(Un)Intended Effects of Preferential Tax Regimes

The Case of European Patent Boxes*

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Abstract

The preferential taxation of income from intellectual property (IP) has become an increasingly popular policy instrument in the European Union and the US to attract mobile tax bases of multinational enterprises (MNEs) and to foster productivity. This paper estimates the size of the (un)intended effects of this new tax regime. We show that MNE affiliates that can benefit from the preferential taxation of IP income report 8.5 percent higher profits. The profit change splits up into a profit shifting and a productivity effect in proportions two third and one third. Surprisingly, the profit shifting response includes an unintended, reversed profit shifting out of the affiliate. Contrary to widely held beliefs, the overall behavioral adjustment might lower tax revenues collected from MNEs.

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1 Introduction

Over the last years, intellectual property (IP) rights have become ever more important as an input factor and, in response, national governments have started to differentiate taxation of income from IP rights vis-à-vis regular corporate income. The instrument, a so-called patent box, grants a substantially lower tax burden of only 50 or even only 20 percent of the regular corporate tax rate on IP income. Since the mid 2000s, patent boxes diffused rapidly in the European Union and around the world.[1] Yet, despite their popularity, their effects are controversially discussed. On the one hand, the preferential tax treatment offered by patent boxes is argued to foster research and development and to raise productivity and growth. On the other hand, patent boxes are expected to be actively used in fiscal competition rather than only being a pro-innovation policy instrument (Hall, 2019; Bloom et al., 2019). In short, "although patent box schemes purport to be a way of incentivizing research and development, in practice they induce tax competition by encouraging firms to shift their intellectual property royalties into different tax jurisdictions (Bloom et al., 2019, pp. 170-1)."[2,3]

In this paper, we analyze the behavioral response of firms to the preferential tax treatment of IP income in several European countries and the fiscal implications for these countries. Estimating the fiscal effect of patent boxes involves a number of challenges. First, patent boxes have the potential effect of increasing productivity in addition to fostering profit shifting.[4] The productivity effect will be erroneously attributed to the profit shifting behavior when adopting the standard approach of regressing pre-tax profits on tax incentives. To isolate profit shifting by multinational enterprises (MNEs), we make use of the fact that affiliates of domestic conglomerates cannot exploit international tax rate differences to save on taxes. We thereby follow an increasing strand of literature that resorts to comparing domestic firms and MNE affiliates to isolate the effect of profit shifting (Dharmapala and Hebous, 2018; Bilicka, 2019; Egger et al., 2020, Torslov et al., 2023, among others). To account for differences across the two groups of firms (in addition to the access to tax planning strategies), we adopt a difference-in-differences design and allow the treatment effect to vary for domestic firms and MNE affiliates. This empirical approach allows levels of profits as well as general trends in pre-tax profits to

[1] Mostly after 2007, several European countries including Belgium, Cyprus, France, Hungary, Ireland, Liechtenstein, Luxembourg, Malta, the Netherlands, Portugal, Spain, Switzerland, and the United Kingdom implemented patent box regimes. Similarly, the 2017 US corporate tax reform 'Tax Cuts and Job Acts' (TCJA) has effectively implemented a patent box regime in the US tax system.

[2] The view that IPs are a key channel of profit shifting and that patent boxes facilitate profit shifting via this channel is central to political discussions surrounding international tax challenges in the digital economy. See OECD (2015, 2019), for instance.

[3] Analyses on the merits of preferential tax regimes include Keen (2001), Janeba and Smart (2003), Bucovetsky and Haufler (2007) and Haufler and Schindler (2023).

[4] A rise in productivity is in line with the observation that patent boxes increase innovation activity of MNEs and domestic firms (Ohrn, 2016; Schwab and Todtenhaupt, 2021; Bornemann et al., 2023). Similarly, the success rate of patent applications increases in countries that implement patent boxes (Davies et al., 2020).

differ across the two types of firms, while netting out country- and industry-level effects.

Second, the inward shifting into the patent boxes might be coupled with simultaneously outward profit shifting. While the preferential tax treatment incentivizes MNEs to shift profits into the patent box, the resulting profit allocation might not be in line with the overall tax minimizing strategy of an MNE. The MNE might be inclined to shift profits out of the patent-box country again. These counteracting profit shifting responses are inherently related to patent box regimes. Different to the usual one-rate corporate tax system, a patent box introduces a split-rate system: a low rate for IP-income and a higher (i.e. the regular) corporate tax rate for non-IP income. MNEs have an incentive to report higher income that is taxed at the low rate and report less non-IP income that is taxed at the regular rate. The non-IP income can be manipulated downwards through e.g. higher MNE-internal interest payments that are deductible at the regular corporate tax rate.[5] Thus, part of the tax-preferred IP income might only be passed through the affiliate in the patent-box country and, by doing so, generates a tax saving twice for the MNE.[6] The outcome variable pre-tax profit combines these two counteracting behavioral adjustments, and adopting the standard approach of regressing pre-tax profit on tax incentives does not allow to separate them out.[7] To estimate behavioral adjustments through inward and outward profit shifting, we use the alternative outcome variable, earnings before interest and taxes (EBIT). This variable includes interest payments, so that differences between pre-tax profit and EBIT changes allow us to infer adjustments in internal interest payments.[8]

Third, contrary to general corporate tax provisions, patent boxes are practically available only to firms that have eligible income. We construct a novel measure approximating an affiliate's ability to benefit from the preferential tax treatment offered by a patent box (our definition of treatment). Intuitively, our empirical strategy is to differentiate between affiliates with low and high costs of accessing the tax relief. Patent creation and patent applications are subject

[5] See Mintz and Smart (2004) and Desai et al. (2004), among others.

[6] The strategy is in line with anecdotal evidence on how MNEs respond to patent boxes. For instance, the Dutch IKEA affiliate, Inter-IKEA, has internally acquired IPs to benefit from the preferential tax treatment offered by the Dutch patent box. The internal transaction was financed by an internal loan with overly high interest provided by the Liechtenstein IKEA holding (see Auerbach, 2016). This way, a portion of IKEA's worldwide pre-tax profit is shifted, in the form of royalty payments, into the Dutch patent box and benefits from preferential taxation. At the same time, the profit of the Dutch IKEA affiliate is used to serve the internal loan provided by the Liechtenstein IKEA holding. These interest payments are tax-deductible at the regular corporate tax rate in the Netherlands.

[7] With a uniform corporate tax, as classically observed, MNEs use internal interest payments and other profit shifting channels simultaneously to shift profits into a low-tax affiliate (Haufler and Schjelderup, 2000; Mintz and Smart, 2004). The effect on pre-tax profits is sufficient to infer tax revenue effects since both responses alter tax revenues according to the regular corporate tax rate.

[8] In line with our findings, royalty payments between the U.S. and foreign countries with a patent box respond to the implementation of patent boxes (Ohrn, 2016). Chen et al. (2017) exploit cross-country variation in the implementation of patent boxes and estimates the effect on earnings before interest and taxes (EBIT) of MNE affiliates in patent-box countries. Our analysis relies on within-country and -industry variation in policy exposure of affiliates of worldwide MNEs and decompose the observed income changes of MNE affiliates in inward and outward profit shifting responses.

to high (fixed) costs. Thus, in the presence of historical patent ownership either directly at the affiliate level or indirectly via the affiliate's majority shareholder, the costs of benefiting from the tax relief provided by a patent box are low. Conversely, our control group are affiliates that cannot use patent boxes due to the absence of historical patent ownership directly at the affiliate level or indirectly at the level of the majority shareholder. Accounting for indirect patent ownership in the definition of treatment builds on the insight that the location of patents within a MNE network is tax sensitive and, in particular, patent box regimes tend to lead to a transfer of patents to the patent-box country (Karkinsky and Riedel, 2012; Griffith et al., 2014; Bosenberg and Egger, 2017; Alstadsaeter et al., 2018, Ciaramella, 2023, among others). To the best of our knowledge, this is the first paper to explicitly account for this indirect link of IP ownership. We use coarsened exact matching (CEM) to ensure comparability of affiliates in the treatment and control group, where we match on various historical affiliate-level information.

Our findings are as follows. First, we show that patent-box countries experience a substantial increase in income that MNE affiliates report in these countries. Our estimate of profit shifting into the patent box amounts to roughly 15 percent of pre-tax profits. The estimate is larger as compared to the tax sensitivity of the royalty payment channel that is (implicitly) captured by existing profit shifting estimates.[9] The higher tax sensitivity might be due to the salience of patent box regimes and, related to it, the significant tax rate reductions that patent boxes offer. The empirical finding is consistent with the political intention of the preferential tax policy, namely, to increase profit shifting into the country operating the patent box. Second, at the same time as MNEs shift profits into the patent-box country, they also shift income that is subject to the higher, regular corporate tax rate out of that country.[10] Accounting for inward and outward profit shifting behavior, MNE affiliates in patent-box countries report on average 5 percent higher pre-tax profits. Third, although the overall effect on pre-tax profits is positive, the shifting behavior of MNEs potentially reduces corporate tax revenues in the patent-box countries. Intuitively, the reduced rate levied on in-flowing IP income is often as low as only 50 sometimes even only 20 percent of the statutory corporate tax rate, while the out-shifted income reduces tax revenues by the full amount of the statutory corporate tax rate. Illustrative calculations show that the critical tax differential, which renders the tax revenue change negative, ranges at around 45 percent of the statutory corporate tax rate. Given the current design of European patent boxes, it is not implausible that the behavioral responses

[9] As detailed below, expressed as a semi-elasticity w.r.t. tax rates, our estimate of profit shifting into the patent box is of a similar magnitude as previous estimates of profit shifting, where the consensus pre-tax profit semi-elasticity is 0.8 (Dharmapala, 2014). However, the consensus estimate combines different channels of profit shifting (such as royalty payments, intra-firm trade in goods and debt shifting), while our estimate relies on royalty payments only.

[10] The outflow of income is related to the use of internal debt, as explained below. Interest payments to other affiliates in the MNE can be deducted from the tax base that is subject to the regular corporate tax rate.

of MNEs reduce tax revenues in patent-box countries. The finding is presumably unintended by policy makers that use patent boxes to attract reported income and that widely expect the adjustment in transfer pricing to increase tax revenues.

In addition, we uncover heterogeneity in the behavioral responses of affiliates. When the majority shareholder of the MNE affiliate resides in a tax haven we do not find significant effects. Also, the effect is smaller in magnitude (and possibly statistically insignificant) when the patent box grants the preferential tax treatment only to newly created patents (essentially disqualifying pre-existing or acquired patents).

Finally, note that patent boxes offer a change in the tax environment that allows addressing standard challenges of identification. Patent box regimes allow comparing treated and non-treated affiliates within a country that are subject to the same socio-economic changes, which helps to ensure that our estimate is not confounded by country-level changes in the socio-economic environment. Moreover, patent boxes offer the quite rare possibility to use stark changes in tax incentives to identify the behavioral responses of firms. Tax rates that are embedded in patent boxes are frequently 50 and up to 80 percent lower than the statutory corporate tax rate. The tax variation is salient and presumably large enough for adjustment costs not to suppress the responses in firm behavior. In general, changes of corporate tax rates are not too frequent and not overly significant in size, which raises concerns of identification (Dharmapala and Hebous, 2018).

The paper proceeds as follows. Section 2 provides an overview of the different patent box legislation in Europe. Section 3 lays out a theoretical model and derives the theoretical predictions that we put to a test. Section 4 specifies the empirical strategy, Section 5 describes the data and Section 6 details the matching technique we use. Section 7 presents the estimation results, followed by a discussion of the results in Section 8, and the conclusion in Section 9.

2 Patent Box Regimes

Patent boxes have become increasingly popular in attracting mobile income. As of 2015, almost half of all EU countries have special tax rules that stipulate a reduced tax burden on IP income. France and Ireland were the first two countries to introduce precursory tax measures related to IP income in the early 1970s, followed by Hungary in 2003. However, the first patent box was introduced in the Netherlands in 2007 and only thereafter the use of patent box systems as a means of profit shifting became popular among MNEs (Evers, 2015). Luxembourg and Spain introduced a patent box in 2008 and the Belgium one became effective from the 2008 tax year onward (EY, 2008; Atkinson and Andes, 2011). France and the Netherlands substantially adjusted their IP-related tax treatment in 2010 followed by Hungary in 2012. In essence, both

reforms resulted in a more generous tax treatment of IP income.[11]

Table 1 reports details about the specific characteristics of the IP box regimes considered in our empirical analysis. All IP box regimes feature a substantially lower tax burden on IP income vis-à-vis income derived from a firm's standard business activity. In France and the United Kingdom, a separate rate of 15 percent and 10 percent, respectively, is applied in taxing IP income. All other countries resort to adjustments of the tax base, exempting between 50 percent and 80 percent of the income derived from IP when computing taxable income. The effective tax rate on IP income varies greatly across countries and amounts to around 5 percent in Belgium, Luxembourg, and the Netherlands, around 10 percent in Spain, Hungary and up to 15 percent in France (EY, 2015).

