(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 11.8 percent higher profits. The change in profit can be decomposed into two nearly equally-sized components: profit shifting (approximately 45%) and a productivity effect (about 55%). 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 patent box countries collect from IP-owning MNEs.

JEL-Classification: H25, H26, F23, C21, C23

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1 Introduction

In recent years, intellectual property (IP) rights have become ever more important as a factor of production, and, in response, many national governments have started to differentiate taxation of income derived from IP rights vis-à-vis regular corporate income. The instrument, a so-called IP or patent box, offers a substantially reduced tax rate, usually between 5 and 10 percent, on income from IP. Since the mid 2000s, patent boxes proliferated rapidly across the European Union and globally. Yet, despite their widespread adoption, the effects of patent boxes are controversially discussed. On the one hand, proponents argue that the preferential tax treatment provided by patent boxes fosters research and development, thereby enhancing productivity and economics growth. On the other hand, critics contend that patent boxes are actively used in fiscal competition, rather than as a genuine innovation policy instrument (Hall, 2019; Bloom et al., 2019). For instance, Bloom et al. (2019, pp. 170-171) note, "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."[1,2]

In this paper, we quantify the extent of profit shifting by multinational enterprises (MNEs) facilitated by the preferential tax treatment of IP income under patent box regimes in several European countries. Estimating profit-shifting behavior and the fiscal impact of patent boxes presents several methodological challenges. First, patent boxes simultaneously foster productivity and enable profit-shifting opportunities, making it challenging to isolate their specific impact on an affiliate's pre-tax profits. The productivity effect will be erroneously attributed to profit shifting when adopting the standard approach of regressing pre-tax profits on tax incentives. To isolate profit shifting by 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 affiliates of domestic conglomerates and MNE affiliates to isolate the effect of profit shifting.[3] 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 affiliates of domestic conglomerates and MNE affiliates. This empirical approach allows levels of profits as well as general trends in pre-tax profits to differ across the two types of affiliates, while netting out country- and industry-level effects.

Second, inward shifting into patent boxes might be coupled with simultaneous outward

[1] The view that IP is a key channel for profit shifting, and that patent boxes facilitate such behavior, features prominently in political discussions on international tax challenges in the digital economy (OECD, 2015, 2019).

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

[3] See, e.g., Dharmapala and Hebous (2018), Bilicka (2019), Egger et al. (2020), and Torslov et al. (2023).

profit shifting. While the preferential tax treatment provides incentives for MNEs to shift profits into the patent box, the resulting allocation of profit might not align with the MNEs' overall tax-minimization strategy. As a result, MNEs may be inclined to shift profits out of the patent-box country again. These countervailing profit-shifting responses are inherent to patent box regimes. Unlike the standard single-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 therefore have an incentive to report higher income subject to the low rate and reduce reported non-IP income subject to the regular rate. The latter can be achieved, for example, through higher intra-group interest payments, which are deductible at the regular corporate tax rate. As a result, part of the tax-favored IP income may simply passed through the affiliate in the patent-box country, thereby generating a double tax saving for the MNE.[4] The outcome variable pre-tax profit combines both of these countervailing behavioral adjustments, and the standard approach of regressing pre-tax profit on tax incentives does not allow to disentangle them.[5] To estimate behavioral adjustments through inward and outward profit shifting, we instead use the alternative outcome variable, earnings before interest and taxes (EBIT). Since EBIT includes interest payments, differences between changes in pre-tax profit and EBIT allow us to infer adjustments in internal interest payments.

Third, unlike general corporate tax provisions, patent boxes are effectively available only to firms with eligible income. We construct a novel measure to approximate an affiliate's ability to benefit from the preferential tax treatment offered by the patent box (our definition of treatment). The intuition behind our empirical strategy is to distinguish between affiliates with low versus high costs of accessing this tax benefit. Patent creation and applications are associated with substantial (fixed) costs. Thus, when historical patent ownership exists, either directly at the affiliate level or indirectly through the affiliate's majority shareholder, the costs of benefiting from the patent box are low. Conversely, our control group consists of affiliates that cannot benefit from patent boxes due to the absence of historical patent ownership at the affiliate and majority shareholder levels. Incorporating indirect patent ownership in the definition of treatment builds on insights from existing literature, showing that the location of patents within an MNE network is tax-sensitive. In particular, patent box regimes have

[4]The strategy is consistent with anecdotal evidence on how MNEs respond to patent box regimes. For example, the Dutch IKEA affiliate, Inter-IKEA, internally acquired IPs to benefit from the preferential tax treatment under the Dutch patent box. The transaction was financed through an intra-group loan with excessively high interest provided by the Liechtenstein-based IKEA holding (see Auerbach, 2016). As a result, part of IKEA's world-wide pre-tax profit was shifted into the Dutch patent box in the form of royalty payments, thereby benefiting from preferential taxation. At the same time, the profit of the Dutch affiliate was used to service the intra-group loan, with the corresponding interest payments deductible at the regular corporate tax rate in the Netherlands.

[5]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; Desai et al. (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.

been shown to incentivize the transfer of patents to countries offering such regimes. To the best of our knowledge, this is the first paper to explicitly account for this indirect form of IP ownership. To ensure comparability between affiliates in the treatment and control groups, we employ coarsened exact matching (CEM), and match on a range of historical affiliate-level characteristics.

Our main findings are as follows. First, we show that patent box countries experience a substantial increase in the income reported by MNE affiliates. Our estimate of profit shifting into the patent box amounts to roughly 7 percent of pre-tax profits. This effect is broadly consistent with the tax sensitivity of the royalty payment channel, which is (implicitly) captured by existing profit-shifting estimates. Second, while MNEs shift profits into the patent-box country, they simultaneously shift income subject to the higher, regular corporate tax rate out of that country.[6] Once both inward and outward shifting are accounted for, MNE affiliates in patent-box countries report, on average, 3 percent higher pre-tax profits. Third, although the net effect on pre-tax profits is positive, the shifting behavior of MNEs may reduce corporate tax revenues in patent-box countries. Intuitively, the inflowing IP income is taxed at preferential rates, which are often as low as 50 percent, sometimes only 20 percent, of the statutory corporate tax rate, while the out-shifted income reduces tax revenues by the full statutory rate. Illustrative calculations suggest that the critical tax differential at which the revenue effect turns negative is around 28 percent of the statutory corporate tax rate. Given the design of European patent boxes, it is therefore plausible that the behavioral responses of MNEs reduce, rather than increase, corporate tax revenues. The finding is presumably unintended by policymakers, who introduced patent boxes to attract reported income and widely expected transfer-pricing adjustment to increase tax revenues.

Related Literature Our analysis builds on several strands of the existing literature. First, prior research has shown that the location of patents within MNEs is tax-sensitive, with low-tax affiliates holding a disproportionately large share of patents (Karkinsky and Riedel, 2012; Griffith et al., 2014; Bosenberg and Egger, 2017; Alstadsaeter et al., 2018, Ciaramella, 2023, among others). These findings support the view that patents become more valuable in low-tax countries, enabling MNEs to reduce their tax burden through profit shifting. However, while this literature establishes the link between patent location and tax incentives, it does not explicitly quantify the role of patents in profit shifting or assess their implications for tax revenue, both of which are central to our analysis. Second, our findings on the productivity effects of patent boxes align with empirical evidence showing that patent boxes stimulate research and development,

[6]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.

either directly in affiliates located in patent box countries (Ohrn, 2016; Bornemann et al., 2023), or indirectly in affiliates outside patent-box country that are part of the same MNE (Schwab and Todtenhaupt, 2021). In a similar vein, Davies et al. (2020) find that the success rate of patent applications rises in countries that implement patent boxes. Third, regarding the effect of patent boxes on profit shifting, Ohrn (2016) shows that royalty payments between the U.S. and foreign countries with a patent box respond to the introduction of such regimes. Chen et al. (2023) exploit cross-country variation in the adoption of patent boxes and estimate their effect on the earnings before interest and taxes (EBIT) of MNE affiliates in countries with such regimes. Our analysis differs by exploiting within-country and within-industry variation in affiliates' exposure to patent boxes. Moreover, we decompose the observed changes in affiliate income into inward and outward profit-shifting responses.

The paper proceeds as follows. Section 2 provides an overview of patent box legislation in Europe. Section 3 introduces the theoretical model and derives the testable predictions. Section 4 describes the data, Section 5 details the matching technique, and Section 6 outlines the empirical strategy. Section 7 presents the estimation results, followed by a discussion in Section 8. Section 9 concludes.

2 Patent Box Regimes

The first patent box, even though not referred to it as such at the time, was introduced in Ireland in the 1970s, granting full tax relief on royalties from patents.[7] France adopted a similar regime in 2000, followed by Hungary in 2003. Thereafter, an increasing number of countries introduced patent box regimes, including the Netherlands, Belgium, Luxembourg, Spain, Malta, Switzerland, Cyprus, the United Kingdom, Portugal, and Italy (EY, 2015; Tax Foundation, 2019). By 2015, almost half of all EU member states had enacted special tax provisions that reduced the tax burden on income derived from intellectual property.

The design of most patent boxes enabled MNEs to reallocate patents, and thereby royalty payments, from the jurisdictions where innovation actually occurred to patent box countries offering the preferential tax treatment. As a result, patent boxes increasingly came to be perceived as a widely used instrument for profit shifting by MNEs (Evers, 2015). This absence of a clear link between the location of innovation and the tax benefit for IP-related income led the OECD in its 2015 initiative against Base Erosion and Profit Shifting (BEPS) to classify patent boxes as harmful tax practices. The initiative specified that patent box regimes introduced after 2015 must establish such a link, referred to as the *Modified Nexus Approach*. For existing patent

[7] The scheme was withdrawn in 2010 under the National Recovery Plan, but, at the time of its withdrawal the government announced new regime, the *Knowledge Development Box*, scheduled to take effect in 2016.

box regimes, grandfathering rules were agreed upon, requiring compliance with the Modified Nexus Approach from July 2021 onward (OECD, 2015).

Given the significant policy shift introduced by the Modified Nexus Approach, we restrict our analysis of profit shifting through European patent boxes to the period 2007 to 2015, with a robustness check extending to 2018. Table 1 summarizes details of the European patent box regimes included in our analysis, reporting the year of introduction or major amendment of the patent box, the average of the statutory corporate tax rate and the effective tax rate on IP income over the sample period, as well as specific characteristics, such as the eligibility of existing and acquired patents. In addition, Table 1 provides information on the number of affiliates and the distribution of treated affiliates, distinguishing between those belonging to domestic conglomerates and those belonging to MNEs. We discuss this latter information in greater detail in Section 5.

