential omitted variables problem is addressed by using country fixed effects and further time-varying country characteristics.

5.1. Empirical Results

Columns (1) and (2) in Table 1 report on OLS fixed effects model estimations, columns (3) and (4) report on the NB model. The NB estimations contain the same set of regressors as the OLS regression in column (1) and column (2). While the left-hand side is now measured in level rather than its logarithm, the coefficients of tax rates in the negative binomial model can be interpreted as semi-elasticities. To account for heteroscedasticity and possible serial correlations, we cluster all estimates in Table 1 at the country level.¹³

We first focus on the interpretation of column (2), where the full set of control variables in an OLS regression is included to discuss the hypotheses H1 – H3 of Section 3. As discussed in that section, a change in the statutory corporate tax rate may be different depending on whether the variation happens with an IP regime in place or not.

In the absence of an IP regime, a change in Stat_CIT, by construction, goes along with a change in $\tau_{IP,it}$, as the standard corporate tax then also applies to IP income. This means that, in this case, a one percentage point increase in the CIT leads to an increase in R&D expenditures by some 0.9% ($= -0.0279 + 0.0364$). This, however, is not statistically significant according to line (i) and lends no particular support to H1. Section 3 discussed potential reasons, why effects outside our

¹² Although this suggestion may have an incidental parameter problem, Allison and Waterman (2002) and Greene (2004) suggest that the resultant incidental parameters bias is not disturbing due to moderately small time dimension (Cameron and Trivedi, 2013, p.357).

¹³ Presence of heteroscedasticity is suggested by scatterplots of fitted, predicted and residual values, Breusch-Pagan test, White test and a modified Wald statistic for group-wise heteroscedasticity in the residuals of a fixed-effect regression model.

model could actually lead to a negative effect of the corporate tax rate on R&D. Against this background, it is an interesting observation that a higher tax rate does not seem to have a negative effect on R&D.

Compared to when an IP regime is not in place, H2 expresses the expectation that an increase of the corporate tax has a more positive effect on R&D if such a regime is in place. A change in the corporate tax rate, in this case, leaves the tax on IP income constant as this income is subject to a separate rate. The marginal effect in column 2 then derives from the addition of the coefficient of Stat_CIT and the coefficient of the interaction effect IP Regime (*dummy*) * Statutory CIT: $(0.0364 - 0.0086 =) 2.78\%$ (cf. line (ii)). This linear combination of coefficients is significantly different from zero at the 1%-level. At the 5%-significance level, the marginal effect of the corporate tax increase with an IP regime in place (2.78%) is higher than the marginal effect without a regime (0.9%) according to line (iii). While significance levels are slightly lower in the NB models for some coefficients, the general pattern is preserved and the size of the coefficients is closely comparable, which should give further credibility to the OLS estimates.

The observation that a marginal change in the corporate tax rate has a larger effect if an IP regime is in place is in line with our expectation (H2). In countries without a preferential tax rate regime on IP income, a higher corporate tax makes the deductibility of R&D cost more valuable, but also increases the tax on R&D returns. This is different in IP regime countries, where the income generated from IP is sheltered by the IP regime.

The positive and strongly significant effect of the statutory CIT on R&D expenditures in these countries is compatible with the view that subsidiaries manage to deduct a large share of the cost of R&D at the higher statutory corporate tax rate, while the returns of R&D investments benefit from the lower IP rate. Although formally, this is only allowed under the gross income approach, it could be that countries are lenient under the net income approach and effectively there is always a *de facto* gross approach in place. With R&D costs largely consisting of labor costs, firms might easily report R&D costs as normal costs in order to get their deductibility under the normal statutory corporate income tax rate, while maintaining returns from R&D taxed at the lower (preferential) corporate income tax rate.

Table 1. Estimating tax effects on international R&D expenditures of U.S. majority-owned subsidiaries.

Dependent Variable: R&D Expenditures of U.S. majority-owned subsidiaries				
Model	OLS	OLS	NBM	NBM
	LN (R&D Expn.)	LN (R&D Expn.)	R&D Expn.	R&D Expn.
Regressors	(1)	(2)	(3)	(4)
IP Regime (<i>dummy</i>) (ip_{it})	-0.156 (0.210)	-0.318 (0.203)	-0.0211 (0.195)	-0.221 (0.187)
Tax rate on IP income (τ_{IP_it})	-0.0294*** (0.0100)	-0.0279*** (0.00983)	-0.0276** (0.0111)	-0.0265** (0.0103)
Statutory CIT ($Stat_CIT_{it}$)	0.0391*** (0.0142)	0.0364*** (0.0137)	0.0417** (0.0165)	0.0340** (0.0159)
IP Regime (<i>dummy</i>) * Statutory CIT ($ip_{it} * Stat_CIT_{it}$)	-0.0151 (0.0123)	-0.00858 (0.0110)	-0.0167 (0.0124)	-0.00913 (0.0107)
LN (GDP)		0.703** (0.301)		0.611** (0.281)
LN (GDP pC)		0.0100 (0.348)		0.0382 (0.292)
Unemployment		-0.0266* (0.0151)		-0.0234 (0.0144)
Corruption Perception Index (CPI)		0.00615** (0.00308)		0.00346 (0.00336)
(i) $\tau_{IP_it} + Stat_CIT_{it}$	0.0097 (0.293)	0.0085 (0.349)	0.0141 (0.241)	0.0075 (0.546)
(ii) $(1 + ip_{it}) * Stat_CIT_{it}$	0.0241*** (0.005)	0.0278*** (0.004)	0.0249*** (0.006)	0.0249** (0.018)
(iii): (ii) – (i)	0.0141** (0.038)	0.0193** (0.011)	0.0109* (0.091)	0.0174** (0.013)
Obs.	588	572	621	597
Nr. of countries	75	72	75	72
R ² (within)/ Pseudo R ²	0.30	0.36	0.30	0.31
Log pseudolikelihood			-2846.15	-2765.56
Alpha for overdispersion (std. error)			(.0725) (.0142)	(.0615) (.013)