The countries listed in Table 1 represent the subjects of our empirical analysis. Other European countries introduced IP box regimes later in time, such as Malta in 2010, Liechtenstein and the Swiss canton of Nidwalden in 2011, Cyprus in 2012, the United Kingdom in 2013, Portugal in 2014, and Italy in 2015, whereas Ireland abolished its IP box regime in 2010. Due to data limitations, we are not able to include the latter set of countries in our analysis.[12]

Patent boxes also differ with respect to the types of income that qualifies for the preferential tax treatment. Narrowly defined IP boxes grant preferential tax treatment only to income derived from newly developed patents (i.e. IP registered *after* the introduction of the patent box regime) and associated IP rights, as is the case in Belgium, Luxembourg, and the Netherlands. In all countries except Spain, acquired IP is also eligible for the preferential tax treatment. In the Netherlands acquired IP must be developed further or actively managed in the country in order to qualify (EY, 2015). Several countries such as Spain, Luxembourg, or Hungary also allow trademarks to qualify for the IP box-related tax benefit, while Belgium, France, the Netherlands exclude trade marks (EY, 2015). In the empirical analysis, we also use these characteristics of patent boxes and analyze the sensitivity of the estimates with respect to the different dimensions of patent boxes.

For some time, in particular during our observational period, the tax rules have not imposed a link between the place of innovation and the place of tax declaration of IP-related income. This allows MNEs to relocate patents within MNE conglomerates, and thereby the royalty payments, from countries where the innovation took place into countries with a patent box. However, the

[11] In the Netherlands, the 2010 reform of the patent box resulted in a drop of the effective tax burden on IP income to 5 percent and additionally the cap on income qualifying for the patent box was abolished (EY, 2009, 2010). In France, the 2010 abolition of the surcharge on the corporate tax also impacted the taxation of IP income, reducing the effective tax burden on IP income to 15 percent versus 34.4 percent on regular income (PwC, 2013; Sakar, 2015). In Hungary, the threshold for firm profits that qualify for the reduced corporate tax rate of only 10 percent (5 percent for IP-related income) was significantly increased in 2012, resulting in a substantial reduction in the average tax burden on IP income (EY, 2005, 2012).

[12] Data limitations also restrict the number of before and after treatment years we observe for certain countries in our sample. We select only those countries where we observe at least one year before and after treatment.

recent OECD initiative against base erosion and profit shifting (BEPS) specified that patent box regimes introduced after 2015 must comply with the modified nexus approach, imposing a link between the place of innovation and the place of tax declaration of IP income. For existing patent box regimes, however, grandfathering rules have been agreed on, which stipulate that existing regimes will need to comply with the modified nexus approach from July 2021 onward (OECD, 2015).

3 Theoretical Predictions

In this section, we develop a parsimonious theoretical model of profit shifting that generates the main predictions that we put to a test in the empirical analysis. Consider two firms, located in countries A and B, which are affiliates of the same multinational enterprise (MNE). The affiliate in country A sells the right to use intellectual property (IP) owned by affiliate A to the affiliate in country B for royalty payment q and the affiliate in country B uses the input to generate sales y_B. The *true* price of the IP input is unity and not directly observable by tax authorities. The MNE can set the royalty payment q different from unity subject to a concealment cost $\theta(q)$ that satisfies:

$$\theta(1) = 0,\ \theta'(1) = 0,\ sign(\theta') = sign(q-1),\ \theta''(q) > 0.$$

If $q > 1$ there is over-pricing and if $q < 1$ there is under-pricing of the internal input. The concealment cost increases overproportionally the higher the deviation from the true price. Similarly, affiliate A uses its IP to produce an output that leads to pre-tax profits $y_A(i)$. Profits depend on productivity-enhancing investment i and satisfy $y'_A(i) > 0 > y''_A(i)$. Multiple interpretations of the investment are feasible. It may capture an investment in innovation, where the cost of generating innovations is $c(i)$, with $c'(i), c''(i) > 0$. Alternatively, one might interpret i as the level of effort the affiliate manager exerts in utilizing the income potential of the IP. With this interpretation, $c(i)$ measures the cost of managerial effort.

The total after-tax profits of the MNE are:[13]

$$\Pi = (1 - t_A^{PB})(y_A(i) + q - 1) + (1 - t_A)\overline{y}_A + (1 - t_B)(y_B - q) - \theta(q) - c(i), \tag{1}$$

where t_A^{PB} is the preferential corporate tax rate for income that qualifies for the patent box, t_A (t_B) is the regular corporate tax rate in country A (B), and $\overline{y}$ is income of affiliate A that is

[13]For illustration, we assume that $c(i)$ is not tax deductible. All what matters is that the cost and the return to investment are not subject to the same tax rate. For instance, the cost of investment might not be granted an immediate write-off and might only be tax deductible over time, which is usually the case for machinery and equipment. Even when investment outlays are granted an immediate write-off, the cost and return to investment might be taxed differently due to the existence of patent box regimes, for instance. This implies that the level of investment is tax-sensitive, as modeled above. Equally, the cost of transfer pricing, $\theta(q)$, might be tax deductible in one of the two countries without qualitatively changing the results.

subject to the regular tax rate in country A. In case a patent box exists in country A, the two tax rates satisfy $t_A^{PB} < t_A$. Otherwise, $t_A^{PB} = t_A$. In choosing the profit-maximizing royalty payment, the MNE aligns the tax advantage $t_B - t_A^{PB}$ with the marginal concealment cost:

$$t_B - t_A^{PB} = \theta'(q). \tag{2}$$

For a positive (negative) tax differential $t_B - t_A^{PB} > (<)\ 0$, the MNE over-prices (under-prices) the IP input (e.g., Haufler and Schjelderup, 2000; Gresik, 2001). The optimal investment level aligns the marginal return on investment with the marginal cost:

$$(1 - t_A^{PB}) y_A'(i) = c'(i). \tag{3}$$

A patent box in country A leads to a preferential tax treatment of income that is eligible for the patent box, $y_A(i) + q$. The first-order conditions (2) and (3) imply that a drop in t_A^{PB} increases the amount of profit shifted into affiliate A as well as the level of productivity-enhancing investment, i.e. $dq/dt_A^{PB} < 0$ and $di/dt_A^{PB} < 0$. The two adjustments increase pre-tax profits in country A. To summarize:

Proposition 1: *Assume country A has introduced a patent box. Then, provided affiliate A's patent income qualifies for the patent box, profit shifting into the patent box as well as productivity-enhancing investment increase. In response, pre-tax profit of affiliate A rises.*

The adopted specification is a parsimonious way of modeling the effect of innovations on profits. We might augment the specification by allowing the concealment cost $\theta(q)$ to also depend on i and to become less convex w.r.t. q as i increases.[14] Intuitively, the investment makes the intermediate input more innovative and, thereby, idiosyncratic, which renders it more difficult for tax authorities to infer tax-induced deviations from the true price. We might also allow the investment to increase the output of affiliate B, y_B, possibly due to the public good character of innovations and technology transfer within an MNE.[15] The relevant predictions of the model stated in the proposition will not change with these extensions.

Further, we extend the set of testable predictions of the model by allowing the MNE to use a second channel of profit shifting. Consider the MNE has an affiliate in country C, which is the financial center of the MNE and provides internal debt financing to the affiliate in country A. The affiliate in country A pays interest z on internal debt to the affiliate in country C, where the

[14] In this case, the concealment cost $\theta(q, i)$ satisfies $sign(1 - q) = sign(\partial^2\theta(q, i)/\partial q \partial i)$ in addition to the properties imposed above. With this extension, a higher investment level i following the existence of the patent box 'relaxes' the marginal concealment cost in (2) with the consequence that the MNE sets a higher transfer price to be paid to affiliate A.

[15] See Schwab and Todtenhaupt (2021), for instance.

income stream is taxed at a rate t_C. In turn, affiliate A can deduct the interest payment from its corporate tax base that is subject to the regular corporate tax rate t_A. With this extension, total MNE after-tax profits are:

$$\begin{aligned} \Pi &= (1-t_A^{PB})(y_A(i)+q-1)+(1-t_A)(\overline{y}_A-z)+(1-t_B)(y_B-q)+(1-t_C)z \\ &- \theta(q)-c(i)-\gamma(z,E_A). \end{aligned} \tag{4}$$

The term $\gamma(z, E_A)$ captures the concealment cost associated with internal debt shifting from country A to C, where E_A measures affiliate A's earnings before interest and taxes (EBIT), i.e. $E_A = y_A(i) + \overline{y}_A + q - 1$. The cost term satisfies:

$$\frac{\partial\gamma(\cdot)}{\partial z}>0, \qquad \frac{\partial^2\gamma(\cdot)}{\partial z^2}>0 \qquad \text{and} \qquad \frac{\partial^2\gamma(\cdot)}{\partial z\partial E_A}<0.$$

The concealment cost rises with the amount of interest payments, z, at an increasing rate. Also, the marginal concealment cost $\partial\gamma(\cdot)/\partial z$ decreases as EBIT, E_A, rises. Intuitively, E_A lowers marginal concealment costs because tax authorities might well accept higher interest deductions for internal debt when the economic activity of the affiliate, as measured by e.g. EBIT, increases. The general reasoning motivates various anti-tax avoidance provisions and, in particular, underlies so-called thin capitalization rules that are intended to curb profit shifting via internal interest payments. They generally permit higher interest deductions when the affiliate's EBIT rises (Gresik et al., 2017; Mardan, 2017).[16]

Assuming that the location of the financial center is a low-tax jurisdiction vis-à-vis country A ($t_A > t_C$), the optimal level of internal debt shifting trades off the tax advantage $t_A - t_C$ with the marginal concealment cost:

$$t_A - t_C = \frac{\partial\gamma(z,E_A)}{\partial z}. \tag{5}$$

The existence of a patent box in country A affects the level of internal debt shifting as it 'relaxes' the marginal concealment cost. This is because a lower rate of tax t_A^{PB} increases q and i and thereby affiliate A's EBIT, which in turn reduces the marginal concealment cost in (5). A formal derivation of the comparative static result is relegated to Appendix A.[17] To summarize:

Proposition 2: *Assume country A has introduced a patent box. Then, internal interest paid by affiliate A increases since the rise in affiliate A's EBIT (Proposition 1) lowers its marginal concealment cost of internal debt shifting. In response, pre-tax profit of affiliate A decreases.*

[16] Such a rule, referred to as earnings stripping rule, has become the dominant form of thin capitalization rule in advanced economies, for instance.

[17] This includes the comparative static analysis for q and i, whose first-order conditions modify when extending the model to include internal debt shifting. The effect of the patent box on q and i, as reported in Proposition 1, is preserved in the extended model.

The patent box introduces a split-rate corporate tax system in country A by lowering the tax rate t_A^{PB} below the regular corporate tax rate t_A. This allows the MNE to benefit whenever inward profit shifting and outward profit shifting increase at the same time.[18] The behavioral responses have counteracting effects on pre-tax profit and corporate tax revenue collected in country A. The counteracting effect is inherently related to patent box regimes. In the absence of a split-rate system ($t_A^{PB} = t_A$), a lower corporate tax in country A tends to encourage inward shifting (or less outward shifting) via transfer pricing and debt shifting. The behavioral responses increase pre-tax profit and corporate tax revenue.

Proposition 1 and 2 provide a set of predictions that we put to a test in the following sections.