[Include Table 1 here]

Overall, our analysis covers eight of the thirteen European countries that had introduced a patent box by 2015. For six of these countries, we examine the introduction of the patent box itself. For two countries (France and Hungary), which had adopted patent boxes prior to our sample period, we instead focus on major amendments enacted in 2010 and 2012, respectively.[8,9] To test whether the introduction of a patent box versus its amendment generates different responses among treated affiliates, we conduct a robustness check (see Section 7.5). The four smaller countries, Malta, Luxembourg, Switzerland (Canton of Nidwalden), and Cyprus, that introduced a patent box during our sample period, are not included in our analysis due to insufficient coverage in ORBIS.[10] Ireland is also excluded, as it abolished its patent box in 2010 and reintroduced it only after our sample period.

All patent box regimes impose a substantially lower tax burden on IP income relative to income derived from a firm's standard business activities. In France and the United Kingdom, this is achieved through separate rates of 15 and 10 percent, compared with general corporate tax rates of 35 and 25 percent, respectively. Other countries instead adopt adjustments to the tax base, exempting between 50 percent and 80 percent of IP-related income when calculating taxable income. As a result, effective tax rates on IP income vary considerably across countries,

[8] In 2010, France abolished the corporate tax surcharge, reducing the effective tax burden on IP income to 15 percent, compared with 35 percent on regular income (PwC, 2013; Sakar, 2015). In 2012, Hungary increased the threshold of IP income eligible for preferential treatment from USD 250,000 to 2.5 million (EY, 2015). Both reforms substantially increased the generosity of IP tax treatment.

[9] Extending the analysis further back is not feasible, as ORBIS coverage prior to 2007 is limited, leading to a significant loss of observations. Moreover, moving closer to the year 2000 would also undermine our identification strategy, which relies on using 2000 to split firms into treatment and control groups.

[10] For Malta and Cyprus, there are no treated domestic or MNE affiliates, while for Switzerland and Luxembourg there are only six treated affiliates each.

ranging from slightly above 5 percent in Belgium, the Netherlands, and Hungary, to around 10 percent in Spain, the United Kingdom, and Portugal, and up to 15 percent in France and Italy (EY, 2015; Tax Foundation, 2019).

Patent box regimes also differ in the types of income that qualify for preferential tax treatment. Narrowly defined regimes grant such treatment only to income derived from newly developed patents (i.e., patents registered after the introduction of the patent box), as in Belgium and the Netherlands. In the other countries except Spain, acquired IP is likewise eligible for preferential treatment. In the Netherlands and the United Kingdom, however, acquired IP must be further developed or actively managed domestically in order to qualify (EY, 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:[11]

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

[11] 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.

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 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 introduces a patent box and affiliate A's patent income qualifies for the patent box. Then, productivity-enhancing investment and profit shifting into the patent box increase. In response, pre-tax profit and EBIT 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.[12] 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.[13] 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.

[12] 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.

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

The affiliate in country A pays interest z on internal debt to the affiliate in country C, where the 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.

$$E_A = y_A(i) + \overline{y}_A + q - 1. \tag{5}$$

The cost term $\gamma(\cdot)$ in equation (4) satisfies:

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

The concealment cost rises with the amount of interest payments, z, at an increasing rate. Moreover, the marginal concealment cost $\partial\gamma(\cdot)/\partial z$ decreases as EBIT, E_A, rises. Intuitively, an increase in E_A lowers the marginal concealment costs because the risk of tax audits and litigation may decline. Tax authorities are more likely to accept higher interest deductions on internal debt when the affiliate's economic activity, as measured by e.g. EBIT, increases.[14]

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:

$$t_A - t_C = \frac{\partial \gamma(z, E_A)}{\partial z}. \tag{6}$$

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 (6). A formal derivation of the comparative static result is relegated to Appendix A.[15] To summarize:

Proposition 2: *Assume country A has introduced a patent box and that marginal concealment cost negatively depends on EBIT. Then, the resulting increase in affiliate A's EBIT*

[14] Alternatively, anti-tax avoidance provisions such as thin capitalization rules are designed to curb profit shifting via internal interest payments and typically allow higher interest deductions when an affiliate's EBIT rises (Gresik et al., 2017; Mardan, 2017). This is a mechanical rule and conceptually different to the modeling adopted here.

[15] 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.

(as established in Proposition 1) increases internal interest payments by affiliate A, and consequently, decreases affiliate A's pre-tax profit.

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.[16] The behavioral responses have counteracting effects on pre-tax profit and corporate tax revenue collected in country A, which are 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 on the periods surrounding the staggered introduction or major amendments of patent box regimes across several European countries. Our baseline estimation relies on the following difference-in-differences model:

$$\begin{aligned} \pi_{ist} &= \beta_0 + \beta_1 k_{it} + \beta_2 \ell_{it} + \beta_3 f_{it} + \beta_4 TAX_{it} \times MNE_i + \gamma_1 Treated_{it} \times DOM_i \\ &\quad + \gamma_2 Treated_{it} \times MNE_i + PostPB_{it} + \eta_i + \alpha_t + \lambda_{st} + \epsilon_{ist}. \end{aligned} \tag{7}$$

The variable π_{ist} denotes the logarithm of unconsolidated pre-tax profits of affiliate i, operating in sector s in year t. The share 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}). In addition, profit shifting incentives that are unrelated to patent box regimes are captured by TAX_{it}, formally defined in the next section.

The treatment indicator, $Teated_{it}$, takes the value of one if affiliate i owned IPs, either directly at the affiliate level or indirectly via the level of the majority shareholder, prior to or by the year 2000. Otherwise, the treatment indicator equals zero. We further allow the treatment to differ between affiliates of domestic (DOM_i) and multinational (MNE_i) conglomerates.

The coefficients γ_1 and γ_2 are central to testing the theoretical predictions outlined in Propositions 1 and 2. Specifically, γ_1 captures the treatment effect for affiliates of domestic conglomerates and thus identifies the impact of patent boxes on pre-tax profits unrelated to tax-motivated

[16] 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).

profit shifting. By definition, domestic conglomerates cannot exploit cross-country tax rate differentials but benefit from the productivity effects of patent boxes.[17]

In contrast, γ_2 captures the treatment effect for affiliates of MNEs, encompassing both the productivity effect and profit shifting. The difference between γ_2 and γ_1 isolates the component of the treatment effect attributable to profit shifting.[18] In doing so, we follow a growing strand of literature that compares domestic firms with MNE affiliates to identify the effect of profit shifting (Dharmapala and Hebous, 2018; Bilicka, 2019; Egger et al., 2020; Torslov et al., 2023, among others). A concern might be that the two groups differ not only in their access to international tax planning strategies but also in other respects, such as profit levels, for instance. To address this, our difference-in-differences strategy allows for differences in both the levels and the general trends of pre-tax profits to vary across affiliates of domestic and multinational conglomerates.[19] It is important to note that the control variables in the first line of equation (7), such as capital and labor inputs, potentially respond to the introduction of patent box regimes. Our empirical strategy is designed to account for these potential responses, thereby ensuring that the coefficients γ_1 and γ_2 capture only the productivity and profit shifting effects associated with patent boxes.

Finally, the indicator variable $PostPB_{it}$ equals one in year t of the introduction or major amendment of a patent box in country i and in all subsequent years. The model also includes affiliate fixed effects, η_i, year fixed effects, α_t, and industry-year fixed effects, λ_{st}. The error term is denoted by ϵ_{ist}. Standard errors are computed using robust estimation.

Our empirical approach is motivated by the idea that affiliates belonging to conglomerates with historical IP ownership can immediately access the preferential tax treatment offered by a patent box. By contrast, affiliates of conglomerates without such a history can benefit from the preferential tax regime only after undertaking R&D investment that generate IP or the acquisition of IP. Both options may be relatively costly compared with the tax savings offered by the patent box.

Accordingly, we define as treated those affiliates that are located in a country where a

[17] Similar to MNEs, domestic firms benefit from the reduced tax rate on qualifying IP income. However, this effect does not appear in pre-tax profits because domestic conglomerates have no incentive to relocate patents or related royalty payments. Even if royalties are inflated in favor of the affiliate that historically holds the IP, we observe a random mix of inflows and outflows of domestic profits at the affiliate level, which is negligible on average. Moreover, for pre-existing IP within the same country, tax auditors can draw on evidence of historically chosen, non-strategic transfer prices, making tax-induced transfer pricing more readily detectable.

[18] Decomposing pre-tax profit changes of MNE affiliates into productivity and profit-shifting components is challenging because pre-tax profit reflects both behaviors, and profit shifting therefore biases productivity estimates (Guvenen et al., 2017). Ideally, one would observe MNE affiliates subject to patent box incentives, some unable to engage in profit shifting and others not experiencing productivity gains (all for exogenous reasons). Such affiliates, however, are not observable. MNE affiliates in non-patent-box countries are also unsuitable as a control group, since neither profit shifting nor productivity responses arise in that group.

[19] In an extension, we modify equation (7) to also allow the input coefficients β_i to differ between domestic and multinational conglomerates. The findings remain unchanged.

patent box was introduced or underwent a major amendment and that historically owned IP, either directly at the affiliate level or indirectly through the majority shareholder prior to or by the year 2000. Accounting for indirect IP ownership at the level of the majority shareholder is consistent with empirical evidence showing that IP location within MNEs is highly 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 (Bösenberg and Egger, 2017; Alstadsaeter et al., 2018; Ciaramella, 2023). Neglecting this indirect link of IP ownership of affiliates eligible for the preferential taxation of their IP income would therefore bias our estimates of profit shifting via patent boxes.

As controls, we select affiliates that have no history of IP ownership prior to or by the year 2000, either directly or indirectly through the majority shareholder. As noted above, such firms may eventually engage in innovation, purchase externally developed patents, or acquire firms holding IP. However, these options are time-consuming and relatively costly compared with the tax benefits provided by a patent box.[20]

Relying on historical IP ownership further allows us to interpret our estimates as intensive-margin responses of firms already engaged in IP creation, while extensive-margin responses are deliberately set aside due to endogeneity concerns.

