

Lüttmann, Malte

**Article — Published Version**

## Taxation of MNE profits in an R&D driven economy: Beneficial tax havens and minimum taxes

The World Economy

**Provided in Cooperation with:**

John Wiley & Sons

*Suggested Citation:* Lüttmann, Malte (2024) : Taxation of MNE profits in an R&D driven economy: Beneficial tax havens and minimum taxes, The World Economy, ISSN 1467-9701, Wiley, Hoboken, NJ, Vol. 47, Iss. 9, pp. 4061-4087,  
<https://doi.org/10.1111/twec.13621>

This Version is available at:

<https://hdl.handle.net/10419/306109>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*



<http://creativecommons.org/licenses/by-nc/4.0/>

# Taxation of MNE profits in an R&D driven economy: Beneficial tax havens and minimum taxes

Malte Lüttmann 

Institute of Public Economics, University of Münster, Münster, Germany

## Correspondence

Malte Lüttmann, Institute of Public Economics, University of Münster, Münster, Germany.

Email: [malte.luettmann@wiwi.uni-muenster.de](mailto:malte.luettmann@wiwi.uni-muenster.de)

## Abstract

Research and development (R&D) by multinational enterprises (MNEs) generates substantial positive cross-country spillovers. With R&D incentives primarily provided by the MNEs' host countries, these nations bear the entire cost of incentivising R&D but only reap a fraction of the benefits, resulting in inefficiently low R&D incentives and investment from a global perspective. Allowing MNEs to shift their profit to a tax haven shelters the firms' profit from foreign taxation and increases the net returns to R&D without reducing the domestic tax base. In this setting, tax havens can be welfare beneficial because they help to internalise the positive cross-country spillovers of R&D. The optimal effective minimum tax balances a reduction in wasteful profit shifting and more efficient R&D incentives for MNEs. Regardless of the welfare effect of R&D, a strictly positive minimum tax is optimal for each country. Uncoordinated minimum taxes may be excessively high, if R&D investment has a strong impact on productivity. Under certain circumstances, IP boxes are a welfare-improving substitute for tax havens.

## KEYWORDS

corporate taxation, intellectual property, minimum tax, multinational firms, optimum taxation, patent box

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial](https://creativecommons.org/licenses/by-nc/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

© 2024 The Author(s). *The World Economy* published by John Wiley & Sons Ltd.

# 1 | INTRODUCTION

Research and development (R&D) activities by multinational enterprises (MNEs) generate substantial positive cross-country spillovers, for instance via increased consumer surplus or employment. With R&D incentives primarily provided by the MNEs' host countries, these nations bear the entire cost of incentivising R&D but only reap a fraction of the benefits. Thus, the nationally optimal R&D incentives for MNEs and the resulting levels of R&D investment are inefficiently low from a global perspective. In this paper, I show that profit shifting by MNEs may help to overcome the resulting inefficiency. The mechanism is as follows. Allowing MNEs to shift their foreign profit to a tax haven reduces effective tax rates on the firms' profit without reducing the domestic tax base. This increases the net returns to R&D investment and, thus, incentivises additional R&D investment by profit shifting MNEs. That is, tax haven access by MNEs may be beneficial because it is a tool to internalise the positive cross-country spillover of R&D by providing additional R&D incentives to domestic MNEs at the expense of foreign countries.

The prevailing view on tax havens is, however, that they are 'parasitic' (Slemrod & Wilson, 2009), that is they steal tax base from high-tax countries without providing any benefits on their own. Building on this view and the insight that MNEs are successfully using tax havens to avoid to pay taxes in high-tax countries,<sup>1</sup> policymakers have agreed to introduce a global effective minimum tax on MNE profit. Under this agreement, tax havens no longer have the opportunity to tax MNE profit at rates below 15%. For instance, if an MNE is in the habit of shifting its intellectual property (IP) to Bermuda, the implementation of a global minimum tax will increase effective tax rates on the MNE's returns to its IP to 15%, reducing the MNE's incentive to invest in R&D. In this paper, I argue that, if tax havens are used as a tool to provide R&D incentives to MNEs, a trade-off between a reduction in wasteful profit shifting and additional R&D incentives for MNEs emerges and investigate how the optimal effective minimum tax balances these effects.