4 Empirical Strategy

We center our empirical analysis around the time of the staggered introduction or major amendments of the European countries' patent box regimes. Our baseline estimation consists in the following difference-in-difference model:

$$\begin{aligned} \pi_{ist} &= \beta_0 + \beta_1 k_{it} + \beta_2 \ell_{it} + \beta_3 f_{it} + \beta_4 TAX_{it} \times MNE_i + \\ &\quad + \gamma_1 T_{it} \times DOM_i + \gamma_2 T_{it} \times MNE_i + \theta_\tau + \lambda_{st} + \eta_i + \epsilon_{ist}. \end{aligned} \tag{6}$$

Variable π_{ist} denotes the logarithm of unconsolidated pre-tax profit of affiliate i, operating in sector s in year t. The portion of pre-tax profit generated through production is a function of inputs, proxied by logged fixed assets (k_{it}), logged labor costs (ℓ_{it}) and financial leverage (f_{it}). Instead, pre-tax profit from inward profit shifting depends on the difference in the tax exposure of affiliate i vs. the rest of the MNE, captured by the tax indicator TAX_{it}.

The treatment indicator, T_{it}, takes the value of 1 if affiliate i owned IPs (directly at the affiliate level or indirectly via the level of the majority shareholder) by the year 2000 and a patent box was introduced or amended in or before year t (>2000).[19] Otherwise, the treatment indicator is zero. Crucially, we allow the treatment to differ, for affiliates of domestic (DOM_i) and multinational (MNE_i) firm conglomerates.

The coefficients γ_1 and γ_2 are informative for testing the theoretical predictions in Propositions 1 and 2. γ_1 measures the treatment effect for affiliates of domestic conglomerates and hence captures the productivity effects of patent boxes. γ_2 measures the treatment effect for affiliates of MNEs and captures both the productivity effect and profit shifting. The difference between γ_2 and γ_1 isolates the effect of patent boxes on profits shifting. The controls in the first

[18] The tax planning strategy is akin to a so-called "double dipping", i.e. two expense deductions are used for the same real economic activity (here production in affiliate B).

[19] As robustness checks, we move the reference year backwards to 1995 and 1997, and forwards to 2001, 2002 and 2003. All results remain similar, but the sample size reduces substantially when using earlier reference years.

line of equation (6) (such as capital or labor) potentially respond to patent box regimes. Our empirical approach is to isolate these effects so that only the profit shifting and productivity effect of patent boxes run into the coefficients γ_1 and γ_2.

Finally, θ_τ denotes a set of treatment-year dummies of the form $\tau = t - t_{PB,i}$ and accounts for the distance in time between year t and the year of introduction or major amendment of the patent box, $t_{PB,i}$, in the country where affiliate i is located. In addition, we control for industry-year fixed effects, λ_{st}, and specify the composite error term as the sum of the affiliate unobserved fixed effects, η_i, and the idiosyncratic error, ϵ_{ist}. To allow for correlation in the response of two affiliates controlled by the same shareholder, we cluster the standard errors at the majority shareholder level.

We motivate our empirical approach as follows. Affiliates of conglomerates that already own IPs can access outright the preferential tax treatment offered by a patent box. On the other hand, affiliates of conglomerate that have no history of innovative activity leading to IP ownership could only access the preferential tax treatment after either an investment or an IP acquisition. Therefore, we define as part of our treatment group those affiliates that historically owned IPs, either directly at the level of the affiliate or indirectly at the level of the affiliate's majority shareholder, and that are located in a country where a patent box was introduced, or a major amendment to it happened. Accounting for the indirect IP ownership at the level of the majority shareholder mirrors empirical findings that IP location within a MNE is tax sensitive (Dischinger and Riedel, 2011; Karkinsky and Riedel, 2012; Griffith et al., 2014; Boehm et al., 2015) and that patent box regimes incentivize MNEs to relocate IP to affiliates in patent-box countries (Boesenberg and Egger, 2017; Alstadsaeter et al., 2018; Ciaramella, 2023). One strength of this approach is that historical IP ownership addresses potential endogeneity issues related to reactions to the introduction of patent boxes on IP ownership. This allows us to interpret our estimates as intensive margin responses of firms that already engage in IP creation. We leave, instead, extensive margin responses explicitly out of the analysis due to endogeneity concerns.

As a control group we choose affiliates that have not owned any IP until the year 2000, neither directly nor indirectly via the majority shareholder.[20] Of course, firms have the option to purchase externally developed patents or acquire firms that own patents. Alternately, firms can undergo structural changes and start innovating. However, all these options are expensive or time-consuming relative to the tax benefit offered by a patent box.[21] To account for potential

[20] In a robustness analysis, we also exclude affiliates with trademarks from the control group. See Table C2 in Appendix C.2.

[21] Innovation is a time-consuming process and patents have been argued to constitute a barrier of entry due to the high set-up costs to generate patents and adapt firm structures that allow IP to be used within a firm. See, for instance, Mueller and Tilton (1969), Klepper (1996), and Keller and Yeaple (2013). Thus, newly patenting MNEs might create patents only with a substantial time lag, possibly only after our observation period. In fact,

endogenous IP ownership of affiliates with no historical IP ownership, we keep the MNEs' ownership structure constant and eliminate affiliates from the control group that undergo change in firm structure as it is the case when purchasing an affiliate with IP, for instance.

As stated above, we allow for the treatment effect to differ for affiliates of domestic and multinational firm conglomerates, as captured by the dummy variables DOM_i and MNE_i in equation (6). Estimating the treatment effect for affiliates of domestic conglomerates allows us to identify the effect of patent boxes on pre-tax profit that are unrelated to tax-motivated profit shifting.[22] As by definition, domestic conglomerates cannot take advantage of cross-country tax rate differentials but might benefit from productivity effects of patent boxes.[23] In doing so, we follow an increasing strand of literature that resorts to the comparison of domestic firms and MNE affiliates to isolate the effect of profit shifting (Dharmapala and Hebous, 2018; Bilicka, 2019; Egger et al., 2020; Torslov et al., 2023, among others). Arguably, the two groups of firms might differ in e.g. levels of profit. To account for differences across the two group of firms (in addition to the access to international tax planning strategies), our difference-in-differences strategy not only allows levels of profits, but also general trends in pre-tax profits to differ across the two groups of firms. In an extension, we modify equation (6) and also allow the input coefficients β_i to differ for multinational and domestic conglomerates. The findings remain unchanged.

5 Data

We use the ORBIS database (Bureau van Dijk) to retrieve historical information on firms' corporate ownership structures for the years 2007-2012, along with information on firm's financial accounts and patent registration for the years 1996-2012. As we do not observe any ownership links beyond 2012, we only select active affiliates located in those European countries that introduced or made major amendments to a patent box between 2007 and 2012. Hence, in

we only observe a small number of affiliates with newly registered patents (between 2000 and 2007) in the control group. The results are robust to excluding these affiliates from the control group. See Table C2 in Appendix C.2.

[22] Decomposing pre-tax profit changes of MNE affiliates into productivity and profit shifting changes is challenging because pre-tax profit summarizes both behaviors and, hence, profit shifting biases productivity estimates (Guvenen et al., 2017). Ideally, one would like to observe MNE affiliates that are subject to the patent box incentives, some of which can not engage in profit shifting while others do not realize productivity enhancements (all for exogenous reasons). These are not observable. Instead, using MNE affiliates in non-patent-box countries as a group of comparison does not help to estimate the profit shifting and productivity effect separately since none of the two materializes in that group.

[23] Domestic firms benefit from the lower tax rate on qualifying IP income as MNEs do. However, the mechanical effect of the lower tax rate does not show up in pre-tax profits, because all-domestic conglomerates have, different to MNEs, no incentive to relocate patents within their group. They are more likely to inflate royalty payments in favor of the unit that historically hosts the IP. Because we only observe affiliates at a low level of the conglomerate, we have a random mix of inflowing and outflowing domestic profit shifting, making this issue negligible on average. Furthermore, in the case of all-domestic conglomerates owning pre-existing IP, tax auditors have evidence of the non-strategically chosen IP-related transfer price (the *true* price) before the patent box was in place and might more readily detect tax-induced transfer pricing upon the implementation of a patent box.

our sample we have affiliates of domestic and multinational conglomerates located in Belgium, Spain, Luxembourg, France, the Netherlands, and Hungary.[24] We exclude firms in these countries that are independent standalone units not linked to any other active firm, and we define an affiliate's parent as the firm within the conglomerate that controls the largest share of the affiliate.[25] Further, we condition on the affiliate to preserve the same ownership structure, i.e. domestic vs. multinational, over the entire observational period. Following the existing literature, we limit our analysis to the sample of affiliates that report positive pre-tax profits for at least two consecutive years during our observational period 2007-2012. The procedure leaves us with a sample of 90,662 affiliates, of which just short of 10 percent (8,249 affiliates) belong to multinational conglomerates. In a next step, we collect unconsolidated financial accounts for the affiliates in our sample. Table 2 provides a summary and definition of these variables.

To identify affiliates with historical innovation activity, we collect data on the number of patents owned and the respective year of patent registration. To overcome issues related to patent quality, patent double counting and skewness in the distribution of patents, we define an indicator variable with a value of 1 if a patent is owned in or before the year 2000 and 0 otherwise. We interact the indicator variable with the respective firm level (affiliate vs. majority shareholder) that controls the patent. This enables us to differentiate between the effects arising from direct patent ownership at the affiliate level versus indirect ownership at the upper tier (majority shareholder). In our sample, roughly 25 percent of MNE affiliates and 15 percent of domestic affiliates belong to firm conglomerates with historical IP ownership and thus qualify as treated. For MNEs the concentration of IP ownership at the level of the majority shareholders is substantial, amounting to 30 percent. Given the high degree of transferability of IP within an MNE, neglecting this indirect link of IP ownership for affiliates that can benefit from preferential taxation of IP income would generate biased estimates when quantifying profit shifting of MNEs.

Finally, we construct affiliate-time-specific tax measure, variable TAX_{it} in equation (6). The variable is included in all estimations and captures the incentives for profit shifting independent of the patent box faced by the affiliate's foreign majority shareholder. Following the literature on profit shifting (Dharmapala, 2014), we compute the difference in the statutory corporate tax rate in the country of affiliate i and the country of the majority shareholder p, i.e. $\tau_{it} - \tau_{pt}$. As an alternative tax measure, we consider the difference between the statutory corporate tax rate levied in the country of the affiliate i and that levied in the country of the affiliate facing the lowest statutory corporate tax rate within the MNE conglomerate, i.e. $\tau_{it} - \tau_{min,t}$, with

[24] All ownership links to individuals, mutual funds, insurance companies and corporations with unidentified location are discarded. Affiliates located in the same country as the shareholders are classified as domestic.

[25] For cases where the ownership of an affiliate is equally distributed among several shareholders, we take the global ultimate owner (GUO) as the parent firm.

$\tau_{min,t} = min\{\tau_{jt}\}_{j=1,j\neq i}^{J}$, with J denoting the $N-1$ other affiliates of the MNE. Table B1 reports the tax measures averaged over the time period 2007-2012.[26]

6 Matching

The assignment of affiliates into the treatment group is naturally affected by the firms' structural characteristics and is thus endogenous to a series of factors. Not accounting for the absence of random treatment assignment would produce biased estimates. To deal with this, we resort to *coarsened exact matching* (CEM) to achieve a balance between the treatment and control group.[27] To reduce the imbalance in the pre-treatment variables, we match affiliates on characteristics that are found to be important in the innovation literature.[28] In particular, we match affiliates on their ownership structure, country of establishment, and sector of activity (in 2 digit NACE code) and coarsen them according to their age in the year 2000 and financial performance, measured by size (volume of sales), profit margin and intangible-to-total-asset ratio.[29]

Our one-to-one matching results in a reduction of the overall $\mathcal{L}$ statistic from 0.9856 to 0.6350 (c.f. Table B2), implying that the matched sample achieves an increased balance in all pre-treatment covariates. After matching, no statistically significant differences in the means of the treated and matched control group exist.[30] From the full sample of 14,686 treated and 75,976 control affiliates, we obtain 14,266 one-to-one matches (see Table B3).[31]

Figure 1 shows event-study plots[32] for the evolution of yearly pre-tax profit separately

[26] We have also used alternative tax measures as proposed in Huizinga and Leven (2008). The findings are qualitatively unaffected.

[27] The method supports monotonic imbalance bounding (MIB), meaning that increasing the balance on one variable cannot increase the imbalance on others (Blackwell et al., 2009, and Iacus et al., 2012.), which can happen when using propensity score matching (PSM). In a robustness analysis, we obtain qualitatively similar results when constructing a matched sample based on the same covariates using PSM (see Table C3).