5 Data

We use the ORBIS and ORBIS IP databases (Bureau van Dijk / Moody's Analytics) to retrieve historical information on firms' corporate ownership structures for the years 2007 to 2015 (and to 2018 for the extended sample used in the robustness check), along with information on firms' financial accounts and patent registrations for 1996 to 2015 (2018). We select all active affiliates located in European countries that introduced or substantially amended a patent box between 2007 and 2015. Accordingly, our sample includes affiliates of both domestic and multinational conglomerates located in the Netherlands, Belgium, Spain, France, the United Kingdom, Hungary, Portugal, and Italy.[21] We exclude independent firms that are not linked to any other active entity. An affiliate's parent is defined as the firm within the conglomerate that controls the largest ownership share.[22] Furthermore, we require affiliates to maintain the same ownership status (i.e., domestic or multinational) throughout the observation period. Following

[20] Innovation is a time-consuming process, and patents have long been argued to constitute a barrier to entry due to the high setup costs of generating patents and adapting 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 may create patents only with a substantial time lag.

[21] Affiliates located in the same country as their shareholders are classified as domestic.

[22] In cases where ownership is equally distributed among multiple shareholders, we designate the global ultimate owner (GUO) as the parent firm. We also discard ownership links to individuals, mutual funds, insurance companies, and corporations with unidentified locations.

the literature, we restrict the sample to affiliates that report positive pre-tax profits for at least two consecutive years during the sample period. This procedure yields 210,393 affiliates, of which approximately 15 percent belong to MNEs. In a next step, we collect unconsolidated financial accounts for all affiliates in our sample.

To identify affiliates with historical innovation activity, we use data from ORBIS IP on the number of patents owned by each firm and the year of patent registration. To address issues related to patent quality, double counting, and the skewness of the patent distribution, we construct an indicator variable equal to one if a firm owns at least one patent registered in or before the year 2000, and zero otherwise.[23] We further refine our treatment indicator by differentiating it according to the firm level (affiliate versus majority shareholder) that controls the patent. This allows us to distinguish between effects arising from direct patent ownership at the affiliate level and indirect ownership at the parent (majority shareholder) level.

In our sample, approximately 9 percent of affiliates belong to conglomerates with historical IP ownership and thus qualify as treated. Among these treated affiliates, about 46 percent are part of multinational conglomerates and 54 percent of domestic conglomerates. Their distribution across the countries included in our analysis is reported in Table 1. Moreover, among MNEs we observe that roughly 40 percent of IP is held at the affiliate level and 60 percent indirectly at the level of the majority shareholder.

Finally, we construct an affiliate-time-specific tax measure, denoted as TAX_{it} in equation (7). Following the literature (e.g., Dharmapala, 2014), we calculate the difference between the statutory corporate tax rate in the country of affiliate i and the lowest statutory tax rate faced by any of its majority shareholders, the global ultimate owner, or any other majority-owned affiliate within the entire conglomerate (cg), i.e. $\tau_{i,t} - min(\tau_{cg,t})$. This variable is included in all estimations and captures incentives for profit shifting independent of the patent box. Table B1 reports the statutory tax rates and these tax differences for treated and control affiliates, as well as for the full unmatched sample, separately for domestic and multinational affiliates, averaged over the sample period 2007 to 2015. The table also presents the share of affiliates linked to tax havens.

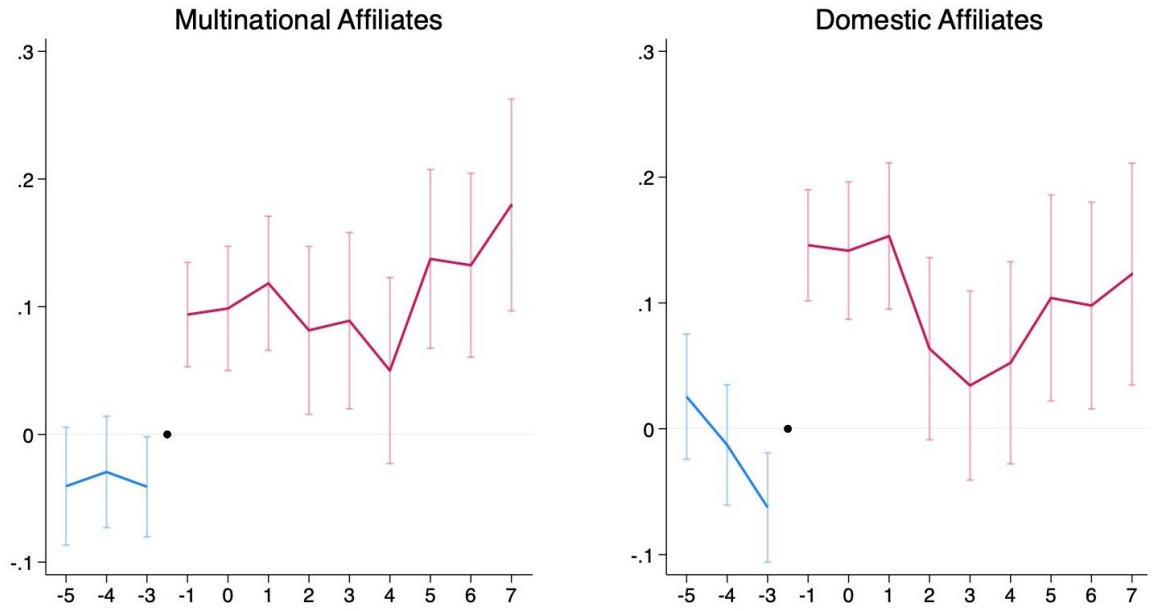
6 Matching and Event Study Plot

The assignment of affiliates to the treatment group is systematically influenced by firms' structural characteristics and is therefore endogenous to several factors. Failing to account for the non-random nature of treatment assignment would lead to biased estimates. To address this is-

[23] We choose 2000 as the reference year because it predates the widespread awareness and exploitation of patent boxes as a profit-shifting instrument, which became common only in the late 2000s (Evers, 2015).

sue, we employ *coarsened exact matching* (CEM) to achieve balance between the treatment and control groups. Specifically, to reduce imbalance in pre-treatment variables, we match affiliates based on their ownership structure, country of establishment, industrial sector, and historical financial performance. For the latter, we construct a composite index to accommodate the extensive data requirements of the matching procedure.[24] Our one-to-many (k2m) matching substantially improves balance across all pre-treatment covariates. After matching, no statistically significant differences remain in the means of the treated and matched control groups. Details on the matching procedure, the improvement of the overall $\mathcal{L}$ statistic, and the composition of the full and matched samples are reported in Appendix B.2 and the accompanying tables.

Figure 1: Event Study Plot on Matched Sample conditional on controls



To gain a first impression of the informational content in the matched data, we conduct an event study. Figure 1 presents event-study plots of the evolution of yearly pre-tax profits for matched affiliates of MNEs and domestic firm conglomerates over the analyzed sample period, normalized to the year prior to the introduction or major amendment of the patent box.[25]

[24]The composite index is based on affiliate-specific historical financial data, averaged over 1996 to 2006. It incorporates affiliates' age in the year 2000, turnover and number of employees (as a proxy for size), profit margin (ratio of pre-tax profits to sales), the ratio of intangible to total assets, and fixed assets. This approach ensures that our matching captures most characteristics that are also recognized as important in the innovation literature, such as industry structure, firm size, and productivity, (see Pakes and Griliches, 1980; Acs and Audretsch, 1988; Atkeson and Burstein, 2010; Hall and Lerner, 2010; Mohnen and Hall, 2013).

[25]In analogy to equation (7), the regression equation for the event study is

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

For MNE affiliates, pre-tax profits prior to treatment do not differ significantly from those of the control group. After treatment, however, pre-tax profits of treated MNE affiliates become substantially higher and this difference persists throughout the observation period.

A qualitatively similar, pattern emerges for affiliates of domestic conglomerates. Before treatment, there is little difference in pre-tax profits between treated and control affiliates. After treatment, the pre-tax profits of treated domestic affiliates increase relative to those of the control group, although the statistical significance is weaker. The larger confidence intervals might well be related to the unbalanced nature of our panel data.

7 Results

7.1 Baseline Estimates

We begin our analysis by following the existing literature and quantifying tax incentives for profit shifting that are unrelated to patent boxes. In equation (7), we set the $Treated_{it}$ dummies equal to zero and estimate the relationship between pre-tax profits and fixed assets, labor costs, financial leverage, and the MNE-affiliate-specific tax measure, defined as the tax rate difference between affiliate i and either the lowest rate within the conglomerate or the lowest rate faced by any majority shareholder. The estimation is based on a linear panel model with affiliate fixed effects as well as treatment-year and industry-year dummies. The results, reported in Appendix C.1, indicate that affiliates facing the lowest tax rate within the conglomerate report 6 to 7 percent higher pre-tax profits (depending on the tax measure used). These estimates are broadly consistent with prior findings in the literature, which report consensus estimates of roughly 8 percent using affiliate-level panel data (Dharmapala, 2014).

To account for the tax benefit introduced by patent boxes, which is available only to MNEs with eligible IP income, we expand the analysis by considering the $Treated_{it}$ dummies as specified in equation (7). Specifically, we estimate the heterogeneous treatment effect of patent boxes on pre-tax profits and EBIT for affiliates with historical IP that belong to domestic or multinational conglomerates. Table 3 reports the results. Column [1] presents the specification with a homogeneous treatment effect. Column [2] allows for heterogeneous effects between affiliates belonging to domestic and multinational conglomerates. Column [3] extends this specification by including the control variables we used in the estimation of tax incentives for profit shifting unrelated to patent boxes (coefficients of these controls are omitted in all subsequent tables for brevity). Column [4] re-estimates specification [3] using the full unmatched sample. Finally, Columns [5] and [6] replicate specifications [3] and [4], respectively, using EBIT as the dependent

where $T_0 = -5$ and $T_1 = 7$ are the lowest and highest number of lags and leads and the pre-event reference period is -2, to capture any announcement effects.

variable.