Preferential tax regimes for returns to intellectual property (IP boxes) are introduced with the stipulated goal to provide additional R&D incentives to MNEs by reducing the effective tax rates on MNE profit. In the real world, IP boxes often serve as on-shore tax havens.<sup>2</sup> In light of the double purpose of these preferential tax regimes, the political debate has shifted in favour of a stricter rules on preferential tax regimes for returns to IP. In this paper, I investigate whether IP boxes can be beneficial in a manner similar to tax havens. As tax havens, IP boxes may serve as a means to internalise the positive cross-country spillovers of R&D by reducing the effective tax rate on foreign (and domestic) returns to IP. I argue that, under some circumstances, IP boxes are a welfare-enhancing substitute for tax havens.

I consider a setting with two countries and a tax haven. Each country hosts a continuum of heterogeneous multinational firms, which are active in both countries. Firms differ in productivity, as in Melitz (2003) and Helpman et al. (2004). However, instead of considering the choice whether to export or to make an FDI, I consider the choice of using a tax haven and upgrading the firm's technology via R&D, as in Bustos (2011). An upgrade implies lower marginal cost and an additional fixed cost. Each country's government allows domestic MNEs to shift their foreign

<sup>1</sup>In a meta study, Heckemeyer and Overesch (2017) find a semi-elasticity of reported subsidiary profits of  $-0.8$ . Beer et al. (2020) report a semi-elasticity of  $-1.5$  for more recent years. Tørsløv et al. (2022) estimate that, from a global perspective, \$600bn per year are rerouted to tax havens.

<sup>2</sup>Numerous studies suggest that governments implement IP boxes to shelter the profit of domestic MNEs from foreign taxation. See for instance Baumann et al. (2020), Köthenbürger et al. (2018) and Mohnen et al. (2017).



profit to a tax haven, which levies no corporate tax. In contrast, domestic income is taxed in the country of residence. Tax haven use involves a fixed setup cost. In the market equilibrium, tax haven use and technology upgrades are chosen by the more productive firm types. It turns out to be crucial for my results whether the productivity threshold for tax haven access is above or below the productivity threshold for R&D investment. If more firms choose an upgrade than use a tax haven, havens are unambiguously 'parasitic', that is shutting them down increases welfare. If the opposite holds, tax havens are potentially beneficial. I, therefore, focus on the case in which upgrading firms are a subset of tax haven using firms.

Profits are taxed at source and the home country provides a tax incentive for R&D. Since R&D lowers consumer prices and increases local tax revenue, there is a positive cross-country spillover from R&D activities. In the competitive equilibrium with each country optimally setting R&D incentives, R&D is inefficiently low from a global perspective. Allowing firms to access tax havens, increases MNEs R&D incentives and, consequently, makes R&D decisions more efficient. In this restricted sense, tax havens are beneficial. I show that, somewhat counter-intuitively, tax havens are only desirable as a policy instrument if firms respond to a reduction in the minimum tax rate by manipulating royalty payments (i.e. by shifting profits in the narrow sense), because this forces the foreign country to contribute to the R&D incentive for domestic MNEs.

In my framework, the optimal minimum tax trades off reducing wasteful profit shifting and providing additional R&D incentives to MNEs. With optimal tax deductions for R&D, I show that the optimal minimum tax is strictly positive. This is noteworthy since it highlights that a minimum tax is desirable for high-tax countries, regardless of the welfare effect of R&D. The optimal minimum tax is inefficiently high (from a global perspective) if profit shifting and R&D spillovers are large. In the absence of profit shifting (i.e. if firms do not manipulate the royalty fees for tax saving purposes), the optimal minimum tax equals the residence country's corporate tax rate – which implies that tax havens are effectively shut down.