[28] Most notably, these include industry structure, firm size and productivity. See Pakes and Griliches (1980), Acs and Audretsch (1988), Atkeson and Burstein, 2010, Hall and Lerner (2010), and Mohnen and Hall (2013), among others.

[29] For the financial performance indicators we collect affiliate-specific averages over the 1996-2006 decade to ensures independence from the business cycle. The volume of sales serves as a proxy for size, and the ratio of pre-tax profits to sales as a proxy of operating profit margin.

[30] The $\mathcal{L}$ statistic, introduced by Iacus et al. (2012), measures the global imbalance of the sample and is based on the difference between the multidimensional histogram of the chosen pre-treatment characteristics. $\mathcal{L}=1$ indicates complete imbalance and $\mathcal{L}=0$ perfect balance.

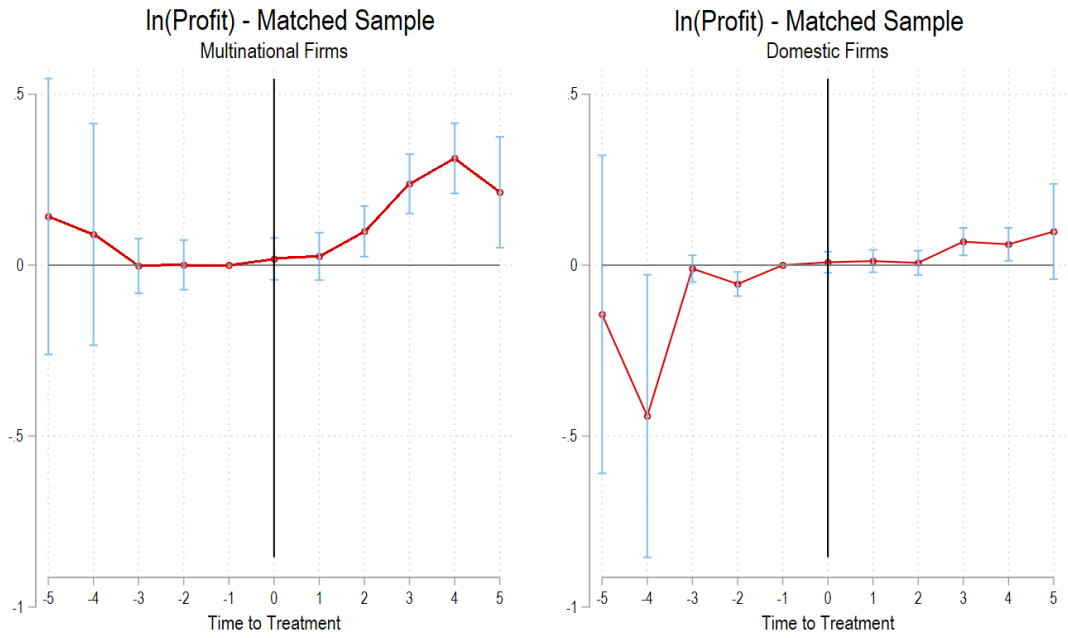
[31] Due to the varying coverage of firms in different countries in the ORBIS database and the extensive data requirement for the matching procedure, we are left with only a limited number of observations for some countries, including Luxembourg, the Netherlands and Hungary. Despite these data limitations, our results turn out to be very robust to different specifications.

[32] In analogy to equation (6), the regression equation for the event study is

$$\begin{aligned}\pi_{ist} =& b_0 + b_1 k_{it} + b_2 l_{it} + b_3 f_{it} + b_4 TAX_{it} \times MNE_i \\ &+ \Sigma_{k=T_0}^{-2} \gamma_{1k} Treated_{ik} \times DOM_i + \Sigma_{k=0}^{T_1} \gamma_{1k} Treated_{ik} \times DOM_i \\ &+ \Sigma_{k=T_0}^{-2} \gamma_{2k} Treated_{ik} \times MME_i + \Sigma_{k=0}^{T_1} \gamma_{2k} Treated_{ik} \times MME_i \\ &+ \theta_\tau + \lambda_{st} + \eta_i + e_{ist},\end{aligned}$$

for matched affiliates of MNEs and domestic firm conglomerates over the period 2007-2012, normalized around the year of introduction or major amendment of the patent box. We find that pre-tax profit of MNE affiliates before treatment are not different from the ones of MNE affiliates in the control group. However, after treatment pre-tax profit gradually increases and become significantly different from the pre-tax profit of MNE affiliates in the control group. Similarly, for the matched sample of domestic affiliates the diagrams show almost no difference in pre-tax profit between domestic treated and control affiliates before treatment. After treatment, pre-tax profit of treated domestic affiliates increases relative to the affiliates in the control group in the course of time. Note, the confidence intervals tend to be become larger at the beginning and at the end of the event window due to the reduced number of observations in these periods.

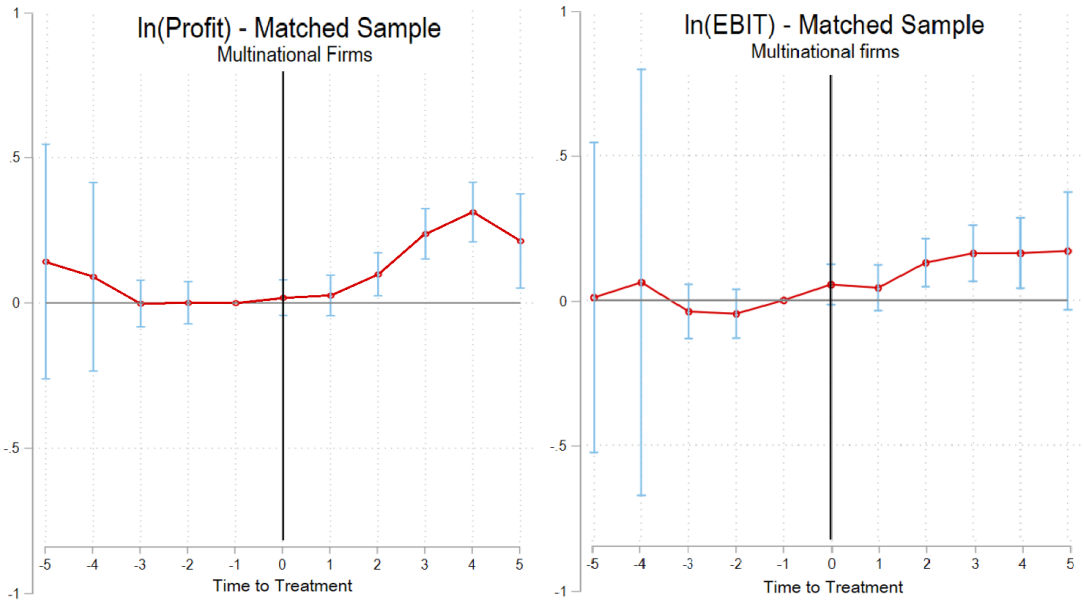
Figure 1: Event Study Plot: ln(Profit) with 95% Confidence Intervals



For MNE affiliates, we are also interested in the evolution of earnings before interest and taxes (EBIT) in order to analyze outward shifting behavior. Figure 2 shows event-study plots for the evolution of EBIT for matched MNE affiliates over the period 2007-2012, again normalized around the year of introduction or major amendment of the patent box. The plot for pre-tax profit is repeated for ease of comparison. Similar to the pattern of pre-tax profit of MNE affiliates, the EBIT measure for MNE affiliates shows no difference compared to the MNE affiliates in the control group. However, after treatment EBIT of treated MNE affiliates increases vis-à-vis EBIT of MNE affiliates in the control group.

where $T_0 = -5$ and $T_1 = 5$ are the lowest and highest number of lags and leads and the pre-event reference period is -1.

Figure 2: Event Study Plot: ln(Profit) and ln(EBIT) with 95% Confidence Intervals



7 Results

7.1 Baseline Estimates

In a first step, we follow the existing literature and quantify the tax incentives for profit shifting that are unrelated to patent boxes. We set $T_{it} = 0$ in equation (6) and estimate the relationship between pre-tax profits and fixed assets, cost of employees, financial leverage as well as MNE-affiliate-specific tax measure using a linear panel model with affiliate-level fixed effects, treatment-year and industry-year dummies. The results reported in Appendix C.1 show that affiliates with a lower tax rate than their parents report between 6 and 4 percent higher pre-tax profits (depending on the underlying tax measure) compared to affiliates with higher tax rates than their parents. The estimates are comparable in size with the results found in the existing literature using affiliate-level panel data (Dharmapala 2014).

In a next step, we estimate the heterogeneous treatment effect of patent boxes on pre-tax profits and EBIT of affiliates belonging to domestic or multinational firm conglomerates. The results in Table 3 show the estimates for the simple case of a homogeneous treatment effect in Column [1], a specification with heterogeneous treatment effect for affiliates of domestic vs. multinational conglomerates in Column [2], and in Column [3] a specification that additionally includes the control variables already used when estimating the tax incentives for profit shifting that are unrelated to patent boxes. For simplicity, we do not report the coefficients of these control variables in all subsequent tables. The results reported in Column [4] and [5] are the re-estimation of the specification in [3], based on the full unmatched sample, and using earnings before interest and taxes (EBIT) as the dependent variable, respectively.

[Include Table 3 here]

In line with our hypothesis, we find that affiliates located in a patent-box country and with a historical record of patent ownership report 4.7 percent higher pre-tax profits compared to affiliates that are similar, except that they did not own any patent by the year 2000. This result is significant at the 1-percent level.

However, affiliates of domestic and multinational firm conglomerates might respond differently to the introduction or major amendment of a patent box. While the patent box might increase productivity due to innovations or more intensive utilization of IP in both types of affiliates, only the MNE affiliate can utilize cross-country tax differentials to save on taxes via profit shifting. Hence, affiliates of MNEs might experience a higher change in pre-tax profits, which is the sum of both a profit shifting response and a productivity effect. To identify the heterogeneous treatment effect, we expand the specification in Column [1] and allow for the effect of the patent box to vary across affiliates of domestic and multinational conglomerates.

The results in Column [2] confirm our hypothesis. Pre-tax profits of affiliates located in a country with a patent box and belonging to a domestic conglomerate with historical patent ownership are 3.6 percent higher than the one of affiliates belonging to the control group, i.e., domestic conglomerates with no historical IP ownership. For affiliates of multinational conglomerates, the post-treatment difference between treated and control affiliates amounts to 10.9 percent and is thus more than 7 percentage points higher compared to domestic conglomerates. With an F-test of 13.77, we reject the hypothesis of no difference in the treatment effect of domestic and multinational affiliates at the 1-percent significance level. As shown in Column [3], introducing the control variables into the profit shifting equation reduces the absolute magnitude of the two treatment effects. The difference in the treatment effect between affiliates of domestic and multinational conglomerates is reduced to 5.1 percentage points. The results in Column [3] are robust to (*i*) relaxing the assumption of common input factor coefficients across the two groups of domestic and multinational conglomerates[33], and (*ii*) hold also when estimated on the full unmatched sample, c.f. Column [4].

For the results in Column [5], the dependent variable pre-tax profits is replaced by logged EBIT. In this specification, the treatment effect for affiliates of domestic conglomerates stays roughly the same as in the previous specifications (c.f. Columns [2] to [4]). However, the point estimate for affiliates of multinational conglomerates turns out larger than the estimate in Column [3], implying that also the difference in the change of EBIT for affiliates of multinational vs. domestic conglomerates is larger, amounting to 7.4 percentage points.[34]

[33] Allowing the coefficients for fixed assets, cost of employees and financial leverage to differ for affiliates of domestic and multinational conglomerates, the post-treated coefficient for the two groups of affiliates are 0.0366 (0.0166) and 0.0779 (0.0330), respectively.