Note: The dependent variable in columns (1) and (2) is the log of R&D expenditures; in the negative binomial models of columns (3) and (4) R&D expenditures (in \$mill) is used. Levels of significance: *** p<0.01, ** p<0.05, * p<0.1. p-values are based on robust standard errors, clustered at the country level. Countries are observed during 2009-2017 (unbalanced sample). All estimations include country-fixed effects and time-fixed effects. Numbers in columns (1) and (2) represent coefficients rather than odds ratios. The unit of observation is country-year. The alpha parameter informs about the degree of dispersion, if alpha is significantly greater than zero the data are over dispersed and are better estimated using a negative binomial model than a Poisson model.

The coefficient of *IP Regime (dummy)*, is not statistically significant across columns. This in itself would indicate no significant increase of R&D expenditures if a host country introduces such a

regime; the coefficient is even negative. At the same time, such a regime allows for a reduced rate on intellectual property income. The effect of an IP Regime derives from both the IP Regime (dummy) and the reduced tax rate on IP income (τ_{IP_it}). The significantly negative coefficient of this latter variable indicates that (given an IP regime is in place) a lower tax rate on IP income (keeping the corporate income tax constant) indeed is associated with higher R&D expenditures: a *reduction* of the rate on IP income by one percentage point increases local R&D expenditure by some 2.8%.¹⁵ Again, the results are closely comparable across columns and models (OLS/NB), providing support for H3. As noted, to evaluate whether the introduction of an IP regime has a stimulating effect on R&D, a look at the coefficient of ipr_{it} is insufficient, as an IP regime also comes with a reduced tax. Assuming that the introduction of an IP regime reduces the applicable rate from the average of the corporate income tax rate (24.1%) rate to the average rate of IP regimes in the sample (8.0%), from column (2), we receive a small positive overall effect of 0.128 ($= -0.318 + 16 \cdot 0.0279$) on the log of R&D expenditures. However, the suggested increase is statistically insignificant.

The coefficients of the four control variables have plausible signs. We find a positive effect of country size on R&D, as measured by the coefficient of LN (GDP). Freedom of corruption (CPI) enters positively, although only insignificantly in the NB model. A negative effect of the unemployment rate is weakly significant in the OLS and insignificant in the NB model. GDP per capita, LN (GDP pC), enters positively, but without statistical significance.

5.2. Gross income approach

The results in Table 1 are based on a pooling of IP regimes with a gross or a net approach. This reflected the expectation that, for tax purposes, it is difficult to tell apart R&D related expenditures from other expenditures. In such a situation, MNEs have, for tax purposes, the incentive to flag R&D expenditures as normal expenditures to receive an increased tax shelter and de facto the distinction of the net and gross approach should be of restricted relevance in practice.

At the same time, it is possible to tell apart the few countries that indeed use a gross approach *de jure*. It should be kept in mind, though, that in this case some results are then based on a very limited subsample. In our data set, out of the 22 countries that used an IP regime during 2009-2017, only Belgium, Hungary, Portugal, and Spain used the gross approach of an IP regime at least

¹⁵ Note that changing the IP rate and holding the CIT rate constant is only possible for $ip_{it} = 1$.

for some years.¹⁶ As one of our main interests lies in the R&D effect from a change of the corporate tax rate (i.e., in an interaction effect), identification depends on observing corporate tax rate changes while an IP regime is in place. In the group of the four IP regimes countries with a gross approach, only two, Hungary and Portugal, had at least one corporate tax rate change during our sample period. Three of the four countries had a tax rate change when it comes to the rate on IP income (Hungary, Portugal and Spain).