I show under which circumstances IP boxes are a welfare-improving substitute for beneficial tax havens and under which the two may coexist in equilibrium. In my model IP boxes only apply to own-developed IP and IP cannot be moved to other countries.<sup>3</sup> I show that the optimal tax on IP income within the box is strictly positive. Uncoordinated tax incentives for R&D may be inefficiently low if R&D has little impact on productivity and inefficiently high if profit shifting is unpronounced. As tax havens, preferential tax regimes for returns to R&D are only attractive to countries as a policy instrument (compared to tax deductibility of R&D fixed cost), if there is profit shifting into the IP box, which serves as a means to make the foreign country contribute to the R&D incentive. If IP boxes are used to foster R&D, tax havens may be useful to mitigate the revenue cost of offering preferential tax treatment in IP boxes. If tax havens are used to incentivise R&D, IP boxes may be used to mitigate the private cost from using tax havens.

The argument that tax havens may be beneficial has first been developed by Hong and Smart (2010) and Johannesen (2010), who build upon theoretical work by Keen (2001) and empirical work by Desai et al. (2006).<sup>4</sup> In these contributions, tax havens are used to achieve a differentiation in taxation that is, for some reason, infeasible within the domestic tax system. A

<sup>3</sup>That is, the IP boxes in the model are compliant with the OECD's nexus requirements.

<sup>4</sup>In Marceau et al. (2010), preferential tax regimes for mobile firms are only desirable if countries differ in their productivity, Mongrain and Wilson (2018) show that, if countries differ in size, smaller countries find preferential regimes desirable. Mongrain et al. (2020) find that, when countries compete for mobile firms, less strict anti profit-shifting policies allow policymakers to set higher statutory tax rates, potentially resulting in increased tax revenues.

similar role is taken by tax havens in my model, however, with an additional feature. Tax havens are not only used as a specific tax break; they are rather used to make the foreign country contribute to incentivising R&D. IP boxes can have the same effect if they make the firm shift profit from abroad to the firm's home country. However, tax deductibility of R&D expenses does not have this effect. Lastly, replacing tax havens with IP boxes for own-developed IP is potentially welfare enhancing, depending on country characteristics.

This paper builds on the observation, that profit-shifting opportunities affect real activities. Notably, Suárez Serrato (2018) finds that restricting the access of US MNEs to tax havens reduces the affected firms' investment activity within the US. Analogously, de Mooij and Liu (2020) document significant reductions in the investment of MNEs in their home country in response to stricter anti profit-shifting policies. Schwab and Todtenhaupt (2021) find an increase in R&D expenditures and the number of patents granted in non-haven countries, if an MNE gains access to a tax haven.<sup>5</sup> In this paper, I argue that this effect is driven by the location of returns to the newly generated IP in low tax jurisdictions. In line with empirical findings, I assume that the location of an MNE's headquarter has an effect on the location of IP. More precisely, only the foreign returns to IP are shifted to the tax haven, domestic returns to IP are fully taxed in the MNEs' home country.<sup>6</sup>

The effects of minimum taxes (as in the OECD/G20 Inclusive Framework's proposal) enjoy increased attention. Hindriks and Nishimura (2021) show that a minimum tax may make high-tax countries worse off, because it could induce low tax countries to pull out of international coordination efforts.<sup>7</sup> Hebous and Keen (2023) find room for Pareto-improvements (among high-tax countries) via the introduction of a worldwide minimum tax rate. By investigating potential welfare benefits of tax havens, I provide more restrictive conditions for a scenario in which effective minimum taxes are desirable for all non-haven countries. Johannesen (2022) focuses on the trade-offs between net profit losses and additional tax revenue when implementing a global minimum tax threshold. Dyrda et al. (2022) show that, whilst it significantly increases global tax revenue, an effective minimum tax would result in a reduction of global economic growth and output.

The remainder of the paper is organised as follows. The Section 2 describes the model setup and derives the equilibrium. Section 3 analyses a range of policy experiments, for example the introduction of minimum taxes and IP boxes. Section 4 concludes.

## 2 | THE MODEL

### 2.1 | Setup

Consider two countries, domestic ( $d$ ) and foreign ( $f$ ), and a tax haven. In each of the two countries, there is a representative household and a continuum of firms. Each country's government levies taxes to finance a public good.

<sup>5</sup>If R&D can be exploited across all affiliates of an MNE, activity within the firm may become complementary. See Desai et al. (2009), Becker and Riedel (2012) as well as Kovak et al. (2021) for empirical evidence.

<sup>6</sup>There is a large literature proving (indirect) evidence for the use of IP in profit shifting activities, see for instance Desai et al. (2006) or Mutti and Grubert (2009).