[34] Note that EBIT, not including interest, is computed differently than pre-tax profit. For this reason we cannot

In fact, the difference in the coefficients offers a more nuanced perspective on the profit shifting behavior of MNEs compared to what the existing literature suggests.[35] The higher magnitude of the treatment effect on EBIT vs. pre-tax profit for affiliates of multinational conglomerates points to profit shifting out of the patent-box country and is in line with the theoretical prediction in Proposition 2. Patent boxes incentivize MNEs to shift income into the patent-box country, however, the resulting profit allocation might not be in line with the MNE's overall tax minimizing strategy. Hence, the MNE can redirect shifted profits out of the affiliate in the patent-box country using internal loans, for instance. Interest payments on internal loans, which are negatively accounted for in the pre-tax profit measure, reduce the magnitude of the estimate for pre-tax profit but not of the one for EBIT. The complementarity between inward profit shifting into the patent box and outward profit shifting out of the country via internal loans is in line with the observed level of corporate tax rates in patent-box countries (c.f. Table 1). On average, the tax rate in these countries is relatively high as compared to the regular tax rate in *typical* low-tax countries where the financial center of MNEs frequently reside. This incentivizes MNEs to engage in internal debt shifting (Mintz and Smart, 2004). Thus, and in addition to the tax savings offered by the patent box, MNEs can reap a tax subsidy when shifting profit out of an affiliate in a patent-box country to an affiliate in a low-tax country via internal loans.[36] We relegate a detailed decomposition of the pre-tax profit response of MNE affiliates and an analysis of the tax revenue implications of the bi-directional shifting behavior of MNEs to Section 9.

7.2 Heterogeneous Effects: Pre-Existing Tax Environment

The findings in our baseline analysis might be sensitive to the tax environment of the affiliate in the conglomerate. For instance, an MNE that uses a particular profit shifting channel, like income shifting into low-tax countries or tax havens, might reconsider its tax savings strategy once a patent box has become available in one of the countries the conglomerate is present. To proxy for tax incentives unrelated to patent box regimes, we allow the MNE treatment effect in the baseline model (Column [3] in Table 3) to vary by (i) whether the affiliate is a high-tax or low-tax affiliate in the MNE conglomerate and (ii) whether the MNE has a link to a tax haven.

test the significance of the difference in the treatment effect of the two models.

[35] In existing literature, profit shifting via transfer pricing and internal debt shifting is considered unidirectional and MNEs might opt for one or the other (or possibly both) type of profit shifting into an affiliate in a low-tax country (Haufler and Schjelderup, 2000; Mintz and Smart, 2004; Buettner et al. 2012). This reflects the fact that, in general, only a single statutory tax rates applies to all corporate income. This is not the case for patent boxes. Countries with a patent box are low-tax countries for IP income, but possibly high-tax countries otherwise.

[36] As explained in more detail in footnote 6, the tax planning strategy is in line with anecdotal evidence on how e.g. IKEA uses the tax benefits offered by the Dutch patent box (Auerbach, 2016).

High-Tax vs. Low-Tax Affiliate In Table 4, we allow the effect on treated multinational affiliates to vary according to whether the affiliate is located in a country with a lower tax rate than the country of its majority shareholder or in a country with the minimum tax rate faced at the conglomerate level (Column [2]).

Columns [4] to [6] repeat the exercise after substituting EBIT for pre-tax profit as the dependent variable.

[Include Table 4 here]

The point estimates for the change in pre-tax profit of treated MNE affiliates located in high-tax countries are larger than the ones of treated MNE affiliates in low-tax countries. The treatment effect is roughly 2 to 3 percent higher when the affiliate faces a larger statutory tax rate than its parent company (Column [1]) and a statutory tax rate which is higher than the minimum tax rate relevant to any other affiliate within the conglomerate (Column [2]). The point estimates are consistently larger when substituting EBIT for pre-tax profit as the dependent variable, but quite similar for high-tax and low-tax affiliates (Columns [4] and [5]). The latter finding suggests that the inward shifting is not influenced by the tax status of the affiliate in the MNE conglomerate. Differently, the outward shifting, which lowers pre-tax profits, is more pronounced in high-tax affiliates. However, the differential effect is not overly pronounced since confidence intervals of the pre-tax profit estimates largely overlap.[37] The findings are not supportive of the view that patent boxes are differently used as a tax-savings device in high-tax and low-tax MNE affiliates.

The Role of Tax Havens We find a differential use of patent boxes when interacting the treatment effect with the existence of a link to a tax haven in the MNE conglomerate. Columns [3] and [6] in Table 4 allow the effect on the treated multinational affiliates to vary according to whether the affiliate is linked to a shareholder located in a tax haven.[38] The introduction of a patent box yields an effect of 11 percent higher pre-tax profits and of 13 percent higher EBIT for affiliates of MNEs that are not linked to a tax haven through the conglomerate. The effect is not significant for affiliates belonging to a MNE that is linked to a tax haven. The finding is

[37] The observation that the effects are not too different for high-tax and low-tax affiliates is in line with the theoretical analysis in Section 3. The model predicts that EBIT responds more strongly to patent box tax incentives as compared to pre-tax profits. The way the EBIT and pre-tax profit estimate varies with the level of pre-existing tax rates (in comparison to tax rates of other affiliates) is ambiguous in sign. A formal analysis is available upon request.

[38] As a matter of choice, we use the tax haven classification in Hines and Rice (1994). Luxembourg is on the tax haven list and a patent-box country in our sample. When excluding Luxembourg from the sample, the findings are unchanged.

consistent with the interpretation that MNE affiliates with no link to a tax haven use patent boxes to save on taxes, while those with a link do not use the new tax savings device.[39]

The former estimate on the effect of a link to a tax haven possibly masks some heterogeneity, which we investigate in greater detail in Table 5. In particular, the type of link to a tax haven can have a significant impact on the profit shifting behavior of MNEs, especially if shareholders ultimately intend to repatriate profits back to the headquarter or majority shareholders (see, for instance, Dischinger et al., 2014). In the case the majority shareholders already reside in tax havens, they might not want to share the net tax savings by using the patent box instead of the tax haven, which discourages the shareholders from using the new tax savings option (Schindler and Schjelerup, 2012). Hence, the profit shifting of a MNEs with the majority shareholders already located in tax havens would not be affected by the introduction of a patent box. Instead, the profit shifting behavior of a MNE that relies on a tax-haven affiliate (different to the majority shareholder) to transfer profits might very well be affected by the introduction of a patent box and the opportunity of repatriating profits towards the high-tax country by means of IP royalties. This seems particularly profitable for an MNE that saves on concealment costs by shifting profits into an affiliate in a European country with a patent box in place, such as France and Spain, instead of a tax haven affiliate.[40]

To account for this type of reasoning, we differentiate between affiliates of MNEs where the majority shareholder is located in tax havens (Column [1]), one or more MNE affiliates are located in tax havens (Column [2]) and where the link to a tax haven exists because either an affiliate, the majority shareholders or both reside in tax havens (Column [3]). Columns [4] to [6] repeat the specifications in Columns [1] to [3] after substituting EBIT for pre-tax profit as the dependent variable.

[Include Table 5 here]

The treatment effect is not statistically significant when the shareholder resides in a tax haven (c.f. Columns [1] and [4] in Table 5). Otherwise, treated MNE affiliates that have a link to at least one or more tax haven affiliates within the MNE behave in the same way as treated affiliates with no link to tax havens. In line with the rationale discussed above, affiliates in patent-box countries whose majority shareholders reside in tax havens are not used for tax saving purposes. Shareholders do not tend to shift profits into the affiliate and, in response, part of it out of the affiliate via internal loans.

[39] A nearly zero, possibly negative point estimate is not contrary to the existence of productivity effects. It may represent the net effect on pre-tax profits and EBIT after the majority shareholder has shifted profits out of the affiliate, possibly to the tax haven where the shareholder resides.

[40] Fiscal authorities might well use any shifting of profits into a tax haven affiliate as a signal of tax avoidance or tax evasion which increases concealment cost. This might apply to a lesser extent to MNEs that shift profits into an affiliate in a European country instead of the Cayman Islands, for instance.

7.3 Heterogeneous Effects: (In)Direct Patent Ownership and Restrictions for Qualifying IP Income

We further look into the heterogeneity of the baseline results by allowing the results to differ for directly and indirectly owned patents. MNEs use the patent box for tax savings through transfer pricing and possibly relocate patents to affiliates in a country with a patent box. In this case, indirectly owned patents and their effect on pre-tax profits and EBIT should matter.

[Include Table 6 here]

Column [1] and [4] of Table 6 present the results where the treatment effect for MNE affiliates varies according to whether the treated affiliate directly owns patents in or prior to the year 2000. MNE affiliates with only indirect historical patent ownership via the majority shareholder report 10 percent higher profits and 12 percent higher EBIT than the affiliates in the control group. Thus, indirect patent ownership appears to be an important driver that determines the ability of MNEs to use patent boxes and explains the empirical findings in our analysis.[41]

Given the importance of indirectly-owned patents, the issue arises whether treatment effects still exist when acquired patents do not quality for patent boxes. In fact, patent box regimes impose different restrictions on which income qualifies for the preferential tax treatment. As shown in Table 1, patent box legislation differs as to whether acquired patents or patents that already exist prior to the introduction of the patent box can benefit from the preferential tax rate. This allows us to shed light on the effectiveness of these restrictions, which are presumably intended to protect the domestic corporate tax base and/or to create incentives to generate new patents rather than acquiring existing ones. In the specifications in Column [2] and [3], the treatment effect for MNE affiliates differs according to whether the MNE affiliate is located in a country where (i) acquired patents qualify for the preferential tax treatment by the patent box, and (ii) pre-existing patents also qualify for the tax benefit provided by the patent box.[42]

We find no significant effect for treated MNE affiliates in countries where the IP income of acquired patents is not eligible for the preferential tax treatment (Column [2] and [5]), and a much smaller significant effect for MNE affiliates in countries where IP income from pre-existing patents does not qualify for the reduced patent-box tax rate (Column [3] and [6]).[43] In particular the former finding is consistent with the importance of indirectly-owned patents for the treatment effect which we report above. These are not valuable for the affiliate in the

[41] The finding is in line with empirical evidence on tax-induced patent relocation. See Karkinsky and Riedel (2012), Griffith et al. (2014), Bosenberg and Egger (2017), Alstadsaeter et al. (2018), Ciaramella (2023), among others.

[42] In our sample, acquired patents do not qualify in Spain. Income of pre-existing patents is not eligible in Belgium, the Netherlands, and Luxembourg.

[43] As explained above, a nearly zero, possibly negative point estimate is not contrary to the existence of productivity effects. These may be shifted out of the affiliate when restrictions apply and the tax benefit of the patent box cannot be accessed.

patent-box country when acquired patents do not qualify for the tax benefit of the patent box. Thus, restrictions on qualifying IP income can be effective in reducing the tax-sensitivity of pre-tax profits of MNE affiliates.

8 Discussion

The empirical findings allow us to shed light on the behavioral responses of MNEs and the tax revenue implications.

Decomposing MNE Responses To decompose the pre-tax profit changes into its different components, we return to the theoretical model from Section 3. For notational simplicity, we omit the country index here and suppress the dependence of y_A on investment i. Pre-tax profit, π, and EBIT of an affiliate located in a country with a patent box is given by $\pi = y + \overline{y} + q - 1$ and $E = y + \overline{y} + q - 1$, respectively. Following the introduction of a patent box or a decline in the preferential tax rate on IP income, the change in pre-tax profits is

$$\Delta\pi = \Delta E - \Delta z, \tag{7}$$

where

$$\Delta E = \Delta y + \Delta q. \tag{8}$$

The first equation decomposes the change in pre-tax profit into a change in EBIT and a change in interest expenses. The second equation separates the change in EBIT into a change in output (productivity), y, and profit shifting into the patent box, q. Given our estimates of the relative change in pre-tax profit and EBIT, we can back out the change in interest expenses Δz from equation (7) after some synchronization of the unit of measurement. The latter is necessary because pre-tax profits and EBIT refer to different bases and therefore changes in the two measures cannot be directly compared.

In the empirical analysis, we estimate the *relative changes* in EBIT and pre-tax profits, which enables us to express the change in the outcome variables, $\Delta\pi$ and ΔE, as a fraction of their respective pre-treatment values, i.e. $\Delta\pi/\pi$ and $\Delta E/E$. To align the units of measurement, we express the change in EBIT as a fraction of pre-tax profit, i.e. $\Delta E/\pi = \Delta E/E \cdot E/\pi$. In our baseline specification in Table 3, $\Delta E = 0.11E$. To assess the ratio E/π, we compute the average value of E/π of treated MNE affiliates in the pre-treatment years, i.e. in the years of our baseline sample period prior to the introduction or major amendment of a patent box, which is $E/\pi = 1.7$. Using the information, we obtain $\Delta E = 0.187\pi$. Coupled with the estimated pre-tax profit change in the baseline specification of $\Delta\pi = 0.085\pi$, the change in interest expenses is $\Delta z = 0.102\pi$. This suggests that the total change in earnings before subtracting interest

payments is 18.7 percent of pre-tax profit. Interest expense adjustments due to internal debt shifting reduce the observed relative change in pre-tax profits to 8.5 percent.