To identify possibly different effects for gross and net income approaches, we slightly modify our empirical framework. We introduce a further dummy variable named $Gross_approach_{it}$, which takes on the value one if a country with a preferential IP regime in year t allows the current R&D expenses to be deducted from non-IP income, which is taxed at the regular corporate tax rate. In addition, this new dummy is interacted with the standard corporate tax rate and the IP rate forming the variables $Gross_approach*Stat_CIT$ and $Gross_approach*\tau_{IP}$. Consequently, the new regression equation reads:

$$\begin{aligned} \text{LN (R\&D Expn.)}_{it} = & \alpha_0 + \beta_1 ipr_{it} + \beta_2 \tau_{IP_{it}} + \beta_3 Stat_CIT_{it} + \\ & + \delta_1 Stat_CIT_{it} * ipr_{it} + \beta_4 Gross_approach_{it} + \delta_2 Gross_approach_{it} * Stat_CIT_{it} + \\ & + \delta_3 Gross_approach_{it} * \tau_{IP_{it}} + \beta_5 X_{it} + \varphi_i + \gamma_t + u_{it} \end{aligned} \quad (7)$$

Table 2 reports the results for equation (7). The four columns again report on OLS and NB regressions. The full set of controls is included in columns (2) and (4), while in columns (1) and (3) only the main variables of interest are included.

We first concentrate on the results for OLS in column (2). As in Table 1, the preferential tax rate on IP income enters significantly negative for R&D expenditures, resulting in a semi-elasticity of some -3.4%. As we have added an additional interaction of this rate with the gross approach dummy, the value of 3.4% is estimated for net approach regimes. The interaction with the gross approach dummy enters surprisingly with a positive sign that is statistically significant in columns (2) and (4), although not in (1) and (3).

Again, the statutory corporate income tax rate increases R&D expenditures only insignificantly in countries that do not offer a preferential tax rate on IP income, while it exerts a positive effect of some 2.6%, significant at the 5% significance level in countries that have an IP regime (net income approach) in place.

¹⁶ Spain moved from a 'gross-income' to a 'net-income approach' as part of the comprehensive reform of the IP Box implemented in September 2013 (Law 14/2013 of 27 September 2013), (Evers, 2015, p.71).

The heterogeneity we are interested in when estimating equation (7) concerns the new variables that indicate the application of the gross income approach. A significantly positive coefficient of $Gross_approach*Stat_CIT$ would suggest that IP regimes with a gross approach help better to cushion the effects of a corporate tax increase than those with net approach. The fact that we observe only an insignificant positive coefficient is in line with the view that *de facto*, all IP boxes tend to be used as if they were following the gross income approach. This said, we should also keep in mind the limited observations that identify the size of the interaction effect and that limits statistical power.

If we concentrate on IP-regime countries with a gross approach in place, the coefficient representing the marginal effect of the statutory corporate income tax rate on the log of R&D expenditures is hardly changed (2.68%) compared to net approach countries, but is not significant according to the test in line (iv) of Table 2.

Somewhat less expected, the coefficient on the interaction $Gross_approach*\tau_{IP}$, turns out positive and statistically significant at the 1% significance level in columns (2) and (4). It suggests that there is a difference on the effect of the preferential tax rate depending on whether a change in the tax rate happens in a gross or net IP regime approach. Lowering the preferential rate in a gross approach, which should be the more generous approach, seems to be less stimulating for R&D. Again, the fact that the estimation is based on tax rate change in only a few (here three) countries adds an important caveat.

Table 2. Tax effects on R&D expenditures: Differentiating between gross and net approaches.

Dependent Variable: R&D Expenditures of U.S. majority-owned subsidiaries				
Model	OLS	OLS	NBM	NBM
	LN (R&D Expn.)	LN (R&D Expn.)	R&D Expn.	R&D Expn.
Regressors	(1)	(2)	(3)	(4)
IP Regime (<i>dummy</i>)	-0.00729 (0.169)	-0.231 (0.201)	0.0945 (0.160)	-0.148 (0.176)
Tax rate on IP income	-0.0373*** (0.00905)	-0.0343*** (0.0100)	-0.0357*** (0.00981)	-0.0328*** (0.0103)
Statutory CIT	0.0459*** (0.0140)	0.0424*** (0.0143)	0.0481*** (0.0161)	0.0395** (0.0163)
IP Regime (<i>dummy</i>) * Statutory CIT	-0.0265*** (0.00998)	-0.0167 (0.0109)	-0.0271*** (0.0103)	-0.0165 (0.0103)
Gross approach	-0.996 (0.723)	-0.537 (0.520)	-0.771 (0.697)	-0.468 (0.477)
Gross approach * Statutory CIT	0.0183 (0.0260)	0.00118 (0.0215)	0.00804 (0.0282)	-0.00469 (0.0202)
Gross approach * Tax rate on IP income	0.0490 (0.0345)	0.0464*** (0.0163)	0.0526 (0.0456)	0.0513** (0.0234)
LN (GDP)		0.695** (0.308)		0.602** (0.288)
LN (GDP pC)		0.0112 (0.354)		0.0431 (0.298)
Unemployment		-0.0269* (0.0153)		-0.0232 (0.0142)
Corruption Perception Index (CPI)		0.00589* (0.00308)		0.00315 (0.00345)
(i) $\tau_{IP_it} + Stat_CIT_i$	0.0085	0.0080	0.012	0.0067
(ii) $(1 + ipr_{it}) * Stat_CIT_{it}$	0.019**	0.0256**	0.0209**	0.023**
(iii): (ii) – (i)	0.0107*	0.0176**	0.0086	0.016**
(iv) $(1 + ipr_{it} + Gross\ approach) * Stat_CIT_{it}$	0.037	0.026	0.029	0.018
(v): (iv) – (ii)	0.018	0.012	0.008	-0.0046
(vi) $\tau_{IP_it} (1 + Gross\ approach)$	0.011	0.012	0.016	0.018
Obs.	588	572	621	597
Nr. of countries	75	72	75	72
R ² (within)/ Pseudo R ²	0.30	0.36	0.30	0.31
Log pseudolikelihood			-2844.55	-2764.64
Alpha for overdispersion (std. error)			(.0720) (.0140)	(.0612) (.0129)