<sup>7</sup>See also Peralta and van Ypersele (2006) and Kiss (2012).

### 2.1.1 | Households

The representative household in each country is endowed with one unit of labour and owns all domestic firms. The household derives utility from consuming a numéraire good  $z$  and varieties  $Q$  of a differentiated consumption good as well as a public good  $B$ . Preferences are represented by a quasi-linear utility function with a standard CES utility subfunction.

$$U = z + \beta^{-1} Q^{\frac{\beta}{\sigma}} + \gamma B \quad (1)$$

with

$$Q = \int_0^N q(\omega)^\sigma d\omega \quad (2)$$

where  $q(\omega)$  denotes the quantity consumed of variety  $\omega$ ,  $N$  is the total number of variety producing firms,  $\beta, \sigma, \gamma > 0$  are fixed preference parameters with  $\sigma, \beta < 1$  and  $\gamma \geq 1$ . Varieties are pairwise substitutes (due to  $\sigma < 1$ ). Furthermore, I assume  $\beta < \sigma$  such that the utility function is convex in  $Q$ .<sup>8</sup> The numéraire's role is mainly to facilitate the analysis and to allow for tractable policy analysis later on. It takes up all income effects, that is policy changes affecting household income but not relative prices will not affect the demand for  $Q$ .

The household's budget constraint is

$$I = z + \int_0^N p(\omega) q(\omega) d\omega \quad (3)$$

where  $I$  is the household's total income.  $p(\omega)$  denotes the price of variety  $\omega$ . Utility maximising demand for variety  $\omega$  is

$$q(\omega) = \frac{\mathbf{P}^{\varepsilon - \frac{1}{1-\beta}}}{p(\omega)^\varepsilon} \quad (4)$$

where  $\mathbf{P} = \left( \int_0^N p(\omega)^{1-\varepsilon} d\omega \right)^{\frac{1}{1-\varepsilon}}$  is the price index for varieties of the consumption good sold in  $d$  and  $f$ .  $\varepsilon = \frac{1}{1-\sigma}$  is the elasticity of substitution between varieties. With  $\varepsilon > \frac{1}{1-\beta}$  (due to  $\sigma > \beta$ ), the price level drives up demand for variety  $\omega$ , whereas its own price decreases demand for it.

Inserting (3) in (1) I get

$$U = I + \frac{1-\beta}{\beta} \mathbf{P}^{-\frac{\beta}{1-\beta}} + \gamma B \quad (5)$$

### 2.1.2 | Firms

The numéraire is produced by a large number of competitive firms using a constant returns to scale technology with labour as the only input. Since  $z$  can be traded freely across  $d$  and  $f$  without

<sup>8</sup>As a consequence, the marginal utility of a variety  $\omega$  decreases in the amount of  $Q$ .

additional cost, the wage cost is identical in both countries and normalised to one. Accordingly, the representative household's wage income is 1.

Firms in the differentiated good sector operate under monopolistic competition. That is, each of the firms has monopoly power over its own variety  $\omega$ . Each firm transforms one unit of labour into  $\theta$  units of the differentiated good. Total cost of production is given by  $C(q, \theta) = F + \frac{q}{\theta}$  where  $F$  denotes the fixed cost of production. Firms in each country differ in the productivity level  $\theta \in [\theta^-, \theta^+]$ . Since there is an unambiguous mapping of varieties  $\omega$  on productivity levels within a country, I will refer to a variety  $\omega$  by indicating the associated productivity level  $\theta_i$  of a firm from country  $i$ . The index  $i$  is necessary since there are two firms (one from  $d$  and one from  $f$ ) of the same productivity offering two different varieties.