Some of the observed change in EBIT might be due to profit shifting into the patent box, Δq, and the productivity effect, Δy. The estimated change in the pre-tax profits of domestic affiliates provides a measure of the productivity effect these affiliates face due to patent boxes. Provided the estimate is also representative for MNE affiliates, the decomposition in (8) allows us to back out the amount of profit shifting into the patent box. Again, using the baseline estimate of $\Delta E = 0.187\pi$ and a productivity effect of $\Delta y = 0.035\pi$, the level of profit shifting into the patent box is $\Delta q = 0.152\pi$. Thus, the total amount of profit shifting into the patent box is 15.2 percent of pre-tax profits, while, stated above, 10.2 percent of pre-tax profits are shifted out of the country via internal debt shifting. This leaves a net effect of profit shifting on pre-tax profits, as measured by $\Delta q - \Delta z$, of 5 percent of pre-tax profits.

We should emphasize that the magnitude of profit shifting into the patent box of 15.2 percent relates to the treatment effect, i.e. the implementation or a major amendment of a patent box. It cannot be directly compared to estimates in the literature, which express the relative change per percentage point change in the tax rate. The difference between the regular corporate tax rate and reduced tax rate of the patent box is significant, c.f. Table 1. Weighting the tax differential by the number of treated MNE affiliates, the (weighted) average of the tax rate reduction amounts to 20 percentage points. Thus, the pseudo semi-elasticity of the profit shifting response into the patent box associated with a percentage point decrease in the tax rate for IP income is 0.76 (= 0.152/0.2), which is in line with recent estimates of profit shifting. The consensus estimate is 0.8 (Dharmapala, 2014; Heckemeyer and Overesch, 2017). We should note that the consensus estimate combines different profit shifting channels (profit shifting via royalty payments, internal trade in inputs and internal debt finance), while our estimate relies on royalty payments only, since patent boxes lower the tax treatment of this income stream. Thus, our estimate of the elasticity for royalty payments is generically larger that the one that underlies the consensus estimate. The observation is in line with the stark tax rate changes associated with patent box regimes and the salience of this new tax instrument, which might have prompted MNEs to respond stronger to this policy change as compared to smaller corporate tax rate changes that are frequently available in empirical work (Dharmapala and Hebous, 2018).

Tax Revenue Implications To assess the effect of the MNE response on domestic corporate tax revenues, we denote initial tax revenues that are collected from MNEs as $T = \tau\pi$, where τ is the regular statutory corporate tax rate and pre-tax profits π correspond to the tax base. Defining $\Delta\tau = \tau_{pb} - \tau$ as the difference between the preferential tax rate of the patent box

and the regular statutory corporate tax rate and π_{pb} (π_{-pb}) as the profit stream that is (is not) eligible for the patent box, the change in tax revenues following the introduction of the patent box is

$$\Delta T = \Delta\tau \cdot \pi_{pb} + \underbrace{\tau_{pb} \cdot \Delta\pi_{pb} + \tau \cdot \Delta\pi_{-pb}}_{=\Delta T_{beh}}. \tag{9}$$

The first term is the mechanical effect of the patent box on tax revenues, while the remaining terms summarize the behavioral effect on tax revenues due to adjustments in the tax base that qualifies for the preferential tax treatment of the patent box, $\Delta\pi_{pb}$, and which does not qualify, $\Delta\pi_{-pb}$. The mechanical effect is negative in sign, which leaves it to the behavioral response of the MNE to expand the tax base or at least limit the revenue shortfall. From (9), the behavioral response can be rewritten as

$$\Delta T_{beh} = \tau \left(\gamma \cdot \Delta\pi_{pb} + \Delta\pi_{-pb}\right), \tag{10}$$

where the tax rate of the patent box is expressed as a fraction γ of the regular tax rate, $\tau_{pb} = \gamma\tau$. For $\tau > 0$ and $\Delta\pi_{pb} > 0$, which we observe empirically, we can write

$$\Delta T_{beh} \gtreqless 0 \qquad \Leftrightarrow \qquad \gamma \gtreqless -\frac{\Delta\pi_{-pb}}{\Delta\pi_{pb}}. \tag{11}$$

The tax revenue change ΔT_{beh} is positive provided the tax advantage of the patent box is not too strong, i.e. γ is sufficiently high. Given our baseline estimates, the rise of patent box income due to profit shifting into the patent box is $\Delta\pi_{pb} = 0.152\pi$. Assuming that the productivity gain is subject to the regular tax rate, the corporate tax base π_{-pb} increases due to the productivity rise by 3.5 percent of pre-tax profits and decreases due to higher interest expenses by 7.5 percent of pre-tax profits, i.e. $\Delta\pi_{-pb} = (0.035 - 0.075)\pi$.[44] Thus, from (11) it follows that the value of γ at which the behavioral response of MNEs is revenue neutral is $\gamma^* = 0.44$. Based on Table 1, empirically observed values of γ range between 0.2 and 0.5. This implies that the tax base adjustments do not necessarily translate into higher corporate tax revenues collected from MNEs. In that sense, the tax costs associated with the empirically identified outward shifting of profits via internal debt might outweigh the positive effects on tax revenues due to inward profit shifting and higher productivity. The observation is contrary to the widely-held expectation that patent boxes attract reported income and that the behavioral adjustment increase tax revenues collected from MNEs.[45]

[44] Attributing the productivity gain to π_{pb} would render the effect of the behavioral responses on corporate tax revenues more likely negative.

[45] Domestic affiliates benefit from the productivity enhancement, which expands the corporate tax base. Whether the total effect on corporate tax revenues turns positive depends on the level of taxable profits of domestic and MNE affiliates and their decomposition in taxable profits that qualify for the patent box, which is not available in the ORBIS database. For this reason, we have to leave such a comparison to future research.

9 Conclusion

In recent years, patent box regimes have become increasingly popular as a tool to attract taxable income from intellectual property (IP). In this paper, we quantify the effect of the European patent box regimes on the profit shifting behavior of MNEs. We find that affiliates that have been selected into the treatment group because of their historical patent ownership report a rise in their pre-tax profit levels of 8.5 percent. The estimated change in profits does not capture the full magnitude of the MNEs usage of the patent box legislation due to profit shifting for different reasons. First, patent boxes also increase productivity, raising profit levels unrelated to profit shifting. Second, MNEs shift profits into the patent box as well as out of the patent-box country via internal debt arrangements. Only the net effect shows up in the change of estimated profits. When decomposing the in- and outward shifting behavior of MNEs, we find that the propensity to shift profits into the patent box is much higher, amounting to 15 percent of pre-tax profits.

The shifting behavior of MNEs has a possibly surprising influence on corporate tax revenues. Albeit only a fraction of the incoming profits leaves the patent-box country again via internal debt arrangements, the type of 'round tripping' is costly for the patent-box country. It certainly lowers corporate tax revenues and might even lead to a reduction in revenues that the patent-box country collects from MNEs.

These findings are of policy relevance and provide a foundation for policies that have recently been suggested to combat the use of patent boxes for profit shifting. The modified nexus approach endorsed by the OECD and the G20 member countries constrains the use of patent boxes by introducing restrictions on whether, among others, acquired patents are eligible for the preferential tax treatment.[46] Our analysis already sheds some light on the effectiveness of such restrictions. Exploiting differences in the generosity of existing patent box regimes, we find that excluding acquired patents from the tax benefit reduces the tax sensitivity of MNE profits.

Finally, the paper focuses on the responses of affiliates within a patent-box country. MNE structures provide a way by which affiliates become interrelated and, thereby, the effects of patent boxes might also propagate within an MNE conglomerate to affiliates in non-patent-box countries. Albeit interesting, such analyses are beyond the scope of the paper and left to future research.

[46] In general terms, the modified nexus approach stipulates a nexus between the location of R&D activity, i.e., the patent creation, and the eligibility of the IP royalties for the preferential tax treatment granted by the patent box legislation (OECD, 2015).

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Tables

Table 1: **Characteristics of European Patent Box Regimes (2015)**

	BE	ES	LU	FR*	NL*	HU*
Year (introd./reform)	2008	2008	2008	2010	2010	2012
Top CIT Rate	0.330	0.280	0.292	0.333	0.250	0.190
Effective Tax Rate on IP	0.066	0.112	0.058	0.150	0.050	0.095
Base Exempted from CIT	0.80	0.60	0.800	0.00	0.80	0.500
Separate Rate on IP	No	No	No	Yes	No	No
New Patents	Yes	Yes	Yes	Yes	Yes	Yes
Existing Patents	No	Yes	No	Yes	No	Yes
Acquired Patents	Yes	No	Yes	Yes	Yes**	Yes
Know-How	No	Yes	Yes	No	No	Yes

Note: Listed countries introduced or substantially reformed their patent box regimes in the period 2007-2013. (*) Indicates countries with a major reform of the patent box regime in the year reported in the first row of the table and that resulted in a major reduction of the effective tax burden on IP income. The post-reform effective tax burden on IP income is as stated in the third row of the table. (**) Acquired IP must be further developed and/or actively managed.

Table 2: **Definition of Variables**

Variable	Definition
Pre-Tax Profits	Operating profits + Financial profits before tax (in logs)
EBIT	Earnings before interest and taxes (in logs)
Financial Leverage	Ratio of total debt to total assets
Capital	Volume of fixed assets (in logs)
Labour	Total cost of employees (in logs)
Intangible Assets	Volume of intangible fixed assets (in logs)
Profit Margin	(Profits before tax / Operating revenue) * 100
Liquidity Ratio	(Current assets - Stocks) / Current liabilities
Industrial Sector	Affiliate 2-digit NACE code
Number of Patents	Sum of all patents owned by affiliate and shareholders
Tax Rates	Top statutory tax rate on corporate income (between 0 and 1)

Note: All financial variables are collected from ORBIS and are originally provided in EUR units, then converted to 2005 EUR units. Tax rates are collected from the Worldwide Corporate Tax Guide, EY (various years).

Table 3: **Difference-in-Difference Model - Baseline Heterogeneous Treatment**

Dep. Variable:	Pre-Tax Profits				EBIT
	Homog. Treatment [1]	MNE vs DOM [2]	Controls [3]	Full Sample [4]	same as [3] [5]
After * Treated	0.0472***				
	(0.0159)				
After * Treated * DOM Affiliate		0.0375**	0.0346**	0.0346***	0.0320**
		(0.0165)	(0.0166)	(0.0130)	(0.0149)
After * Treated * MNE Affiliate		0.1088***	0.0854***	0.0755***	0.1063***
		(0.0310)	(0.0330)	(0.0261)	(0.0311)
Fixed Assets			0.0219***	0.0304***	0.0458***
			(0.0073)	(0.0043)	(0.0068)
Cost of Employees			0.2698***	0.2667***	0.2666***
			(0.0164)	(0.0092)	(0.0149)
Financial Leverage			-0.1745***	-0.1978***	-0.0327**
			(0.0157)	(0.0091)	(0.0140)
MNE Affiliate in Low-Tax Country			0.0535**	0.0907***	0.0602***
			(0.0268)	(0.0166)	(0.0245)
Treatment Year Dummies	YES	YES	YES	YES	YES
Year x Industry Dummies	YES	YES	YES	YES	YES
Observations	131,592	131,592	131,592	409,776	131,794
Total Number of Affiliates	28,532	28,532	28,532	90,662	28,379
Treated MNE Affiliates	1,624	1,624	1,624	2,033	1,624
Treated DOM Affiliates	12,624	12,624	12,624	43,298	12,624

*Note: All models are estimated using a linear panel model with affiliate level fixed effects. The sample includes all affiliates matched with CEM. Treatment is defined as patent ownership directly by the affiliate or indirectly by the majority shareholder by the year 2000. In columns [2] to [5], treatment is allowed to vary according to the time-invariant ownership structure of the affiliate conglomerate (multinational or domestic). Standard errors are clustered at the shareholder level and reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 4: **Difference-in-Difference Model - Confounding Tax Incentives**