Note: The dependent variable in columns (1) and (2) is the log of R&D expenditures, in columns (3) and (4) R&D expenditures (in \$mill). Levels of significance: *** p<0.01, ** p<0.05, * p<0.1. p-values in parentheses are based on robust standard errors clustered at the country level. The model is estimated via OLS estimation method in regressions (1) and (2), and via a negative binomial model in regressions (3) and (4). Countries are observed during the period 2009-2017 (unbalanced sample). All estimations include country-fixed effects and time-fixed effects. Numbers in columns (1) and (2) represent coefficients rather than odds ratios. The unit of observation is country-year. The alpha parameter informs about the degree of dispersion, if alpha is significantly greater than zero the data are over dispersed and are better estimated using a negative binomial model than a Poisson model.

6. Conclusions

A growing literature indicates that high corporate taxes are detrimental to the number of patent applications by MNEs in these high-tax countries. Conversely, the question of whether high corporate taxes also reduce R&D expenditures and real research activity has received much less attention, but is the focus of the present paper. We hope that this paper may trigger a larger discussion on taxes and the location of real R&D activities. While the location of patents may be informative on tax planning activities of MNEs, in the end, we expect that it is the location of real R&D activity that is decisive when it comes to international spillover effects in knowledge.

Using a model of R&D decisions by MNEs, we identified mechanisms that could induce more R&D expenditures when the tax rate increases. An intuition for this somewhat counter-intuitive tax effect is that R&D costs are tax deductible and the value of this deduction tends to be the highest where the corporate tax is the highest. Given that R&D expenditures are tax deductible against the high corporate taxes, the possible positive R&D effect reflects a tax asymmetry: not all R&D returns are subject to the higher tax. First, since R&D creates a public good within the MNE, some of the R&D benefit is taxed at other countries' tax rates that are not subject to the tax increase. Second, some of the R&D benefits are taxed at a lower IP regime tax rate. Therefore, a higher corporate tax, which increases value of the cost deductibility of R&D, may foster R&D.

This expectation is empirically supported by country-by-country R&D data of U.S.-owned subsidiaries for countries that do have an IP regime. When it comes to the effect of IP regimes, we find a small overall impact on R&D expenditures, which is insignificant.

Several caveats and opportunities for future research remain. One issue is that our theoretical model is tailored to MNEs. It does not necessarily allow similar conclusions for national firms that conduct R&D. On the empirical side, one possible problem is that, as in the vast majority of papers evaluating the tax effects on patent behavior, we have taken changes in tax characteristics of countries as exogenous variations. While countries' corporate tax rate decisions, much more than IP regimes, may be set with a focus on a broad set of goals, we cannot rule out that corporate taxes are set also with an eye to attracting R&D. At the same time, we did not find evidence that countries that introduced an IP regime systematically changed their headline corporate tax.

Our empirical estimations are based on the R&D expenditures of U.S. wholly-owned subsidiaries, aggregated at the country-year level. Although the U.S. reports R&D for up to 75 different countries, confirming our results with confidential BEA firm-level data would be a worthwhile project, but would have to occur from within the BEA. Although subsidiary-level R&D

expenditures are difficult to attain, using data from non-U.S. MNEs would also be a useful endeavor.

Appendix A: Summary Statistics and Variables' definitions

Table A1. Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
R&D expenditures (\$mill)	621	697.1465	1413.46	0	9133
LN (R&D expenditures)	588	4.361953	2.655943	0	9.119
Statutory Corporate income tax rate	621	24.09087	7.129464	0	40.69
Preferential tax rate on IP income	135	8.030148	5.283505	0	16.5
IP Regime	621	.2173913	.4128035	0	1
Gross approach	621	.0434783	.2040955	0	1
LN (GDP)	617	26.24841	1.58703	22.26175	30.14147
LN (GDP pC)	621	9.67313	1.11811	7.009761	12.15173
Unemployment	616	7.388815	4.865881	0	27.47
Corruption Perception Index	597	54.41876	20.73738	9	95
Property Rights Index	607	59.14119	23.98959	0	97.1
Trade	599	95.0702	69.43888	22.11	442.62