Each firm may invest in R&D, which leads to an upgrade of its production technology with certainty, as in Bustos (2011). The upgrade reduces marginal cost to  $\frac{1}{\lambda\theta}$ , with  $\lambda > 1$ . The cost of R&D is  $\Delta^u F$  which adds to the fixed cost of production. That is, total cost of a firm of type  $\theta$  with upgraded technology ( $u$ ) is  $C^u(q, \theta) = F(1 + \Delta^u) + \frac{q}{\lambda\theta}$ . With  $c^m(\theta) \in \left\{ \frac{1}{\theta}, \frac{1}{\lambda\theta} \right\}$  denoting marginal cost, variable profit of a firm of type  $\theta$  from country  $i$  is given by

$$(p(\theta_i) - c^m(\theta_i))q(\theta_i) \quad (6)$$

Using  $q(\theta_i) = \frac{\mathbf{P}^{\epsilon - \frac{1}{1-\beta}}}{p(\theta_i)^\epsilon}$  (and assuming that each individual firm takes  $\mathbf{P}$  as given), the profit-maximising price is

$$p(\theta_i) = \frac{c^m(\theta_i)}{\sigma} \quad (7)$$

i.e. each firm sets a constant (i.e. type-independent) mark-up of  $\frac{p(\theta_i) - c^m(\theta_i)}{c^m(\theta_i)} = \frac{1-\sigma}{\sigma}$  over marginal cost. Variable profit is thus

$$\pi_i = (1 - \sigma)(p(\theta_i))^{1-\epsilon} \mathbf{P}_i^{\epsilon - \frac{1}{1-\beta}} \quad (8)$$

### 2.1.3 | Taxation and tax havens

Each country taxes profit at source with the tax rate given by  $t_i$ . Without tax haven access or upgrade, the source tax base at a firm's headquarters is  $\pi_i + r\pi_{-i} - \psi^e F$  and its foreign tax base is  $(1 - r)\pi_{-i}$ , where  $r$  represents the share of foreign profit that is paid as a royalty fee to the firm's headquarters. The fixed entry cost is deductible at rate  $\psi^e \geq 0$ .

Royalty payments refer to existing and newly generated firm-specific IP. Note that, if a firm upgrades its technology, there is an upward jump in the royalty share  $r$  (since the eligible IP income is increased to  $r^u$ ).

I assume that countries let their firms shift the right to exploit their IP for foreign business purposes to a tax haven. The income from exploiting IP on the domestic market is fully taxed at home. This assumption is in line with the observable practice of many existing MNEs. My results do not, however, crucially depend on them. I will discuss relaxing this assumption in the section 3. With access to tax havens, the royalty payment  $r\pi_{-i}$  is accounted for in the tax haven. The firm's headquarters' jurisdiction may levy a minimum tax  $t^{\min}$  on the profit accounted for in the tax haven. Such a minimum tax is similar to the main instrument in the Pillar 2 package: a minimum tax based on the income inclusion rule (IIR), which allows the parent firm's jurisdiction



to include (a part of) the income accounted for in the tax haven in the domestic tax base such that the effective tax on this income equals the minimum tax rate. Let  $\tilde{t}_i \in \{t_i^{\min}, t_i\}$  denote the tax on foreign profit depending on whether the firm has access to a tax haven or not. Let  $\bar{r}(\pi_{-i})$  denote the ‘true’ royalty share, that is the level of  $r$  which the firm is entitled to pay out, given a profit level of  $\pi_{-i}$ . The firm may deviate from  $\bar{r}(\pi_{-i})$  at a convex cost of  $\alpha(r)$ , which is short for  $\alpha(r - \bar{r}(\pi_{-i}))$ . If the tax on royalty fees,  $\tilde{t}_i$ , is below the tax on ‘normal’ profit,  $t_{-i}$ , such a deviation pays off. The optimal royalty share is implied by  $\alpha'(r) = t_{-i} - \tilde{t}_i$  implying  $\frac{dr_i}{dt_i} = -\frac{1}{\alpha''} < 0$ . Without manipulation, the cost  $\alpha(r)$  is zero.