[Include Table 3 here]

In line with our hypothesis, we find that affiliates located in a patent-box country with a historical record of patent ownership report 13 percent higher pre-tax profits compared to otherwise similar affiliates that did not own any patents by the year 2000. This effect is statistically significant at the 1-percent level. Affiliates of domestic and multinational conglomerates, however, may respond differently to the introduction or major amendment of a patent box. While patent boxes may enhance productivity through innovation or more intensive use of IP in both types of affiliates, only MNE affiliates can exploit cross-country tax differentials to reduce their tax burden via profit shifting. Consequently, affiliates of MNEs may exhibit a larger increase in pre-tax profits, reflecting both profit shifting and productivity effects. To identify this heterogeneous treatment effect, we extend the specification in Column [1] and allow the effect of the patent box to vary between affiliates of domestic and multinational conglomerates.

The results in Column [2] support our hypothesis. Pre-tax profits of affiliates located in a patent-box country and belonging to domestic conglomerates with historical patent ownership are 10.8 percent higher than those of affiliates in the control group, i.e., domestic conglomerates without historical IP ownership. For affiliates of multinational conglomerates, the post-treatment difference between treated and control affiliates amounts to 14.8 percent percent, that is 4.0 percentage points higher than for domestic conglomerates. As shown in Column [3], the inclusion of the control variables in the profit-shifting equation unsurprisingly reduces the absolute magnitude of both treatment effects as well as the difference between them. However, as we discuss later, this difference may not fully capture the extent of profit shifting via patent boxes, because their split-rate design also incentivizes MNEs to shift profits out of the affiliates located in patent-box countries. The results in Column [3] are robust to (*i*) relaxing the assumption of common input-factor coefficients across domestic and multinational conglomerates,and (*ii*) estimating the specification on the full unmatched sample (see Column [4]).

For the results in Column [5], the dependent variable pre-tax profits is replaced with logged EBIT. In this specification, the treatment effects for affiliates of both domestic and multinational conglomerates are smaller than in the corresponding specifications using pre-tax profits as the dependent variable (cf. Columns [3] and [4]). This outcome is not surprising given the different base units underlying pre-tax profits and EBIT.[26] On average, for treated affiliates of domestic and multinational conglomerates, EBIT is roughly 1.61 times larger than pre-tax profits. After adjusting for this difference in base measures (multiplying by 1.61), we find that the estimates

[26]EBIT (Earnings Before Interest and Taxes) is defined as revenue minus operating expenses, excluding interest and taxes. Thus, unlike pre-tax profits, EBIT includes (intra-MNE) interest payments.

for pre-tax profits and EBIT are very similar for domestic affiliates, but in contrast, for affiliates belonging to multinational conglomerates, the increase in EBIT is considerably larger, namely by 4.6 percentage points (0.118 versus $0.164 = 0.102 \times 1.61$).

In fact, the difference in the coefficients provides a more nuanced perspective on the profit-shifting behavior of MNEs than what is typically suggested in the existing literature.[27] The higher magnitude of the treatment effect on EBIT relative to pre-tax profit for affiliates of MNEs points to profit shifting out of the patent-box country, consistent with the theoretical prediction in Proposition 2. While patent boxes incentivize MNEs to shift income into the patent-box country, the resulting profit allocation may not align with the MNE's overall tax-minimizing strategy. Consequently, MNEs can redirect shifted profits out of the affiliate located in the patent-box country, for example through internal loans. Interest payments on such internal loans, which are deducted in the calculation of pre-tax profits but not in EBIT, lower the magnitude of the pre-tax profit estimate without affecting the EBIT estimate.

The complementarity between inward profit shifting into the patent box and outward shifting via internal loans is consistent with the corporate tax levels observed in patent-box countries (cf. Table 1). On average, these countries levy relatively high tax rates compared to the usual rates in *typical* low-tax jurisdictions that often serve as financial centers for MNEs. This creates an additional incentive for internal debt shifting (Mintz and Smart, 2004). Thus, beyond the tax savings provided by the patent box, MNEs can capture an additional tax subsidy by shifting profits via internal loans out of affiliates in patent-box countries into affiliates in low-tax jurisdictions.[28] A detailed decomposition of the pre-tax profit response of MNE affiliates, along with an analysis of the tax revenue implications of their bi-directional shifting behavior, is presented in Section 8.

Beyond profit shifting through patent boxes and internal debt, MNEs may also exploit channels such as transfer price manipulation or royalty payments. While cross-sectional data on affiliates' pre-tax profits and EBIT enable us to control for internal debt shifting, the lack of affiliate-level data on transfer pricing and royalty payments limits our ability to identify these alternative channels.

[27] In the existing literature, profit shifting via transfer pricing and internal debt shifting is usually 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 standard case in which a single statutory tax rate applies to all corporate income. This is not the case for patent boxes. Countries with patent boxes are low-tax jurisdictions for IP income, but may be high-tax jurisdictions for other types of income.

[28] As discussed further in footnote 4, this tax planning strategy is consistent with anecdotal evidence on how, for example, IKEA exploits the tax benefits offered by the Dutch patent box (Auerbach, 2016).

7.2 Heterogeneous Effects: Tax Environment and Tax Havens

The findings in our baseline analysis might be sensitive to the tax environment of the affiliate within the conglomerate. For instance, an MNE that employs a specific profit-shifting channel, such as shifting income into low-tax countries or tax havens, might reconsider its tax-saving strategy once a patent box becomes available in one of the countries where the conglomerate operates. 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 within the MNE conglomerate and (*ii*) whether the MNE has a link to a tax haven.

High-Tax vs. Low-Tax Environment In Table 4, we allow the effect on treated multinational affiliates to vary depending on whether the affiliate is located in the country with the minimum tax rate within the conglomerate. In Columns [1] and [2], we use pre-tax profit and EBIT, respectively, as the dependent variable.

[Include Table 4 here]

The results indicate that the point estimates for the change in pre-tax profit of treated MNE affiliates located in low-tax countries are larger than those for treated affiliates in high-tax countries. The treatment effect is approximately 1.4 percent higher when the affiliate faces the lowest statutory tax rate within the conglomerate. This slightly stronger effect is consistent with the view that shifting profits to the affiliate facing the lowest tax rate within the conglomerate aligns with the MNE's overall tax-minimizing strategy. Additionally, the higher estimate may also reflect reduced outward shifting of profits from affiliates located in low-tax environments.

The latter explanation is also consistent with the estimates for EBIT in Column [2], which, however, becomes apparent only after adjusting the unit of measurement to make the EBIT estimates directly comparable to those for pre-tax profits. Specifically, the ratio of EBIT to pre-tax profit is, on average, considerably larger for affiliates in high-tax countries than for those in low-tax countries. This inflates the EBIT estimates for affiliates in high-tax countries relative to those in low-tax countries. Combined with the smaller pre-tax profit estimates for affiliates in high-tax countries, this pattern suggests greater outward shifting of profits from affiliates located in high-tax jurisdictions than from those in low-tax jurisdictions, as one would expect. However, since the difference in pre-tax profit estimates is relatively small, the findings do not provide strong support for the view that patent boxes are used very differently as a tax-saving device by high-tax versus low-tax MNE affiliates.

The Role of Tax Havens When interacting the treatment effect with the presence of a tax haven link within the MNE conglomerate, we find evidence of differential use of patent boxes. Specifically, Columns [3] and [4] in Table 4 allow the effect on treated affiliates to vary according to whether the affiliate is linked to a tax haven if it is either controlled by a majority shareholder located in a tax haven or if it controls a subsidiary located in a tax haven.[29] The introduction of a patent box increases pre-tax profits by about 12 percent for affiliates of MNEs without a tax haven link, whereas the effect on pre-tax profits is insignificant for affiliates of MNEs with such a link. This finding is consistent with the interpretation that affiliates without a tax haven connection use patent boxes as a tax-saving device, while affiliates with a tax haven link do not.[30] For instance, if majority shareholders already reside in tax havens, they may prefer not to share net tax savings by using the patent box instead of the tax haven. This, discourages reliance on the patent box as a tax-saving device (Schindler and Schjelderup, 2012).

As reported in Colum [4] of Table 4, the estimates for EBIT are positive and significant regardless of whether a link to a tax haven exists within the conglomerate. In particular, the larger estimate for EBIT when such a link is present may indicate a greater degree of outward profit shifting from the affiliate located in the country which introduced a patent box.

7.3 Heterogeneous Effects: (In)Direct IP Ownership and Innovators

In the next step, we further examine the heterogeneity of the baseline results by distinguishing between directly and indirectly held patents and considering the role of MNE innovators. In our sample, roughly 40 percent of patents are held directly at the level of the affiliate located in the patent box country, while for the majority, about 60 percent, treatment occurs because the affiliate in the patent box country is owned by a majority shareholder that holds eligible IP. In the latter case, MNEs might still access the tax benefits of the patent box by relocating the patent to the affiliate in the patent box country (Bösenberg and Egger, 2017; Alstadsaeter et al., 2018; Ciaramella, 2023).

[Include Table 5 here]

Columns [1] and [4] of Table 5 present the results where the treatment effect for MNE affiliates varies according to whether the treated affiliate directly owned patents in or prior to the year 2000, or indirectly via the majority shareholder, using pre-tax profit and EBIT, respectively, as the dependent variable. We find that MNE affiliates with only indirect historical patent

[29] We adopt the tax haven classification from Hines (2010).

[30] A non-significant or near-zero point estimate does not contradict the existence of productivity effects. Rather, it may capture the net effect on pre-tax profits and EBIT after the majority shareholder has shifted profits out of the affiliate, potentially to the tax haven where the shareholder resides.

ownership via the majority shareholder report roughly 11 percent higher profits, while the estimate rises to 12.8 percent when accounting for both directly and indirectly held IP. This suggests that indirect patent ownership is an important factor, which determines the ability of MNEs to benefit from patent boxes and helps explain the empirical findings in our analysis.[31]

For EBIT, we find nearly identical estimates when considering either indirectly held IP alone or both direct and indirect IP. This points to outward profit shifting as a more relevant channel in the case of indirect patent ownership, as evidenced by the larger difference between the base-measure-adjusted EBIT estimate and the one for pre-tax profits.

A possible explanation for the heterogeneous effects related to (in)direct patent ownership, and the weaker role of profit shifting under direct ownership, may lie in the observation that a particular subset of firms may be especially inclined to engage in profit shifting (see Davies et al., 2018, among others). Accordingly, MNEs that re-located patents to affiliates in relatively high-tax countries prior to the introduction of patent boxes may have done so for reasons other than profit shifting. As a consequence, they may exhibit a lower propensity to shift profits compared to those that held IP at the majority shareholder level and potentially relocated patents only after the introduction of the patent box.