Table A2. Variables' definition and data sources

R&D expenditures	Research and Development Expenditures of all U.S. Majority-owned Foreign Affiliates measured in millions of dollars, in country i in year t . Source: Bureau of Economic Analysis, U.S. Department of Commerce
LN (R&D expenditures)	Natural logarithm of R&D expenditures Source: Bureau of Economic Analysis, U.S. Department of Commerce
Statutory CIT	Statutory Corporate Income Tax Rate Source: OECD Statistics database; KPMG International Corporate Tax Rates; EUROSTAT.
Tax rate on IP income	Tax rate on IP income equals the Statutory corporate income tax rate if the host country of the U.S. MNE's majority-wholly owned subsidiaries does not have an IP box regime (or similar) in a specific year, and thus taxes the income generated from the exploitation of IP at the normal statutory corporate income tax rate. Otherwise, if an IP regime is in place in country i , in year t , this variable is equal to the preferential (lower) tax rate applied to the IP income based on the IP box rules of that country in the specific year. Source: For the Statutory CIT: OECD Statistics database; KPMG International Corporate Tax Rates; EUROSTAT; For the preferential tax rate on IP income: Initial orientation: OECD database on Intellectual Property Regimes; OECD (2015); OECD (2017); Atkinson and Andes (2011); Ernst and Young (2017); European Commission (2015); Alstadsæter et al. (2015); Evers et al. (2015); Evers (2015); Sakar (2015); De Rassenfosse (2015); Guenther (2017); Schwab and Todtenhaupt (2017); KPMG; PwC; Deloitte; National Website Sources;
IP Regime (<i>dummy</i>)	IP Regime (<i>dummy</i>) takes on the value one if the host country of the U.S. MNE's majority-wholly owned subsidiaries has an IP regime in place in the specific year and zero otherwise. Referring to OECD (2015) and OECD (2017), classification as IP Regime refers to: 1.) IP Regimes of OECD and G20 countries, 2.) IP Regimes of new Inclusive Framework members, 3.) IP regimes of new inclusive framework members that are also reviewed as non IP regimes. Some preferential regimes provides. Source: OECD (2015); OECD (2017); Atkinson and Andes (2011); Ernst and Young (2017); European Commission (2015); Alstadsæter et al. (2015); Evers et al. (2015); Evers (2015); Sakar (2015); De Rassenfosse (2015); Guenther (2017); Schwab and Todtenhaupt (2017); KPMG; PwC; Deloitte; National Website Sources.

Gross approach (<i>dummy</i>)	Gross income approach takes on the value one if the country that has an IP regime in place applies an asymmetric treatment of IP income and IP expenses and as long as the taxpayer has sufficient ordinarily taxed non-IP income from which to deduct the IP expenses, this can produce substantial tax advantage. Thus, this variable takes on the value one if the current expenses are deductible from non-IP income, which is taxed at the regular corporate tax rate, and zero otherwise. Source: Evers et al. (2014); Evers (2015).
LN (GDP)	Natural logarithm of the GDP (in current \$U.S.). GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Source: World Development Indicators from the World Bank database
LN (GDP Pc)	Natural logarithm of the GDP per capita (in \$U.S.), expressed in GDP in PPP dollars per person. Data are derived by dividing GDP in PPP dollars by total population. These data form the basis for the country weights used to generate the World Economic Outlook country group composites for the domestic economy. Source: World Development Indicators Database; International Monetary Fund;; United Nations
Unemployment	Unemployment refers to the share of the labor force that is without work but available for and seeking employment, thus it is expressed as the total % of total labor force). Source: World Bank Database
Corruption Perception Index (CPI)	Transparency International corruption index, which is constructed with higher values of the index indicating lower level of corruption. Source: Transparency International
Property Rights Index	A subcomponent of the Index of Economic Freedom, the <i>property rights index</i> measures the degree to which a country laws protect private property rights, and the degree to which its government enforces those laws. The more certain the legal protection of property, the higher a country's score; similarly, the greater the chances of government expropriation of property, the lower a country's score. Countries that fall between two categories may receive an intermediate score. Source: The Heritage Foundation, 2020 Index of Economic Freedom
Trade	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product. Source: World Development Indicators form World Bank database

Table A3. List of IP regimes across countries

Country	IP regime	Existing before 2009 or year of enactment	Name of the regime	Preferential tax rate
Germany	No			
United Kingdom	Yes	2013	Patent Box	10.00%
Switzerland	No			
China	Yes	Since 2008	Incentives for High and New Technology Enterprises (HNTE)	15.00%
India	Yes	2016	Patent-related Incentive	10.00%
Canada	No			
Ireland	Yes	1973, 2008, 2016	Patent Box, Knowledge Development Box	2.5%; 6.25%
Japan	No			
Israel	Yes	Existing	IP regime (Preferred Technology Enterprise/ Special Preferred Technology Enterprise status)	10.00%; 7.00%; 9.00%; 6.00%
France	Yes	1971	Reduced rate for long term capital gains and profits from the licensing of IP rights	15.00%
Singapore	Yes	2017	Intellectual Property Development Incentive	10.00%
Netherlands	Yes	2007, 2010	Patent Box, Innovation Box	5.00%
Belgium	Yes	2007	Patents Income Deduction	6.80%
Korea, Republic of	Yes	2014	Special taxation for transfer, acquisition, etc. of technology	16.50%
Australia	No			
Brazil	No			