Dep. Variable:	Pre-Tax Profits			EBIT		
	Parent Tax [1]	Minimum Tax [2]	Tax Haven [3]	Parent Tax [4]	Minimum Tax [5]	Tax Haven [6]
After * Treated * DOM Affiliates	0.0285*	0.0285*	0.0289*	0.0251*	0.0255*	0.0257*
	(0.0163)	(0.0163)	(0.0163)	(0.0147)	(0.0147)	(0.0147)
After * Treated * MNE Affiliates:						
in low-tax countries	0.0912*	0.1045**		0.1463***	0.1298***	
	(0.0549)	(0.0461)		(0.0526)	(0.0452)	
in high-tax countries	0.1306***	0.1219***		0.1495***	0.1389***	
	(0.0346)	(0.0320)		(0.0336)	(0.0308)	
linked to a tax haven			-0.0886			0.0608
			(0.1286)			(0.0955)
not linked to a tax haven			0.1088***			0.1317***
			(0.0306)			(0.0292)
Controls	YES	YES	YES	YES	YES	YES
Treatment Year FE	YES	YES	YES	YES	YES	YES
Year x Industry FE	YES	YES	YES	YES	YES	YES
Observations	131,592	131,592	131,592	144,400	144,400	144,400
Affiliates	28,532	28,532	28,532	27,896	27,896	27,896
Treated MNE Affiliates	1,624	1,624	1,624	1,624	1,624	1,624
Treated DOM Affiliates	12,624	12,624	12,624	12,624	12,624	12,624

*Note: All models are estimated using a linear panel model with affiliate level fixed effects. The sample includes all affiliates matched with CEM. Treatment is defined as direct patent ownership by the affiliate or indirectly by the majority shareholder, by the year 2000. For multinational affiliates, treatment is allowed to vary according to the confounding tax incentives faced by the conglomerate the affiliate belongs to. Control variables are identical to the ones in [3], Table 3, but are omitted from the table. Standard errors are clustered at the shareholder level and reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 5: **Difference-in-Difference Model - Role of Tax Havens (TH)**

Dep. Variable:	Pre-Tax Profits			EBIT		
	SH in TH [1]	AF in TH [2]	Any in TH [3]	SH in TH [4]	AF in TH [5]	Any in TH [6]
1After * Treated * DOM Affiliate	0.0350**	0.0346**	0.0346**	0.0323**	0.0320**	0.0320**
	(0.0166)	(0.0166)	(0.0166)	(0.0150)	(0.0150)	(0.0150)
After * Treated * MNE Affiliate						
linked to Tax Haven	-0.1250	0.0878**	0.0789**	-0.0690	0.1178***	0.1129***
	(0.0861)	(0.0391)	(0.0382)	(0.0873)	(0.0388)	(0.0376)
not linked to Tax Haven	0.1003***	0.0838**	0.0907**	0.1186***	0.0983***	0.1010***
	(0.0339)	(0.0401)	(0.0413)	(0.0321)	(0.0372)	(0.0385)
Controls	YES	YES	YES	YES	YES	YES
Treatment Year FE	YES	YES	YES	YES	YES	YES
Year x Industry Dummies	YES	YES	YES	YES	YES	YES
Observations	131,592	131,592	131,592	144,400	144,400	144,400
Affiliates	28,532	28,532	28,532	28,379	28,379	28,379
Treated MNE Affiliates	1,624	1,624	1,624	1,624	1,624	1,624
Treated DOM Affiliates	12,624	12,624	12,624	12,624	12,624	12,624

*Note: All models are estimated using a linear panel model with affiliate level fixed effects. The sample includes all affiliates matched with CEM. Treatment is defined as direct patent ownership by the affiliate or indirectly by the majority shareholder, by the year 2000. For affiliates of multinationals, treatment effect varies according to the type of link the affiliate has with a tax haven (TH). SH (AF) indicates that the majority shareholder (an affiliate in the conglomerate) resides in a tax haven. The variable "Any" indicates that either an affiliate, the majority shareholder or both reside in a tax haven. Control variables are identical to the ones in [3], Table 3, but are omitted from the table. Standard errors are clustered at the shareholder level and reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 6: **(In)Direct Patent Ownership and Patent Box (PB) Restrictions**

	Pre-Tax Profit			EBIT		
	Direct Patents [1]	Acquired Patents [2]	Existing Patents [3]	Direct Patents [4]	Acquired Patents [5]	Existing Patents [6]
After * Treated * DOM Affiliate	0.0348**	0.0342**	0.0345**	0.0322**	0.0313**	0.0318**
	(0.0166)	(0.0166)	(0.0166)	(0.0150)	(0.0150)	(0.0150)
After * Treated * MNE Affiliate						
without Direct Patents	0.0955***			0.1185***		
	(0.0341)			(0.0321)		
with direct patents	-0.0422			-0.0504		
	(0.0809)			(0.0856)		
in UnRestricted PB country		0.0998***	0.1941***		0.1294***	0.2113***
		(0.0338)	(0.0715)		(0.0328)	(0.0725)
in Restricted PB country		-0.0592	0.0650*		-0.1250	0.0867***
		(0.1098)	(0.0352)		(0.0787)	(0.0330)
Controls	YES	YES	YES	YES	YES	YES
Treated x Year FE	YES	YES	YES	YES	YES	YES
Year x Industry Dummies	YES	YES	YES	YES	YES	YES
Observations	131,592	131,592	131,592	131,794	131,794	131,794
Affiliates	28,532	28,532	28,532	28,397	28,397	28,397
R-squared	0.0459	0.0459	0.0459	0.0492	0.0493	0.0492
Treated MNE Affiliates	1,624	1,624	1,624	1,624	1,624	1,624
Treated DOM Affiliates	12,624	12,624	12,624	12,624	12,624	12,624

*Note: All models are estimated using a linear panel model with affiliate level fixed effects. The sample includes all affiliates matched with CEM. Treatment is defined as direct patent ownership by the affiliate or indirectly by the majority shareholder, by the year 2000. The treatment effect varies according to whether patents are owned (in)directly (Column [1] and [4]) and whether the patent box legislation allows to qualify acquired (Column [2] and [5]) or existing (Column [3] and [6]) patents. Control variables are identical to the ones in [3], Table 3, but are omitted from the table. Standard errors are clustered at the shareholder level and reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

A Comparative Static Analysis

After-tax profits of the MNE are:

$$\begin{aligned}\Pi &= (1-t_A^{PB})(y_A(i)+q-1)+(1-t_A)(\overline{y}_A-z)+(1-t_B)(y_B-q)+(1-t_C)z \\ &- \theta(q)-c(i)-\gamma(z,E_A).\end{aligned} \tag{12}$$

Differentiating (12) w.r.t. q, i, and z, and rearranging terms yields:

$$q: \quad t_B - t_A^{PB} - \partial\gamma(z,E_A)/\partial E_A = \theta'(q) \tag{13}$$

$$i: \quad (1-t_A^{PB})y_A'(i) - \partial\gamma(z,E_A)/\partial E_A y_A'(i) = c'(i) \tag{14}$$

$$z: \quad t_A - t_C = \partial\gamma(z,E_A)/\partial z. \tag{15}$$

To simplify notation, we denote the derivatives of $\gamma(z,E_A)$ by subscripts, where the order of the subscripts denotes the order in which derivatives are taken, and we suppress the arguments of the various functions.[47]

We are now interested in how MNE behavior changes when the corporate tax rate of the patent box t_A^{PB} changes. Totally differentiating the first-order conditions (13) - (15) yields (in matrix notation):

$$\begin{pmatrix} -\theta''-\gamma_{EE} & -\gamma_{EE}\ y_A' & -\gamma_{Ez} \\ -\gamma_{EE}\ y_A' & -c''-\gamma_{EE}\,(y_A')^2+ \\ & (1-t^{PB}-\gamma_E)y_A'' & -\gamma_{Ez}\ y_A' \\ -\gamma_{zE} & -\gamma_{zE}\ y_A' & -\gamma_{zz} \end{pmatrix} \begin{pmatrix} dq \\ di \\ dz \end{pmatrix} = \begin{pmatrix} 1 \\ y_A' \\ 0 \end{pmatrix} dt_A^{PB}.$$

Γ denotes the 3 x 3 matrix. Using Cramer's Rule, the solution of the equation system is:

$$\frac{dq}{dt_A^{PB}} = \frac{|\Gamma_1|}{|\Gamma|}, \quad \frac{di}{dt_A^{PB}} = \frac{|\Gamma_2|}{|\Gamma|}, \quad \text{and} \quad \frac{dz}{dt_A^{PB}} = \frac{|\Gamma_3|}{|\Gamma|},$$

where

$$\begin{aligned}|\Gamma_1| &= \left(c''-(1-t_A^{PR}-\gamma_E)y_A''\right)\gamma_{zz} > 0 \\ |\Gamma_2| &= y_A'\theta''\gamma_{zz} > 0 \\ |\Gamma_3| &= \left(-c''+(1-t_A^{PR}-\gamma_E)y_A''-(y_A')^2\theta''\right)\gamma_{zE} > 0.\end{aligned}$$

The sign of $|\Gamma_j|$, $j=1,2,3$, follows from the assumptions we impose on the first and second derivatives of the various functions and from (14), which signs $1-t_A^{PR}-\gamma_E$ positive. At the optimum, the determinant of Γ must be negative, i.e. $|\Gamma|<0$. Combining results yields:

$$\frac{dq}{dt_A^{PB}} < 0, \quad \frac{di}{dt_A^{PB}} < 0, \quad \text{and} \quad \frac{dz}{dt_A^{PB}} < 0.$$

[47] We also suppress the subscript A of earnings before interest of affiliate A when taking derivatives of $\gamma(\cdot)$.

B Descriptive Statistics and Matching

B.1 Tax Measures

Table B1 reports the the affiliate-time-specific tax measures, variable TAX_{it}, averaged over the observational period 2007-2013. In the empirical analysis, we use two different measures. First, the difference in the statutory corporate tax rate in the country of affiliate i and the country of the majority shareholder p, i.e. $\tau_{it} - \tau_{pt}$. Second, as an alternative measure we use the difference in the statutory corporate tax rate levied in the country of affiliate i and the country of the affiliate facing the lowest statutory corporate tax rate within the MNE conglomerate, i.e. $\tau_{it} - \tau_{min,t}$, with $\tau_{min,t} = min\{\tau_{jt}\}_{j=1,j\neq i}^{J}$, with J denoting the $N-1$ other affiliates.

Table B1: **Tax Rates across Treatment and Control Groups (2007-2013 average)**

Tax Measure	Full Sample	Treated	Control
τ_i	32.58	32.76	32.37
τ_p	29.75	29.83	28.97
τ_{min}	27.40	27.59	27.19
$\tau_i - \tau_p$	2.83	2.94	3.39
$\tau_i - \tau_{min}$	4.80	5.18	5.12

Note: Average tax indices computed for different samples of affiliates, over the observational period of 2007-2013. Tax indices are defined as described in Section 5. The samples include the full sample and the treated and the control sample, before matching.

B.2 Coarsened Exact Matching

We resort to *coarsened exact matching* (CEM) to achieve a balance between the treatment and control group, which is measured through the $\mathcal{L}$ statistic (Iacus et al., 2012). The measure is based on the difference between the multidimensional histogram of the chosen pre-treatment characteristics. $\mathcal{L} = 1$ indicates complete imbalance and $\mathcal{L} = 0$ perfect balance.

Table B2: **Coarsened Exact Matching**

	Full Sample (N=90,662)			Matched Sample (N=28,532)		
	$\mathcal{L}$	Mean Diff.	T-test	$\mathcal{L}$	Mean Diff.	T-test
MNE/Domestic	0	0	-	0	0	-
Country	0.091	-0.096	-	0	0	-
Industrial Sector	0.217	-5.475	-	0	0	-
Age in year 2000	0.157	4.246	0.000	0.009	-0.0002	0.9767
Int. to Total Asset Ratio	0.033	-0.007	0.000	0.051	-0.0017	0.2376
Profit Margin	0.001	624.310	0.023	0.011	0.079	0.0789
Log(Sales)	0.203	0.803	0.000	0.047	0.019	0.2884
Num. Employees	0.176	36.457	0.000	0.026	0.003	0.9992
Number of Indirect Patents	0.137	339.360	0.000	0.063	4.7548	0.5665

Note: The "matched sample" includes 14,266 treated affiliates matched with an equal number of non-treated affiliates. The percentage of affiliates controlled by MNEs is equal to 9.09% in the original sample, and equal to 11.50% in the matched sample. After matching 846 out of 2,348 strata, the overall $\mathcal{L}$ statistic measure is reduced from 0.9856 to 0.6350. T-statistic in the third and sixth columns reports the result from a two sided test for the equality of means between the treated and control group, before and after the matching.