The models estimated in Columns [2] and [3], as well as [5] and [6] of Table 5, highlight the role of MNEs that are innovators, that is, those developing additional patents after the year 2000 (our cutoff year for selecting affiliates into the treatment and control groups). For non-innovators, i.e., firms that did not create any further patents after being selected into the treatment group, the increase in pre-tax profit following the introduction of patent boxes amounts to 9.6 percent, which is lower than our baseline estimate of nearly 12 percent (see Column [2]). The role of new patents in enabling affiliates to benefit from the patent box and to engage in profit shifting becomes even more evident when focusing on innovators, particularly affiliates of MNEs that created new patents after the introduction of the patent box (see Columns [3] and [6]). For these firms, we find an increase in pre-tax profit of 12.2 percent, compared to only 7.7 percent for affiliates without new IP creation after the introduction of the patent box.

7.4 Heterogeneous Effects: Restrictions for Qualifying IP Income

Given the relevance of indirectly owned patents and newly created patents discussed above, a key question is the extent to which treatment effects persist when patent box regimes include restrictions on the eligibility of, for example, pre-existing or acquired patents. We exploit heterogeneity in the design of patent boxes and the differences in the restrictions they impose on IP income qualifying for preferential tax treatment. As shown in Table 1, patent box legislation

[31] This finding is consistent with empirical evidence on tax-induced patent relocation, as in Karkinsky and Riedel (2012), Griffith et al. (2014), Bösenberg and Egger (2017), Alstadsaeter et al. (2018), Ciaramella (2023).

differs specifically with respect to whether existing patents (prior to the introduction of the regime) and acquired patents are eligible for the preferential tax rate. This variation allows us to examine the effectiveness of such restrictions, which are presumably intended to protect the domestic corporate tax base and/or to incentivize the creation of new patents rather than the acquisition of existing ones.

In the specifications reported in Columns [1] and [3] of Table 6, the treatment effect for MNE affiliates varies depending on whether the patent box regime allows (*i*) pre-existing patents to qualify for the tax benefit and (*ii*) acquired patents to be eligible for preferential tax treatment.

[Include Table 6 here]

We find a much stronger effect on pre-tax profits, about 17 percent, for treated MNE affiliates in countries where patent boxes exclude pre-existing patents, underscoring the role of newly created patents in accessing the preferential tax treatment offered by the patent box. By contrast, in countries where existing IP also qualifies, the treatment effect amounts to 11.3 percent (Columns [1] and [2]).

Turning to acquired IP, we find no significant effect for treated MNE affiliates in countries where the income from acquired patents is not eligible, but a relatively strong treatment effect of 15 percent, where acquired patents benefit from the preferential tax treatment (Columns [3] and [4]). This result is consistent with the importance of indirectly owned patents, as documented in Table 5. When acquired patents are excluded from preferential tax treatment, indirectly held patents have little value for affiliates in patent box countries and offer limited (no) opportunities for profit shifting. Accordingly, restrictions on qualifying IP income can be effective in reducing the tax sensitivity of MNE affiliates' pre-tax profits.

7.5 Heterogeneous Effects: Robustness Checks

In a final set of estimates, presented in Table 7, we test alternative sample variations to assess the robustness of our results. First, we extend the sample period through 2018 (see Columns [1] and [4]). Second, in Columns [2] and [5], we examine whether the treatment effect for MNE affiliates differs before and after the amendment of the patent box regime and compare this estimate to our baseline results in Table 3. Finally, in the analysis presented in Columns [3] and [6], we include Ireland in the sample of countries; Ireland was required to withdraw its patent box in 2010 under the National Recovery Plan (CITE).

[Include Table 7 here]

By extending the sample period to 2018, we add years that coincided with major discussions surrounding the OECD's initiative against Base Erosion and Profit Shifting (BEPS). Therein,

the OECD classified patent boxes as harmful tax practices, which ultimately led to the implementation of the Modified Nexus Approach. Given the heightened scrutiny of profit shifting in general, and of patent boxes in particular, one might expect MNEs to have become more cautious in channeling profits through patent boxes. This is also reflected in our data. Columns [1] and [4] show that the estimates for affiliates of domestic and multinational conglomerates are now nearly identical, suggesting that profit shifting has diminished in the years following the OECD initiative. The EBIT estimates, after the unit measure adjustment, indicate that some outward shifting may still occur (column [4]), but at a much smaller scale than in the baseline results.

Regarding the distinction between the introduction of a patent box and the amendment of an existing regime, we find that the treatment effect for MNE affiliates increases from roughly 7.5 percent before the amendment to almost 11 percent afterward (Columns [2] and [5]). The post-amendment estimate is therefore very similar in size to our baseline estimate of nearly 12 percent, suggesting that including major amendments to patent boxes, which substantially increased the patent-box tax benefit, does not materially bias our results.

As a final analysis, we include Ireland in the set of countries considered. Ireland represents a special case, as it introduced a patent box-type regime much earlier than other countries and was subsequently forced to abolish it in 2010. The estimates show that including Ireland has no major effect on our results compared to the baseline specification. For treated MNE affiliates, pre-tax profits increase slightly to nearly 13 percent following the introduction of a patent box, while all other estimates remain unchanged from the baseline.

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, E, of an affiliate located in a country with a patent box is given by $\pi = y + \overline{y} + q - 1 - \mathrm{z}$ 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

$$\Delta\pi = \Delta E - \Delta z, \tag{8}$$

where

$$\Delta E = \Delta y + \Delta q. \tag{9}$$

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 (8) after harmonizing of the base 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 compared directly.

In the empirical analysis, we estimate the *relative changes* in pre-tax profits and EBIT, 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 base 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, $\Delta E = 0.102\, E$. 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 $E/\pi = 1.603$. Using the information, we obtain $\Delta E = 0.164\,\pi$. Coupled with the estimated pre-tax profit change in the baseline specification of $\Delta\pi = 0.118\,\pi$, the change in interest expenses is $\Delta z = 0.046\,\pi$. This suggests that the total change in earnings before subtracting interest payments is 16.4 percent of pre-tax profit, and internal debt shifting reduces the observed relative change in pre-tax profits to 11.8 percent.

Following equation (9), the change in EBIT consists of the productivity effect, Δy, and profit shifting into the patent box, Δq. The estimated change in the pre-tax profits of domestic affiliates provides a measure of the productivity effect these affiliates experience from patent boxes. To the extent that this estimate is also representative for MNE affiliates, we can infer the magnitude of profit shifting into the patent box. Starting from the baseline estimate of $\Delta E = 0.164\,\pi$ and a productivity effect of $\Delta y = 0.092\,\pi$, the implied level of profit shifting into the patent box is $\Delta q = 0.072\,\pi$. Thus, the total change in earnings of 16.4 percent can be decomposed into roughly equal components from the productivity effect ($9.2/16.4 \approx 0.56$) and profit shifting $7.2/16.4 \approx 0.44$). However, it is important to note that the 7.2 percent of pretax profits shifted into the patent box, do not remain entirely in the patent-box country. As computed above, 4.6 percent of pretax profits are shifted out via internal debt shifting (Δz). This leaves a net profit-shifting effect of $\Delta q - \Delta z = 2.6$ percent of pretax profits in the patent-box country.

We should emphasize that the magnitude of profit shifting into the patent box of 7.2 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 substantial, 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 roughly 15 percentage points. Thus, the implied pseudo semi-elasticity of the profit-shifting response into the patent box with respect to a one-percentage point decrease in the tax rate on IP income is 0.48 (= 0.072/0.15), which is slightly lower than the consensus estimate of 0.8 (Dharmapala, 2014; Heckemeyer and Overesch, 2017). It should be noted, however, that the consensus estimate combines different profit shifting channels (profit shifting via royalty payments, internal trade in inputs and internal debt finance), whereas our estimate is based solely on IP-related royalty payments, as patent boxes only reduce the tax burden on this specific income stream.

Tax Revenue Implications To assess the fiscal implications of patent box regimes, we examine the effect of MNEs responses on corporate tax revenues. We define tax revenues collected from MNEs as $T = \tau\pi$, where τ denotes the regular statutory corporate tax rate and pre-tax profits π constitute the tax base. Further, we denote the difference between the preferential patent box tax rate and the regular statutory corporate tax rate as $\Delta\tau = \tau_{pb} - \tau$ and π_{pb} (π_{-pb}) represents the profit stream that is (is not) eligible for the patent box. Using these definitions, the change in tax revenues following the introduction of the patent box is

$$\Delta T = \Delta\tau \cdot \pi_{pb} + \underbrace{\tau_{pb} \cdot \Delta\pi_{pb} + \tau \cdot \Delta\pi_{-pb}}_{=\Delta T_{beh}}. \tag{10}$$

The first term captures the mechanical effect of the patent box on tax revenues, while the remaining terms summarize the behavioral effect arising from adjustments in the tax bases that do qualify ($\Delta\pi_{pb}$) and that do not qualify ($\Delta\pi_{-pb}$) for the preferential tax treatment. The mechanical effect is negative, leaving it to the behavioral response of the MNEs to expand the tax base and (partially) compensate the revenue shortfall. From equation (10), the behavioral response can be rewritten as

$$\Delta T_{beh} = \tau\left(\gamma \cdot \Delta\pi_{pb} + \Delta\pi_{-pb}\right), \tag{11}$$

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

$$\Delta T_{beh} \gtreqless 0 \qquad \Leftrightarrow \qquad \gamma \gtreqless -\frac{\Delta\pi_{-pb}}{\Delta\pi_{pb}}. \tag{12}$$

The change in tax revenues, ΔT_{beh}, is positive if the tax benefit of the patent box relative to the statutory tax rate is not too large, that is, if γ is sufficiently high. Based on our baseline estimates, the increase in patent box income resulting from the productivity effect and profit shifting into the patent box amounts to $\Delta\pi_{pb} = 0.092\pi + 0.072\pi$. Simultaneously, the corporate tax base π_{-pb} decreases by 4.6 percent of pre-tax profits due to outward shifting via higher interest expenses, i.e. $\Delta\pi_{-pb} = -0.046\pi$. Thus, from equation (12) it follows that the value of γ at which the behavioral response of MNEs is revenue neutral is $\gamma^* = 0.28$. Based on Table 1, empirically observed values of γ range between 0.2 and 0.5. This suggests 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 observed outward shifting of profits through internal debt may outweigh the positive revenue effects of inward profit shifting and productivity gains. This finding stands in contrast to the widely held expectation that patent boxes attract reported income and that the behavioral adjustments increase tax revenues collected from MNEs.