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Italy	Yes	2015	Taxation of income from intangible assets	13.95%
Sweden	No			
Denmark	No			
Malaysia	No			
Austria	No			
Mexico	No			
Taiwan	No			
Spain	Yes	2008, 2013	Partial exemption for income from certain intangible assets (Federal regime)	15.00%; 12.00%
Poland	No			
Norway	No			
Finland	No			
Russia	No			
Hong Kong	No			
Luxembourg	Yes	Since 2008	Partial exemption for income/gains derived from certain IP rights	5.84%
Argentina	No			
Czech Republic	No			
Thailand	Yes	Existing before	International headquarters regime/Regional operating headquarters regime	10.00%
Hungary	Yes	2003, 2012	IP regime for royalties and capital gains	9.50%; 4.50%
Peru	No			
Costa Rica	No			
Philippines	No			
Turkey	Yes	2015	Technology development zones regime	0.00%
Bermuda	No			
Colombia	Yes	2013	Software Regime	0.00%
Slovakia	No			
Romania	No			
South Africa	No			
Portugal	Yes	2014	Partial exemption for income from patents and other industrial property rights	15.00%; 10.50%
Chile	No			
Greece	No			
New Zealand	No			
Indonesia	No			
Egypt	No			
Bulgaria	No			
Croatia	No			
Venezuela	No			
Saudi Arabia	No			
Panama	No			
Vietnam	No			
Slovenia	No			
Macau	Yes	Existing before	Macau offshore institution	0.00%
Latvia	No			
Ecuador	No			
Honduras	No			
Guatemala	No			
Mauritius	Yes	Existing before	Global Business License 1(3%) and 2 (0%)	3.00%
El Salvador	No			
Ghana	No			
Georgia	No			
Dominican Rep.	No			
Pakistan	No			
Belarus	No			
Monaco	No			
Uruguay	Yes	Existing before	Free Zones & Benefits under lit S art.52 for biotechnology and for software	0.00%
Barbados	Yes	Existing before	International Business Companies	2.50%
Morocco	No			
Oman	No			
Qatar	No			
Jamaica	No			

Note: Classification as IP Regime refers to: 1.) IP Regimes of OECD and G20 countries, 2.) IP Regimes of new Inclusive Framework members, 3.) IP regimes of new inclusive framework members that are also reviewed as non IP regimes. Some preferential regimes provides for benefits to both income from IP and other non-IP geographically mobile activities. These “dual category” regimes are reviewed as both an IP regime and a non-IP regime and therefore have to comply with both substantial activities requirements and two separate conclusions are applicable to the regime.

Main sources: OECD (2015); OECD (2017); OECD database on Intellectual Property Regimes.

Other sources: Look at *Table A2*.

Appendix B: Robustness Tests

Table B1. Additional control variables

Dependent Variable: R&D Expenditures of U.S. majority-owned subsidiaries								
<i>Model</i>	OLS	OLS	OLS	OLS	NBM	NBM	NBM	NBM
<i>Explanatory Var.:</i>	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IP Regime (<i>dummy</i>)	-0.313 (0.202)	-0.295 (0.215)	-0.226 (0.197)	-0.213 (0.208)	-0.200 (0.187)	-0.212 (0.190)	-0.128 (0.173)	-0.140 (0.177)
Tax rate on IP income	-0.0279*** (0.00987)	-0.0280*** (0.00988)	-0.0345*** (0.0101)	-0.0346*** (0.0101)	-0.0266** (0.0104)	-0.0265** (0.0104)	-0.0330*** (0.0105)	-0.0329*** (0.0105)
Statutory CIT	0.0370*** (0.0137)	0.0377** (0.0144)	0.0431*** (0.0144)	0.0437*** (0.0151)	0.0358** (0.0163)	0.0353** (0.0164)	0.0415** (0.0169)	0.0408** (0.0170)
IP Regime (<i>dummy</i>) * Statutory CIT	-0.00899 (0.0110)	-0.00983 (0.0116)	-0.0172 (0.0109)	-0.0178 (0.0113)	-0.0102 (0.0110)	-0.00965 (0.0110)	-0.0176* (0.0107)	-0.0170 (0.0107)
Gross approach (<i>dummy</i>)			-0.533 (0.515)	-0.507 (0.517)			-0.451 (0.471)	-0.473 (0.466)
Gross approach (<i>dummy</i>) * Statutory CIT			0.000792 (0.0214)	0.000120 (0.0214)			-0.00562 (0.0201)	-0.00499 (0.0200)
Gross approach (<i>dummy</i>) * Tax Rate on IP income			0.0471*** (0.0164)	0.0465*** (0.0167)			0.0521** (0.0232)	0.0525** (0.0230)
LN (GDP)	0.670** (0.316)	0.667** (0.320)	0.660** (0.324)	0.658** (0.327)	0.567* (0.305)	0.567* (0.306)	0.557* (0.313)	0.556* (0.314)
LN (GDP pC)	0.00439 (0.353)	0.00239 (0.351)	0.00577 (0.360)	0.00417 (0.358)	0.0205 (0.300)	0.0243 (0.300)	0.0262 (0.307)	0.0306 (0.307)
Unemployment	-0.0281* (0.0160)	-0.0280* (0.0158)	-0.0285* (0.0162)	-0.0284* (0.0160)	-0.0259* (0.0149)	-0.0260* (0.0147)	-0.0257* (0.0147)	-0.0258* (0.0146)
Corruption Perception Index (CPI)	0.00625** (0.00302)	0.00612* (0.00313)	0.00599* (0.00302)	0.00588* (0.00312)	0.00363 (0.00328)	0.00375 (0.00329)	0.00332 (0.00335)	0.00345 (0.00336)