Using the tax haven implies a fixed cost of  $\Delta^h F$ , measured in units of labour.<sup>9</sup> This fixed cost is non-deductible from the tax base in  $i$  (it is straightforward to show that the government in  $i$  has no interest in making the fixed cost deductible as long as a switch into the haven does not increase domestic tax payments).<sup>10</sup>

The additional fixed cost  $\Delta^u F$  in case of an upgrade is deductible at a rate of  $\psi^u$ . Since the upgrade implies higher profit, the share of profit accounted for as royalty payments is increased to  $r^u$ . Taxes paid by an upgrading firm headquartered in  $i$  are thus

$$t_i(\pi_i^u - \psi_i^e F - \psi_i^u \Delta^u F) + \tau_i^u \pi_{-i}^u \quad (9)$$

$\tau_i^u = \tilde{t}_i r + t_{-i}(1 - r^u) + \alpha(r^u)$ . Total profit for a firm with an upgrade and tax haven access is thus

$$\Pi_i = \pi_i^u(1 - t_i) + \pi_{-i}^u(1 - \tau_i^u) - F(1 - \psi_i^e t_i) - (1 - \psi_i^u t_i)\Delta^u F - \Delta^h F \quad (10)$$

## 2.2 | Firm behaviour

### 2.2.1 | Market entry

Firms with negative profit do not enter the market. Assuming that the marginal firm (the one that just breaks even) neither upgrades nor uses a tax haven, its total profit is  $\Pi_i = \pi_i(1 - t_i) + \pi_{-i}(1 - t_{-i}) - F(1 - \psi_i^e t_i)$ . The threshold productivity for market entry is defined by  $\Pi(\theta^e) = 0$  and is given by

$$\bar{\theta}_i^e = \frac{1}{\sigma} \left( \frac{F(1 - \psi_i^e t_i)}{(1 - \sigma) \left( \mathbf{P}_i^{\epsilon - \frac{1}{1-\beta}} (1 - t_i) + \mathbf{P}_{-i}^{\epsilon - \frac{1}{1-\beta}} (1 - t_{-i}) \right)} \right)^{\frac{1}{\epsilon-1}} \quad (11)$$

<sup>9</sup>A fixed cost of tax haven use is one way of modelling non-monotonicities in the response to tax rate differentials. For instance, Dowd et al. (2017) find that the effect of changes in the net of tax rate of US MNE's foreign subsidiaries strongly depends on whether the subsidiary is located in a high or low tax region. They estimate an elasticity of up to 4.7 (with respect to the net of tax rate) for subsidiary profits located in tax havens and much lower responses for subsidiaries in locations with higher tax rates.

<sup>10</sup>To be precise, this case may actually occur with strong profit shifting and relatively large minimum taxes. However, even then, tax deductibility may be undesirable if the fiscal cost of it is important enough. I will ignore these cases in the following.



That is, the number of firms entering the market decreases in the fixed cost of production  $F$  and in the price levels of both countries.

With the definition of  $\bar{\theta}_i^e$ , I can write the price index  $P_i$  as follows

$$P_i = \left( \int_{\bar{\theta}_d^e}^{\theta_d^+} p(\theta)^{1-\varepsilon} d\theta + \int_{\bar{\theta}_f^e}^{\theta_f^+} p(\theta)^{1-\varepsilon} d\theta \right)^{\frac{1}{1-\varepsilon}} \quad (12)$$

### 2.2.2 | Technology upgrade

Which firms choose to upgrade? Upgrading is more attractive for more productive firms. Independent of whether the firm uses a tax haven or not it is indifferent between upgrading and not if

$$\pi_i(1-t_i) + \pi_{-i}(1-\tau_i) = \pi_i^u(1-t_i) + \pi_{-i}^u(1-\tau_i^u) - (1-\psi_i^u t_i) \Delta^u F \quad (13)$$

Note that  $\tau_i^u \leq \tau_i$  since higher IP income allows for higher royalty fees,  $r^u > r$ . If the firm uses a tax haven, this reduces the effective tax rate on foreign profit; if it does not, the effective tax rate may vary depending on the difference between  $t_i$  and  $t_{-i}$ . Let  $\bar{\theta}^u$  denote the type of firm which is indifferent between upgrading or not. The threshold is

$$\bar{\theta}_i^u = \frac{1}{\sigma} \left( \frac{(1-\psi_i^u t_i) \Delta^u F}{(1-\sigma) \left[ P_i^{\varepsilon-\frac{1}{1-\beta}} (\lambda^{\varepsilon-1} - 1) (1-t_i) + P_{-i}^{\varepsilon-\frac{1}{1-\beta}} ((1-\tau_i^u) \lambda^{\varepsilon-1} - (1-\tau_i)) \right]} \right)^{\frac{1}{\varepsilon-1}} \quad (14)$$

The upgrading threshold increases in the fixed cost parameter  $\Delta^u$  and decreases in the efficiency of R&D, measured by  $\lambda$ .