9 Conclusion

Since the mid-2000s, patent box regimes have become increasingly popular as a policy tool to attract taxable income from intellectual property. In this paper, we quantify the effect of European patent box regimes on the profit-shifting behavior of MNEs. We find that affiliates selected into the treatment group on the basis of their historical patent ownership report an increase in pre-tax profits of 11.8 percent. However, this estimated change in pre-tax profits does not fully capture the magnitude of MNEs' use of patent boxes for profit shifting. First, patent boxes may also enhance productivity, thereby raising profit levels independently of profit shifting. Second, MNEs shift profits both into patent box countries and out of them via internal debt arrangements, such that only the net effect is reflected in the estimated change in pre-tax profits. After accounting for productivity effects and decomposing inward and outward shifting behavior, we find that the propensity to shift profits into the patent box is slightly lower, amounting to to 7.2 percent of pre-tax profits.

The inward and outward shifting behavior of MNEs has important implications for corporate tax revenues. Although only a fraction of incoming profits leaves the patent box country again via internal debt arrangements, this type of 'round-tripping' is costly: it reduces corporate tax revenues and may even offset the additional revenue the patent box country collects from MNEs.

These findings are of policy relevance and contribute to debates on measures designed to limit the use of patent boxes for profit shifting. The modified nexus approach, endorsed by the OECD and the G20, constrains the scope of patent box regimes by restricting, among other provisions,

the eligibility of acquired patents for preferential tax treatment. Our analysis provides evidence on the effectiveness of such restrictions: exploiting differences in the restrictiveness of existing patent box regimes, we find that excluding acquired patents from preferential treatment reduces the tax sensitivity of MNE profits.

Finally, this paper focuses on the responses of affiliates within patent box countries. However, because MNEs are integrated structures, the effects of patent boxes may also propagate within conglomerates to affiliates located in non–patent box countries. Albeit highly interesting, such analyses are beyond the scope of this paper and are left to future research.

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Tables

Table 1: **Characteristics of European Patent Box Regimes (2007-2015)**

	NL	BE	ES	FR*	GB	HU*	PT	IT
Year (Introd./Reform)	2007	2008	2008	2010	2013	2012	2014	2015
Statutory Tax Rate[1]	28.7	34.0	30.1	36.0	25.3	19.3	32.0	31.3
Tax Rate on IP[1]	6.67	6.80	11.9	15.9	10.0	6.40	13.6	15.6
Separate Rate on IPs	No	No	No	Yes	Yes	No	No	No
Existing Patents Eligible	No	No	Yes	Yes	Yes	Yes	No	Yes
Acquired Patents Eligible	No	Yes[2]	No	Yes	Yes[2]	Yes	No	Yes
Number of Affiliates	1,153	5,411	63,362	92,563	14,608	6,621	14,381	12,294
Treated Affiliates	230	946	3,305	7,921	3,269	447	427	2,889
Treated MNEs	161	616	1,474	2,895	1,939	219	301	1,289
Treated DOMs	69	330	1,831	5,026	1,330	228	126	1,600

Note: Number of affiliates refer to the sample matched with k2m CEM, used in the baseline model specification of column (3), Table 3. The listed countries introduced or reformed their patent box regime between 2007 to 2015. (*) *France and Hungary first introduced their patent boxes in 2000 and 2003, respectively, and then implemented major reforms in the years reported in the first row of the table, which substantially reduced the effective tax burden on IP income (see Section 2).* [1] *Average of tax rates over the sample period 2007 to 2015.* [2] *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
Tax Rates	Top statutory tax rate on corporate income

Note: All financial variables are collected from ORBIS and are originally provided in EUR units, then converted to 2015 EUR units using the World Bank GDP deflator. Tax rates are collected from the Worldwide Corporate Tax Guide, EY (various years).

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

	Pre-Tax Profit				**EBIT**	
	Homoge-neous Treate-ment	MNE vs DOM Affiliates	with Controls	Full Sample	same as (3)	Full Sample
	(1)	(2)	(3)	(4)	(5)	(6)
After IPBox Introduction	-0.073***	-0.073***	-0.072***	-0.070***	-0.028***	-0.026***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
After * Treated Affiliates	0.130***					
	(0.012)					
After * Treated * DOM Affiliates		0.108***	0.092***	0.089***	0.057***	0.053***
		(0.017)	(0.017)	(0.017)	(0.012)	(0.012)
After * Treated * MNE Affiliates		0.148***	0.118***	0.115***	0.102***	0.099***
		(0.016)	(0.015)	(0.015)	(0.012)	(0.012)
Fixed Assets			0.054***	0.055***	0.131***	0.130***
			(0.002)	(0.002)	(0.002)	(0.002)
Cost of Employees			0.230***	0.229***	0.243***	0.243***
			(0.004)	(0.004)	(0.004)	(0.004)
Financial Leverage			-0.061***	-0.061***	0.000	-0.002
			(0.005)	(0.005)	(0.004)	(0.004)
Tax Differential, $\tau_i - min(\tau_{cg})$			-0.546***	-0.539***	-0.431***	-0.419***
			(0.116)	(0.115)	(0.093)	(0.092)
Within R-squared	0.019	0.019	0.031	0.031	0.056	0.056
Overall R-squared	0.004	0.004	0.499	0.504	0.637	0.641
Observations	1,394,460	1,394,460	1,394,460	1,431,793	1,555,330	1,597,924
Total Number of Affiliates	207,632	207,632	207,632	213,814	210,151	216,511
Number of Treated MNE Affiliates	8,894	8,894	8,894	8,978	8,906	8,906
Number of Treated DOM Affiliates	10,540	10,540	10,540	10,555	10,593	10,593

*Note: all specifications are estimated using a linear panel model with affiliate-level fixed effects. The sample includes all affiliates matched through k2m CEM. Treatment is defined if the affiliate or any of its majority shareholders appears in the ORBIS IP dataset as an applicant or original owner of IPs published in or before 2000. Control affiliates that appear as applicants or original owners of new IPs published after the introduction of an patent box in their country are excluded from the matched control sample. In columns (2) to (6), treatment status varies according to the time-invariant ownership structure of the affiliate's conglomerate (multinational vs. domestic). Robust standard errors are reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 4: **Confounding Tax Incentives and Role of Tax Havens**

	Tax Environment		**Tax Havens**	
	Pre-Tax Profit (1)	EBIT (2)	Pre-Tax Profit (3)	EBIT (4)
After IPBox Introduction	-0.072***	-0.028***	-0.072***	-0.028***
	(0.004)	(0.003)	(0.004)	(0.003)
After * Treated * DOM Affiliates	0.092***	0.057***	0.092***	0.057***
	(0.017)	(0.012)	(0.017)	(0.012)
After * Treated * MNE Affiliates				
in low-tax countries	0.122***	0.111***		
	(0.018)	(0.014)		
in high-tax countries	0.108***	0.077***		
	(0.028)	(0.020)		
linked to Tax Haven			0.088	0.129***
			(0.056)	(0.042)
not linked to Tax Haven			0.120***	0.100***
			(0.016)	(0.012)
Controls	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Year x Industry FE	YES	YES	YES	YES
Overall R-squared	0.499	0.637	0.499	0.637
Observations	1,394,460	1,555,330	1,394,460	1,555,330
Affiliates	207,632	210,151	207,632	210,151

*Note: All models are estimated using a linear panel model with affiliate-level fixed effects. The sample includes all affiliates matched through k2m CEM. Treatment is defined if the affiliate or any of its majority shareholders appears in the ORBIS IP dataset as an applicant or original owner of IPs published in or before 2000. For affiliates of MNEs, the treatment effect varies depending on whether the affiliate is located in the country with the lowest tax rate within the conglomerate (Columns [1] and [2]) or whether a link to a tax haven (Columns [3] and [4]). An affiliate is defined as being linked to a tax haven (TH) if it is either controlled by a majority shareholder located in a tax haven or if it controls a subsidiary located in a tax haven. We classify those countries as tax havens as defined in Hines (2010). Control variables are identical to those in column (3) of Table 3, but are omitted from the table. Robust standard errors are reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 5: **(In)direct Ownership and MNE Innovators**

	Pre-Tax Profit			EBIT		
	Indirect IP (1)	No Innovators (2)	MNE Innovators (3)	Indirect IP (4)	No Innovators (5)	MNE Innovators (6)
After IP Introduction	-0.072***	-0.070***	-0.064***	-0.028***	-0.026***	-0.021***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
After * Treated * DOM Affiliates	0.092***	0.046**	0.084***	0.057***	0.016	0.050***
	(0.017)	(0.020)	(0.017)	(0.012)	(0.015)	(0.012)
After * Treated * MNE Affiliates		0.096***			0.100***	
		(0.018)			(0.014)	
indirect IP only	0.108***			0.101***		
	(0.020)			(0.016)		
direct and indirect IP	0.128***			0.102***		
	(0.022)			(0.017)		
new Patents post-IPBox			0.122***			0.092***
			(0.026)			(0.022)
no new Patents post-IPBox			0.077***			0.091***
			(0.023)			(0.019)
Controls	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Year x Industry FE	YES	YES	YES	YES	YES	YES
Overall R-squared	0.499	0.475	0.496	0.637	0.619	0.636
Observations	1,394,460	1,353,549	1,394,460	1,555,330	1,510,367	1,555,330
Affiliates	207,632	201,948	207,632	210,151	204,443	210,151

Note: All models are estimated using a linear panel model with affiliate-level fixed effects. The sample includes all affiliates matched through k2m CEM. Treatment is defined if the affiliate or any of its majority shareholders appears in the ORBIS IP dataset as an applicant or original owner of IPs published in or before 2000. For affiliates of MNEs, the treatment effect varies depending on whether patents are owned indirectly through any majority shareholder (Columns [1] and [4]), whether no new patents were produced after 2000 (Columns [2] and [5]), or whether new patents were produced after the introduction of the patent box (Columns [3] and [6]). Control variables are identical to the ones in column (3), Table 3, but are omitted from the table. Robust standard errors are reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6: **Patent Box Restrictions**