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Trade	-0.00101 (0.00344)	-0.00107 (0.00345)	-0.00105 (0.00344)	-0.00110 (0.00346)	-0.00142 (0.00277)	-0.00142 (0.00277)	-0.00145 (0.00277)	-0.00144 (0.00278)
Property Rights Index		0.00138 (0.00570)		0.00121 (0.00573)		-0.00110 (0.00364)		-0.00125 (0.00364)
<i>Country-fixed effects</i>	✓	✓	✓	✓	✓	✓	✓	✓
<i>Time-fixed effects</i>	✓	✓	✓	✓	✓	✓	✓	✓
Obs.	563	563	563	563	588	588	588	588
Nr. of countries	71	71	71	71	71	71	71	71
R ² (within)/ Pseudo R ²	0.35	0.35	0.35	0.35	0.31	0.31	0.31	0.31
Log pseudolikelihood					-2716.51	-2716.44	-2715.59	-2715.51
Alpha for overdispersion (std.error)					(.0628) (.0132)	(.0628) (.0132)	(.0625) (.0131)	(.0625) (.0131)

Note: This table consists on the estimation of equation (1) and (2) by adding two other control variables: Trade and Property Rights index. The dependent variable in columns (1), (2) (3), and (4) is the log of R&D expenditures, and the amount of R&D expenditures in columns (5), (6), (7), (8). The levels of significance are reported as *** p<0.01, ** p<0.05, * p<0.1. Coefficients are robust to both heteroscedasticity and serial correlation using the cluster estimator, clustered at country level. The model is estimated via OLS estimation method in regression (1), (2) (3) and (4). In columns (1) - (4) and (3) – (4) all the main variables of interest preserve their sign and their significance levels as respectively in table 1 (column 1 and 2) and table 2 (column 1 and 2). In addition, the model is estimated via a negative binomial model in regressions (5), (6), (7), (8). All estimations include country-fixed effects and time-fixed effects and countries are observed during the period 2009-2017 (unbalanced sample). The unit of observation is country–year. The alpha parameter informs about the degree of dispersion, if alpha is significantly greater than zero the data are over dispersed and are better estimated using a negative binomial model than a Poisson model.

Table B2. Estimation of equation (1) and (2) using an Inverse Hyperbolic Sine Transformation.

Dependent Variable: R&D Expenditures of U.S. majority-owned subsidiaries				
Model	OLS			
Regressors	(1)	(2)	(3)	(4)
IP Regime (<i>dummy</i>)	-0.101 (0.391)	-0.390 (0.404)	0.155 (0.352)	-0.240 (0.416)
Tax rate on IP income	-0.0595*** (0.0211)	-0.0563*** (0.0211)	-0.0748*** (0.0196)	-0.0688*** (0.0215)
Statutory CIT	0.0944*** (0.0290)	0.0898*** (0.0279)	0.108*** (0.0287)	0.102*** (0.0291)
IP Regime (<i>dummy</i>) * Statutory CIT	-0.0370 (0.0247)	-0.0248 (0.0237)	-0.0580** (0.0224)	-0.0398 (0.0244)
Gross approach (<i>dummy</i>)			-1.676 (1.419)	-0.891 (1.058)
Gross approach (<i>dummy</i>) * Statutory CIT			0.0184 (0.0496)	-0.00835 (0.0413)
Gross approach (<i>dummy</i>) * Tax rate on IP income			0.108* (0.0645)	0.0982*** (0.0326)
LN (GDP)		1.070 (0.713)		1.057 (0.729)
LN (GDP pC)		0.234 (0.764)		0.239 (0.776)
Unemployment		-0.0553** (0.0276)		-0.0556* (0.0279)
Corruption Perception Index (CPI)		0.00852 (0.00600)		0.00805 (0.00607)
<i>Country-fixed effects</i>	✓	✓	✓	✓
<i>Time-fixed effects</i>	✓	✓	✓	✓
Obs.	621	597	621	597
Nr. of countries	75	72	75	72
R ² (within)/ Pseudo R ²	0.30	0.36	0.30	0.37

Note: This table reports results of the estimation of equation (1) and (2) while using an Inverse Hyperbolic Sine Transformation of the dependent variable. Differently from the simple logarithmic transformation we used in table 1 and 2, here HIS transformation allows us not to lose 33 observations which have a zero value of R&D expenditures of U.S. majority-owned subsidiaries. The levels of significance are reported as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Coefficients are robust to both heteroscedasticity and serial correlation using the cluster estimator, clustered at country level. In column (2), all the coefficients on the main variables of interest preserve their sign, as well as their significance level, while they result to be higher compared to those reported in column (2) in Table (1), where the simple logarithmic transformation is used. In addition, using the HIS, the marginal effect of the statutory corporate income tax rate on R&D expenditures also in countries without an IP regime in place becomes marginally significant. It remains positive and statistically significant at the 1% significance level in countries with an IP regime in place, although economically higher than the one using the logarithmic transformation.