The $\mathcal{L}$ statistic of the full sample serves as a reference point for the $\mathcal{L}$ statistic obtained after the matching. As reported in Table B2, our one-to-one matching results in a reduction of the overall $\mathcal{L}$ statistic from 0.9856 to 0.6350. The matched sample achieves increased balance in all pre-treatment covariates. After matching, no statistically significant differences in the means of the treated and matched control group exist.

From the full sample of 14,686 treated and 75,976 control affiliates, we obtain 14,266 one-to-one matches (see Table B3).

Table B3: **Matched Sample Composition**

	Full Sample				Matched Sample			
	Treated		Control		Treated		Control	
Affiliates of MNEs	2,033	(13.8%)	6,216	(8.8%)	1,642	(11.5%)	1,642	(11.5%)
Affiliates of DOMs	12,653	(86.2%)	69,760	(91.8%)	12,624	(88.5%)	12,624	(88.5%)
Total	14,683	(100%)	75,976	(100%)	14,266	(100%)	14,266	(100%)

Note: Sample composition after CEM, listed by type of conglomerate. Treatment is defined by historical (pre-2000) direct and indirect (via majority shareholder) ownership of IP.

– Online Appendix –

C Further Analyses and Robustness Checks

C.1 Benchmark Estimation: Profit Shifting

In this Section we identify the tax incentives for profit shifting unrelated to the patent box. Table C1 reports the results of the linear panel model used to estimate the relationship between pre-tax profits, fixed assets, cost of employees, and financial leverage. The model is estimated on the full unmatched sample in Column [1] and the matched sample in Column [2]. The results in Columns [3] to [6] are estimated on a sub-sample and additionally include tax measures, which capture tax incentives for profit shifting unrelated to the patent box.

Table C1: **Benchmark Estimation - Profit Shifting Regression**

Dep. Variable: ln (Pre-Tax Profits)	Full Sample [1]	Matched Sample [2]	Parent Tax Differential [3]	Min. Tax Differential [4]	Parent Tax Dummy [5]	Min. Tax Dummy [6]
Fixed Assets	0.0300***	0.0215***	0.0440***	0.0435***	0.0442***	0.0440***
	(0.0043)	(0.0073)	(0.0102)	(0.0102)	(0.0102)	(0.0102)
Cost of Employees	0.2668***	0.2701***	0.3352***	0.3356***	0.3336***	0.3339***
	(0.0092)	(0.0164)	(0.0305)	(0.0305)	(0.0303)	(0.0303)
Financial Leverage	-0.1982***	-0.1750***	-0.2015***	-0.2011***	-0.2035***	-0.2031***
	(0.0091)	(0.0157)	(0.0245)	(0.0245)	(0.0244)	(0.0244)
Tax Differential: $\tau_i - \tau_j$			-0.0038*	-0.0032***		
			(0.0023)	(0.0010)		
Tax Dummy: 1 if $[\tau_i < \tau_j]$					0.0626***	0.0575**
					(0.0237)	(0.0225)
Treatment Year Dummies	YES	YES	YES	YES	YES	YES
Year x Industry Dummies	YES	YES	YES	YES	YES	YES
Observations	409,776	131,592	37,723	37,723	37,723	37,723
Affiliates	90,662	28,532	8,249	8,249	8,249	8,249

*Note: All models are estimated using a linear panel model with affiliate level fixed effects. In Column [1] and [2], both domestic and multinational affiliates are considered in the full and matched sample, respectively. In Columns [3]-[6], the full sample of multinational affiliates is included. The tax rate indexed j refers to the parent country in Column [3] and [5], and to the country with the lowest tax rate within the conglomerate in Column [4] and [6]. Standard errors are clustered at the shareholder level and reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

In Column [3] and [4], the affiliate-specific time-variant tax measure is the statutory tax rate differential between the affiliate in country i and the headquarter in parent country p (Column [3]), or the affiliate facing the lowest tax rate within the conglomerate (Column [4]). The specifications in Columns [5] and [6] repeat the tax measures used in Columns [3] and [4] but use an indicator variable instead of the statutory tax rate differential.[48]

[48] Affiliate-level fixed effects as well as treatment-year and industry-year dummies are included in all specifications. We additionally estimate a version that includes majority-shareholder-country-year-fixed effects and affiliate-country-year-fixed effects. The results of these richer specifications are generally the same as those presented here. The latter set of fixed effects is not considered because restricting our sample to affiliates with a constant conglomerate (domestic vs. multinational) structure limits the within-affiliate time-variability of the shareholder country-year pairs. In addition, the inclusion of country-year-fixed effects drains the effects of the tax measure, TAX_{it}, which is crucial for identifying confounding tax incentives.

The estimates in Columns [1] and [2] show that, despite the substantial difference in sample size, the relationship between pre-tax profits and the inputs of production is largely unaffected by the sample composition. Furthermore and in line with the existing literature, which uses affiliate-level panel data (see Dharmapala 2014, for a discussion), we find semi-elasticities of around 0.004 in Specifications [3] and [4]. That is, a reduction of 10 percentage points in the tax rate differential between the country of the affiliate and the country of the parent increases the pre-tax profits of the affiliate by 4 percent. For affiliates with a lower tax rate than their parents, we find on average 6.3 percent higher pre-tax profits than affiliates with higher tax rates than their parents, and affiliates facing the lowest tax rate within the entire conglomerate report roughly 5.8 percent higher pre-tax profits than all other subsidiaries.

C.2 New Patent Ownership and Trademarks

For the results in Table C2, we modify the sample composition by first excluding all affiliates that changed their patent ownership between 2000 and 2007 and second, we also consider trademarks in addition to patents.

Table C2: **Sample Composition: Exclusion of Trademarks and New Patents**

Dep. Variable	Baseline	Excluding	Excluding Trademarks	
Pre-Tax Profits	Tab.3 Col.3	New Patents	Historical	Hist. & New
	[1]	[2]	[3]	[4]
After * Treated * DOM Affiliate	0.0346**	0.0350**	0.0354**	0.0337**
	(0.0166)	(0.0166)	(0.0167)	(0.0168)
After * Treated * MNE Affiliate	0.0854***	0.0889***	0.0892***	0.0906***
	(0.0330)	(0.0330)	(0.0331)	(0.0332)
Fixed Assets	0.0219***	0.0220***	0.0214***	0.0216***
	(0.0073)	(0.0073)	(0.0073)	(0.0074)
Cost of Employees	0.2698***	0.2681***	0.2738***	0.2701***
	(0.0164)	(0.0164)	(0.0162)	(0.0162)
Financial Leverage	-0.1745***	-0.1747***	-0.1757***	-0.1734***
	(0.0157)	(0.0157)	(0.0157)	(0.0158)
MNE Affiliate in Low-Tax Country	0.0535**	0.0492*	0.0512*	0.0461*
	(0.0268)	(0.0269)	(0.0270)	(0.0272)
Treatment Year Dummies	YES	YES	YES	YES
Year x Industry Dummies	YES	YES	YES	YES
Observations	131,592	129,413	130,638	129,434
Affiliates	28,532	28,089	28,341	28,092
Treated MNE Affiliates	1,642	1,642	1,642	1,642
Treated DOM Affiliates	12,624	12,624	12,642	12,642

*Note: All models are estimated using a linear panel model with affiliate level fixed effects. The samples vary across columns: [1] uses the matched sample of Table 3, Column [3]; [2] uses the full matched sample, after excluding affiliates in the control group that created new patents between 2000 and 2007 (reducing the control sample to 12,524 domestic and 1,608 multinational affiliates); [3] uses the full matched sample, excluding affiliates in the control group that owned any trademark by the year 2000 (reducing the control sample to 12,483 domestic and 1,592 multinational affiliates); [4] also excludes affiliates in the control group that registered new trademarks between 2000 and 2007 (reducing the control sample to 12,276 domestic and 1,550 multinational affiliates). Standard errors are clustered at the shareholder level and reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

The first exercise addresses concerns that affiliates in the control group may acquire patents after 2000 and thus respond to the introduction or major amendment of the patent box. The second analysis accounts for the fact that some patent boxes also allow income from trademarks to qualify for the preferential tax treatment (c.f. Table 1). Not accounting for trademark ownership could therefore bias estimates as some affiliates in the control group might respond to the patent box.

In Table C2, Column [1] restates the baseline results. Comparing these results with the estimates in Column [2] shows that excluding affiliates that acquired patents between 2000 and 2007 does not affect the results. In the specification in Column [3], any affiliate that owns trademarks prior to the year 2000 is excluded, while in Column [4] affiliates that acquired trademarks between the years 2000 and 2007 are additionally excluded from the sample. Our baseline estimates are robust to these modifications.

C.3 Propensity Score Matching

We further test the external validity of our results by using a different matching procedure. In Table C3, we restate the estimates of our baseline model in Column [1] and compare them to results from the same model estimated on two samples built on a propensity score (PS) matching in Columns [2] and [3], and to the results from the unmatched sample in Column [4].

Table C3: **Sample Selection: Propensity Score (PS) Matching and Full Sample**

Dep. Variable	Tab.3 Col.3	PS Matching		Full
Pre-Tax Profits	CEM Matching	PS (5%)	PS (1%)	Sample
	[1]	[2]	[3]	[4]
After * Treated * DOM Affiliate	0.0346**	0.0378**	0.0380**	0.0346***
	(0.0166)	(0.0191)	(0.0186)	(0.0130)
After * Treated * MNE Affiliate	0.0854***	0.1033***	0.1023***	0.0755***
	(0.0330)	(0.0382)	(0.0378)	(0.0261)
Fixed Assets	0.0219***	0.0330***	0.0335***	0.0304***
	(0.0073)	(0.0098)	(0.0097)	(0.0043)
Cost of Employees	0.2698***	0.3264***	0.3271***	0.2667***
	(0.0164)	(0.0243)	(0.0238)	(0.0092)
Financial Leverage	-0.1745***	-0.1823***	-0.1881***	-0.1978***
	(0.0157)	(0.0212)	(0.0207)	(0.0091)
MNE Affiliate in Low-Tax Country	0.0535**	0.0148	0.0141	0.0907***
	(0.0268)	(0.0304)	(0.0302)	(0.0166)
Treatment Year Dummies	YES	YES	YES	YES
Year x Industry Dummies	YES	YES	YES	YES
Observations	131,592	84,166	86,795	409,776
Affiliates	28,532	17,816	18,328	90,662
Treated MNE Affiliates	1,642	1,003	1,009	2,033
Treated DOM Affiliates	12,624	7,905	8,155	43,298

*Note: All models are estimated using a linear panel model with affiliate level fixed effects. The samples vary across columns: [1] uses the CEM matched sample of Table 3 Column [3]; [2] and [3] use propensity score (PS) matching where the 5 and 1 percent of the treatment observations at which the propensity score density of the control observations is the lowest are discarded; [4] uses the full unmatched sample. Standard errors are clustered at the shareholder level and reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

For the PS matched sample, we choose a similar set up to the one applied with CEM. We estimate the propensity score of multinational and domestic affiliates separately and then include affiliate-country and industry-fixed effects. After estimating the propensity score, we proceed with a *within*-type (multinational and domestic) one-to-one matching of affiliates. To ensure common support, in Column [2] and [3], we discard the 5 and 1 percent of the treatment observations where the propensity score density of the control observations is the lowest. Compared to the CEM-matched sample, the PS-matched samples are very different in composition. The common support restriction leaves us with a smaller total number of affiliates and a lower representation of domestic conglomerates. Yet, our results are consistent and confirm the previous findings. Affiliates connected to MNEs report a larger pre-tax profit response relative to affiliates of domestic conglomerates. Treated affiliates of MNEs located in countries with a patent box report 10 percent higher pre-tax profits compared to their non-treated counterparts. Treated affiliates of domestic groups located in a patent-box country report instead 3.8 percent higher pre-tax profits. The results are largely comparable in size with the CEM-matched sample in Column [1] and the full sample in Column [4].