	Pre-Existing IPs qualify		Acquired IPs qualify	
	Pre-Tax Profit (1)	EBIT (2)	Pre-Tax Profit (3)	EBIT (4)
After IPBox Introduction	-0.072***	-0.028***	-0.072***	-0.028***
	(0.004)	(0.003)	(0.004)	(0.003)
After * Treated * DOM Affiliates	0.092***	0.057***	0.092***	0.057***
	(0.017)	(0.012)	(0.017)	(0.012)
After * Treated * MNE Affiliates				
restricted IPBox Regimes	0.170***	0.126***	-0.028	-0.118***
	(0.045)	(0.034)	(0.038)	(0.026)
un-restricted IPBox Regimes	0.113***	0.100***	0.150***	0.152***
	(0.016)	(0.013)	(0.016)	(0.013)
Controls	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Year x Industry FE	YES	YES	YES	YES
Overall R-squared	0.499	0.637	0.499	0.637
Observations	1,394,460	1,555,330	1,394,460	1,555,330
Affiliates	207,632	210,151	207,632	210,151

*Note: All models are estimated using a linear panel model with affiliate-level fixed effects. The sample includes all affiliates matched through k2m CEM. Treatment is defined if the affiliate or any of its majority shareholders appears in the ORBIS IP dataset as an applicant or original owner of IPs published in or before 2000. For affiliates of MNEs, the treatment effect varies depending on whether the patent box in the affiliate's country allows pre-existing patents (Columns [1] and [2]) or newly acquired patents (Columns [3] and [4]) to qualify for the tax benefit. Control variables are identical to those in column (3) of Table 3, but are omitted from the table. Robust standard errors are reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

Table 7: **Robustness Checks: Sample Variations**

	Pre-Tax Profit			EBIT		
	Up to 2018	IP Amend-ment	with Ireland	Up to 2018	IP Amend-ment	with Ireland
	(1)	(2)	(3)	(4)	(5)	(6)
After IP Introduction	-0.045***	-0.033***	-0.068***	-0.009***	0.009***	-0.026***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
After IP Amendment		0.008			0.070***	
		(0.007)			(0.005)	
After * Treated * DOM	0.080***	0.074***	0.090***	0.055***	0.046***	0.056***
	(0.016)	(0.016)	(0.017)	(0.011)	(0.011)	(0.012)
After * Treated * MNE	0.084***		0.129***	0.087***		0.111***
	(0.014)		(0.015)	(0.011)		(0.012)
before amendment		0.075***			0.077***	
		(0.014)			(0.011)	
after amendment		0.109***			0.102***	
		(0.020)			(0.016)	
Controls	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Year x Industry FE	YES	YES	YES	YES	YES	YES
Within R-squared	0.033	0.034	0.031	0.062	0.063	0.056
Overall R-squared	0.516	0.516	0.502	0.644	0.641	0.638
Observations	1,873,424	1,873,424	1,398,311	2,077,800	2,077,800	1,559,656
Affiliates	210,393	210,393	208,252	212,235	212,235	210,783

Note: All models are estimated using a linear panel model with affiliate-level fixed effects. The sample includes all affiliates matched through k2m CEM. Treatment is defined if the affiliate or any of its majority shareholders appears in the ORBIS IP dataset as an applicant or original owner of IPs published in or before 2000. The sample spans years up to 2018 in Columns [1], [2], [4], and [5], while in Columns [3] and [6] the sample also includes affiliates located in Ireland. The specifications in Columns [2] and [5] allow for a staggered treatment timeline and distinguish between the period from the introduction of the patent box to its amendment and the period after the amendments that took place in France and the Netherlands in 2010, Hungary in 2012, and Italy in 2017. Control variables are identical to those in column (3) of Table 3, but are omitted from the table. Robust standard errors are reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A Comparative Static Analysis

After-tax profits of the MNE are:

$$\begin{aligned}\Pi &= (1-t_A^{PB})(y_A(i)+q-1)+(1-t_A)(\overline{y}_A-z)+(1-t_B)(y_B-q)+(1-t_C)z \\ &- \theta(q)-c(i)-\gamma(z,E_A).\end{aligned} \tag{13}$$

Differentiating (13) w.r.t. q, i, and z, and rearranging terms yields:

$$q: \quad t_B - t_A^{PB} - \partial\gamma(z,E_A)/\partial E_A = \theta'(q) \tag{14}$$

$$i: \quad (1-t_A^{PB})y_A'(i) - \partial\gamma(z,E_A)/\partial E_A y_A'(i) = c'(i) \tag{15}$$

$$z: \quad t_A - t_C = \partial\gamma(z,E_A)/\partial z. \tag{16}$$

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.[32]

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 (14) - (16) 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

$$\begin{aligned}|\Gamma_1| &= \left(c''-(1-t_A^{PR}-\gamma_E)y_A''\right)\gamma_{zz} > 0 \\ |\Gamma_2| &= y_A'\theta''\gamma_{zz} > 0 \\ |\Gamma_3| &= \left(-c''+(1-t_A^{PR}-\gamma_E)y_A''-(y_A')^2\theta''\right)\gamma_{zE} > 0.\end{aligned} \tag{17}$$

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 (15), 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:

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

[32] 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 Measure, $TAX_{i,t}$

In the empirical analysis, we use the difference between the statutory tax rate in the country of affiliate i and the country with the lowest statutory tax rate faced by any majority shareholder, the global ultimate owner, or any other majority-owned affiliate within the conglomerate (cg): $\tau_{i,t} - min(\tau_{cg,t})$. Table B1 reports affiliate-time-specific tax rates averaged over our observational period from 2007 to 2015. Specifically, it presents the statutory tax rate faced by affiliate (τ_i), the measure τ_i^*, which captures the reduction in the statutory tax rate due to the patent box regime (i.e., $\tau_i^* = \tau_i - \tau_i^{pb}$), the minimum tax rate within the conglomerate ($min(\tau_{cg})$), and the tax differences between the rate faced by affiliate i and and the lowest rate within the conglomerate (i.e., $\tau_i - min(\tau_{cg})$), which is used to construct the tax variable $TAX_{i,t}$. In addition, the table reports the share of affiliates with links to tax havens.

Table B1: **Tax Rates across Treatment and Control Groups (2007-2015 average)**

Tax Measure	Matched Control Affiliates		Treated Affiliates		Full Unmatched Sample	
	DOM	MNE	DOM	MNE	DOM	MNE
τ_i	32.13	31.21	32.30	31.01	32.14	31.15
$\tau_i^* = \tau_i - \tau_i^{pb}$	16.53	17.58	18.07	18.38	16.62	17.82
$min(\tau_{cg})$	-	27.94	-	28.54	-	28.17
$\tau_i - min(\tau_{cg})$	-	3.27	-	2.47	-	2.98
% linked to TH	-	6.90	-	9.70	-	7.75

Note: All tax rates reported here are averaged over the observational period from 2007 to 2015.The statutory tax rate of an affiliate's country is denoted by τ_i, while $\tau_i^* = \tau_i - \tau_i^{pb}$ captures the tax reduction resulting from the patent box regime. The tax rate $min(\tau_{cg})$ refers to the minimum tax rate within the entire conglomerate, accounting for any majority shareholders, the global ultimate owner, or any other majority owned affiliate within the MNE. An affiliate is defined as being linked to a tax haven (TH) if it is either controlled by a majority shareholder located in a tax haven or if it controls a subsidiary located in a tax haven. Our classification of tax havens follows Hines (2010).

B.2 Coarsened Exact Matching

We employ *coarsened exact matching* (CEM) to achieve a balance between the treatment and control groups, with balance assessed using the $\mathcal{L}$ statistic (Iacus et al., 2012). This statistic measures overall sample imbalance based on differences between the multidimensional histograms of the selected pre-treatment characteristics. Values of $\mathcal{L} = 1$ indicate complete imbalance, whereas $\mathcal{L} = 0$ indicates perfect balance. The method further ensures monotonic imbalance bounding (MIB), whereby improving balance on one variable cannot increase imbalance on others (Blackwell et al., 2009; Iacus et al., 2012)."

We match affiliates one-to-many (k2m) based on ownership structure, country of establishment, industry, and historical financial performance. For the latter, we construct a composite index to accommodate the extensive data requirements of the matching procedure. The index is based on affiliate-specific financial information averaged over the years 1996 to 2006 and incorporates affiliate age in 2000, turnover and number of employees (proxies for size), profit margin (pre-tax profits to sales), the ratio of intangible to total assets, and fixed assets; characteristics recognized as important in the innovation literature (Pakes and Griliches, 1980; Acs and Audretsch, 1988; Atkeson and Burstein, 2010; Hall and Lerner, 2010; Mohnen and Hall, 2013).

Table B2: **Coarsened Exact Matching**

	Full Sample (N=226,504)		Matched Sample (N=219,293)	
	$\mathcal{L}$	Mean Diff.	$\mathcal{L}$	Mean Diff.
MNE/Domestic	0.34944	0.34944	0	0
Country	0.23857	-0.03318	0	0
Industrial Sector	0.38146	-8.0628	0.15678	-0.04697
Historial Financial Score	0.46004	1.1386	0.21298	0.3633

Note:The matched sample comprises 19,949 treated affiliates, of which 10,827 belong to domestic conglomerates and 9,122 to multinational conglomerates. These are matched to 178,254 and 21,090 control affiliates, respectively. The share of affiliates controlled by MNEs amounts to 15.1% in the original sample and 13.7% in the matched sample. After matching, 646 out of 1050 strata are retained, and the overall $\mathcal{L}$ statistic measure decreases from 0.86569144 to 0.58154683.

As reported in Table B2, our one-to-many matching reduces the overall $\mathcal{L}$ statistic from 0.86569144 to 0.58154683. This indicates that the matched sample attains substantially greater balance across all pre-treatment covariates. After matching, no statistically significant differences remain between the means of the treated and matched control groups.

Finally, Table B3 presents the sample composition before and after matching. From the full sample of 20,054 treated and 212,897 control affiliates, the matched sample comprises 19,949 treated and 199,344 control affiliates.