Table B3. Controlling for input-related R&D tax incentives.

Dependent Variable: R&D Expenditures of U.S. majority-owned subsidiaries				
Model	OLS	NBM	OLS	NBM
Regressors	(1)	(2)	(3)	(4)
IP Regime (<i>dummy</i>)	-0.276 (0.216)	-0.140 (0.185)	-0.189 (0.224)	-0.0821 (0.190)
Tax rate on IP income	-0.0244** (0.0106)	-0.0239** (0.0114)	-0.0308*** (0.0110)	-0.0297** (0.0116)
Statutory CIT	0.0358** (0.0137)	0.0401*** (0.0142)	0.0416*** (0.0147)	0.0453*** (0.0150)
IP Regime (<i>dummy</i>) * Statutory CIT	-0.00832 (0.0120)	-0.0101 (0.0117)	-0.0164 (0.0123)	-0.0165 (0.0122)
Gross approach (<i>dummy</i>)			-0.555 (0.508)	-0.373 (0.456)
Gross approach (<i>dummy</i>) * Statutory CIT			0.00152 (0.0215)	-0.0101 (0.0179)
Gross approach (<i>dummy</i>) * Tax rate on IP income			0.0469*** (0.0158)	0.0536*** (0.0203)
LN (GDP)	0.643* (0.328)	0.611** (0.276)	0.634* (0.338)	0.605** (0.281)
LN (GDP pC)	0.179 (0.379)	0.0433 (0.291)	0.181 (0.387)	0.0479 (0.295)
Unemployment	-0.0313* (0.0169)	-0.0303** (0.0150)	-0.0317* (0.0172)	-0.0298** (0.0150)
Corruption Perception Index (CPI)	0.00402 (0.00313)	0.00192 (0.00329)	0.00372 (0.00309)	0.00163 (0.00334)
Input-related tax incentives (<i>dummy</i>)	-0.364 (0.262)	-0.179 (0.190)	-0.368 (0.263)	-0.181 (0.191)
<i>Country-fixed effects</i>	✓	✓	✓	✓
<i>Time-fixed effects</i>	✓	✓	✓	✓
Obs.	531	546	531	546
Nr. of countries	65	65	65	65
R ² (within)/ Pseudo R ²	0.38	0.30	0.38	0.30
Log pseudolikelihood		-2627.2036		-2626.3451
Alpha for overdispersion (std.error)		.0539542 (.0117088)		.0537075 (.0116643)

Note: This robustness check controls for the presence of input-related tax incentives per country and year (although in the previous estimations, the inclusion of fixed-effects counts for them). We introduce a dummy variable, which equals one if country c in year t offers at least one of the four R&D related tax incentives, i.e., tax credits, tax allowance, accelerated depreciation and/or super deductions, and 0 otherwise. Qualitative information for the quantitative construction of the *Input-related tax incentives dummy* variable is obtained from (i) Ernst and Young Worldwide R&D incentives reference guides, (ii) PwC Worldwide Tax Summaries, (iii) OECD R&D Tax Incentives database, (iv) KPMG's Europe, Middle East & Africa region (EMEA) research and development (R&D) incentives guide, as well as (v) national websites. We obtain this information for 65 out of 75 countries in our original sample. Controlling for input-related R&D tax incentives does not affect our main results, neither the marginal effects as reported in table 1 and 2. On the other hand, R&D input-related tax

incentives seem to exert no impact on R&D expenditures of U.S. majority-owned subsidiaries, which is somehow in line with Knoll *et al.*, (2021), i.e., firms hardly raise their R&D activities due to generous input-related R&D tax incentives. However, we are aware of the fact that our dummy variable cancels out the heterogeneity of input-related R&D tax incentives across countries, leading us to a very naïve and facile result.

In table B3, we report results of the estimation of equation (1) in column 1 and 2 and of the estimation of equation (2) in columns 3 and 4. The levels of significance are reported as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Coefficients are robust to both heteroscedasticity and serial correlation using the cluster estimator, clustered at country level. All estimations include country-fixed effects and time-fixed effects and countries are observed during the period 2009-2017 (unbalanced sample). The unit of observation is country-year. The model is estimated via OLS estimation method in regressions (1) and (3), and via a negative binomial model in regressions (2) and (4). The alpha parameter informs about the degree of dispersion, if alpha is significantly greater than zero the data are over dispersed and are better estimated using a negative binomial model than a Poisson model.

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