Table B3: **Matched Sample Composition**

	Full Sample				Matched Sample			
	Treated		Control		Treated		Control	
Affiliates of MNEs	9,210	(45.9%)	23,386	(11.0%)	9,122	(45.7%)	21,090	(10.6%)
Affiliates of DOMs	10,844	(54.1%)	189,511	(89.0%)	10,827	(54.3%)	178,254	(89.4%)
Total	20,054	(100%)	212,897	(100%)	19,949	(100%)	199,344	(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 patent box regimes. In doing so, we test four different measures for the affiliate-time-specific tax variable. Similar to our main analysis, we compute the difference in statutory corporate tax rates between the country of affiliate i, and the country with the lowest tax rate faced by any of the majority shareholders, the global ultimate owner, or any other majority-owned affiliate within the entire conglomerate (cg): $\tau_{i,t} - min(\tau_{cg,t})$. As an alternative, we consider the difference between the statutory tax rate in the affiliate's country and the lowest statutory tax rate faced by any of the majority shareholders (sh), i.e. $\tau_{i,t} - min(\tau_{sh,t})$. In addition to these continuous tax differences, all of which are positive (see Table C1), we also consider two alternative dummy variables. In the first specification, the dummy equals one if the affiliate's tax rate is higher than that of any other majority shareholder, the global ultimate owner or any other majority-owned affiliate in the conglomerate, $D = 1$ if $\tau_i > \tau_{cg}$. In the second specification, the dummy equals one if the statutory tax rate of affiliate i is higher than that of any of its majority shareholders, i.e., $D = 1$ if $\tau_i > \tau_{sh}$. Table C1 presents the affiliate-time-specific tax rates and tax differences averaged over the observational period from 2007 to 2015.

Table C1: **Tax Rates across Treatment and Control Groups (2007-2015 average)**

Tax Measure	Matched Control Affiliates		Treated Affiliates		Full Unmatched Sample	
	DOM	MNE	DOM	MNE	DOM	MNE
τ_i	32.13	31.21	32.30	31.01	32.14	31.15
$\tau_i^* = \tau_i - \tau_i^{pb}$	16.53	17.58	18.07	18.38	16.62	17.82
$min(\tau_{cg})$	-	27.94	-	28.54	-	28.17
$\tau_i - min(\tau_{cg})$	-	3.27	-	2.47	-	2.98
$min(\tau_{sh})$	-	28.38	-	29.69	-	28.85
$\tau_i - min(\tau_{sh})$	-	2.83	-	1.32	-	2.30

Note: All tax indices reported here are averaged over the observational period from 2007 to 2015. The statutory tax rate of an affiliate's country is denoted by τ_i, while $\tau_i^* = \tau_i - \tau_i^{pb}$ captures the tax reduction resulting from the patent box regime. The tax rates $min(\tau_{cg})$ refers to the minimum tax rate within the conglomerate, accounting for any majority shareholder, the global ultimate owner, or any other majority owned affiliate within the MNE, and $min(\tau_{sh})$ denotes the minimum tax rate of any of the affiliate's majority shareholders.

Table C2 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 [7] are estimated on the full sub-sample of MNEs and include

different tax measures, which capture tax incentives for profit shifting unrelated to patent boxes.

Table C2: **Benchmark Estimation - Profit Shifting Regression**

	Full Sample (1)	Matched Sample (2)	Tax Differential w.r.t. $min(\tau_{sh})$ (3)	$min(\tau_{cg})$ (4)	$min(\tau_{cg})$ (5)	Tax Dummy w.r.t. $min(\tau_{sh})$ (6)	$min(\tau_{cg})$ (7)
Fixed Assets	0.056***	0.055***	0.061***	0.061***	0.060***	0.060***	0.060***
	(0.002)	(0.002)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Cost of Employees	0.234***	0.231***	0.283***	0.283***	0.283***	0.284***	0.284***
	(0.004)	(0.004)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Financial Leverage	-0.064***	-0.061***	-0.159***	-0.158***	-0.158***	-0.160***	-0.160***
	(0.005)	(0.005)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Tax Differential: $\tau_i - \tau_j$			-0.007***	-0.006***			
			(0.001)	(0.001)			
Tax Diff. before IP-Box					-0.005***		
					(0.001)		
Tax Diff. after IP-Box					-0.007***		
					(0.001)		
Tax Dummy: 1 if $\tau_i > \tau_j$						-0.008	-0.006
						(0.015)	(0.015)
Within R-squared	0.031	0.031	0.035	0.035	0.035	0.034	0.034
Overall R-squared	0.510	0.495	0.514	0.510	0.510	0.512	0.512
Observations	1,476,854	1,394,460	193,173	193,173	193,173	193,173	193,173
Affiliates	220,057	207,632	28,616	28,616	28,616	28,616	28,616

*Note: All models are estimated using a linear panel model with affiliate-level fixed effects. Columns [1] and [2] include both domestic and multinational affiliates, using the full sample and the matched sample, respectively. Columns [3]-[7] consider the full sample of multinational affiliates only. The tax rate, denoted by τ_j, refers to the minimum tax rate of the majority shareholder in Columns [3] and [6], and the minimum tax rate within the entire conglomerate in Columns [4], [5] and [7]. Robust standard errors are reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

In Columns [3] and [6], the affiliate-specific time-variant tax measure is the statutory tax rate differential between the affiliate in country i and the affiliate's majority shareholder residing in the lowest-tax country (Column [3]), or the majority shareholder, global ultimate owner or any other majority owned affiliate facing the lowest tax rate within the conglomerate in Columns [4], [5] and [7]). In Column [5], profit shifting unrelated to the patent box, as captured by the tax differential, is estimated separately for the period before and after the introduction or major amendment of the patent box regimes. The specifications in Columns [6] and [7] repeat the tax measures used in Columns [3] and [4] but use an indicator variable instead of the statutory tax rate differential.[33]

[33] 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 the relationship between pre-tax profits and production inputs is largely unaffected by sample composition. Furthermore, consistent with the existing literature that employs affiliate-level panel data (see Dharmapala, 2014, for a discussion), we find semi-elasticities of approximately –0.007 and –0.006 in Specifications [3] and [4], respectively. Note, since $(\tau_i - \tau_j) > 0$, an increase in the tax differential reduces affiliate i's pre-tax profit. Conversely, a 10-percentage-point reduction in the tax rate differential between the country of affiliate i and the country of the shareholder (or any other entity within the conglomerate) with the lowest tax rate increases affiliate i's pre-tax profits by approximately 7.0 (6.0) percent. Additionally, the results in Column [5] indicate that the tax sensitivity of profit shifting unrelated to patent boxes increases following the introduction of patent box regimes. This finding suggests that profit shifting through patent boxes and other channels are complementary. One possible explanation is that the use of patent boxes for profit shifting may result in a profit allocation within the MNE that does not fully align with its overall tax-minimization strategy. Consequently, other channels of profit shifting are employed more extensively to realign profits with the MNE's broader tax objectives, thereby increasing the tax sensitivity of profit shifting unrelated to patent boxes.

In the specification with the indicator variable, we find similarly sized effects on pre-tax profits for affiliates with a higher tax rate than their lowest-taxed shareholder (Specification [6]), or any other lowest-taxed entity within the conglomerate (Specification [7]), although the latter result are not statistically significant.

C.2 Propensity Score Matching

We further assess the external validity of our results by applying an alternative matching procedure. In Table C3, Columns [1] and [3] restate the baseline model estimates (from Column [3] of Table 3) for pre-tax profit and EBIT, respectively. Columns [2] and [4] report the corresponding estimates obtained from the same model using a sample constructed through propensity score (PS) matching.

For the PS-matched sample, we adopt a setup comparable to that used with CEM. Specifically, we estimate the propensity score separately for multinational and domestic affiliates, including affiliate-, country-, and industry-fixed effects. We then implement one-to-one matching of affiliates within type (multinational and domestic). To ensure common support, we discard the 5 percent of treated observations with the lowest propensity score density relative to the control group. The results based on the PS-matched sample are reported in Columns [2] and [4]. Compared to the CEM-matched sample, the PS-matched sample differs in composition. The common support restriction results in a smaller number of treated multinational and

treated domestic affiliates, but a larger number of control affiliates, since the total number of affiliates is greater in the PS-matched sample than in the CEM-matched sample.

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

	Pre-Tax Profit		**EBIT**	
	CEM Matching Col.[3], Tab.3	PS Matching	CEM Matching Col.[5], Tab.3	PS Matching
	(1)	(2)	(3)	(4)
After IPBox Introduction	-0.072***	-0.070***	-0.028***	-0.026***
	(0.004)	(0.004)	(0.003)	(0.003)
After * Treated * DOM Affiliates	0.092***	0.082***	0.057***	0.048***
	(0.017)	(0.018)	(0.012)	(0.013)
After * Treated * MNE Affiliates	0.118***	0.110***	0.102***	0.095***
	(0.015)	(0.016)	(0.012)	(0.012)
Fixed Assets	0.054***	0.054***	0.131***	0.130***
	(0.002)	(0.002)	(0.002)	(0.002)
Cost of Employees	0.230***	0.231***	0.243***	0.243***
	(0.004)	(0.004)	(0.004)	(0.004)
Financial Leverage	-0.061***	-0.062***	0.000	-0.002
	(0.005)	(0.005)	(0.004)	(0.004)
Tax Differential, $\tau_i - min(\tau_{cg})$	-0.546***	-0.521***	-0.431***	-0.400***
	(0.116)	(0.117)	(0.093)	(0.093)
Overall R-squared	0.499	0.498	0.637	0.635
Observations	1,394,460	1,412,914	1,555,330	1,579,968
Total Number of Affiliates	207,632	210,653	210,151	213,598
Nb. of Treated MNE Affiliates	8,894	8,626	8,906	8,626
Nb. of Treated DOM Affiliates	10,540	10,186	10,593	10,186

*Note: All models are estimated using a linear panel model with affiliate-level fixed effects. The sample composition varies across columns. Columns (1) and (3) use the CEM-matched sample from Table 3, while Columns (2) and (4) employ propensity score (PS) matching, discarding the 5 percent of treated observations with the lowest propensity score density relative to the control group. Robust standard errors are reported in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*

For treated affiliates belonging to domestic conglomerates, the change in pre-tax profit amounts to 9.2 and 8.2 percent when using the CEM- and PS-matched samples, respectively. For treated affiliates belonging to MNEs, pre-tax profit is 11.8 percent higher relative to their non-treated counterparts in the CEM-matched sample, compared to 11.0 percent in the PS-matched sample. A comparison of the results reported in Columns [1] and [2] as well as Columns [3] and [4] shows that all estimates are highly comparable across the CEM- and PS-matched samples, confirming consistency and indicating that the choice of matching procedure has virtually no substantive effect on the results.