### 2.2.3 | Tax haven use

Which firms use tax havens? Consider first the case in which the marginal firm (the one being indifferent between using the tax haven and not) does not upgrade. With  $\tau_i^h = t_i^{\min} r^h + t_{-i}(1-r^h) + \alpha(r^h)$  being the tax rate on foreign profit with tax haven use and  $\tau_i = t_i r + t_{-i}(1-r)$  without, the firm is indifferent between accessing a tax haven or not, if

$$\begin{aligned} \pi_i(1-t_i) + \pi_{-i}(1-\tau_i^h) - F(1-\psi_i^e t_i) - \Delta^h F \\ = \pi_i(1-t_i) + \pi_{-i}(1-\tau_i) - F(1-\psi_i^e t_i) \end{aligned}$$

Thus, the threshold  $\bar{\theta}_i^h$  is

$$\bar{\theta}_i^h = \frac{1}{\sigma} \left( \frac{1}{(1-\sigma) P_{-i}^{\varepsilon-\frac{1}{1-\beta}}} \frac{\Delta^h F}{\tau_i - \tau_i^h} \right)^{\frac{1}{\varepsilon-1}}$$



That is, if  $\tau_i^h$  approaches  $\tau_i$ , the threshold will, at some point, reach  $\bar{\theta}^+$  and no firm will use a tax haven. The threshold with an upgrade equals  $\frac{1}{\lambda}\bar{\theta}_i^h$ .

I will restrict my attention to the case in which the firm of type  $\bar{\theta}_i^h$  has no upgrade, that is  $\bar{\theta}_i^h < \bar{\theta}_i^u$ . In the case where the tax haven threshold is among firms with upgrades,  $\bar{\theta}_i^h \geq \bar{\theta}_i^u$ , tax havens are unambiguously harmful. Therefore, this scenario is not interesting for the purpose of this study. For a better understanding, note that there is no effect on the price level if the marginal firm chooses to use the tax haven. Therefore, denying access to the tax haven for firms above the threshold  $\bar{\theta}_i^u$  does not affect the overall level of R&D. In this case, tax havens provide windfall profit for firms, which already upgrade, but imply a loss in tax revenue and wasteful concealment cost. As a consequence, each country has an incentive to set the minimum rate such that the tax haven use dries out. However, if tax havens are pervasive enough ( $\bar{\theta}^h < \bar{\theta}^u$ ), the fight against tax havens becomes hesitant, as I will show below.

### 3 | POLICY ANALYSIS

In the following, I will refer to symmetric equilibria in which policy instruments and statutory tax rates  $t_i$  are the same in both countries  $d$  and  $f$ . As a consequence,  $\pi_i = \pi_{-i}$ ,  $\pi_i^u = \pi_{-i}^u$  etc.

#### 3.1 | Government objective

I assume that governments maximise the representative household's utility

$$U_i = 1 + \Pi_i + \frac{1 - \beta}{\beta} \mathbf{P}_i^{-\frac{\beta}{1-\beta}} + \gamma B_i \quad (15)$$

The [Appendix](#) provides detailed expressions for  $\Pi_i$  and  $B_i$  under symmetry.

The following two Lemmas will prove to be useful for the subsequent analysis. The first states that, in each country, an increase in the price level reduces the representative household's utility.

**Lemma 1.** Utility  $U_i$  strictly decreases in the price level  $\mathbf{P}$ .

*Proof.* See the [Appendix](#). ■

The second Lemma states that the price level increases in  $\bar{\theta}_i^e$  and  $\bar{\theta}_i^u$  and is not affected by  $\bar{\theta}_i^h$ .

**Lemma 2.**

(i) The price level decreases in the number of firms entering the market,  $\frac{\partial \mathbf{P}}{\partial \bar{\theta}_j^e} > 0$  for  $j = d, f$ .

(ii) The price level decreases in the number of upgrading firms,  $\frac{\partial \mathbf{P}}{\partial \bar{\theta}_j^u} > 0$  for  $j = d, f$ .

(iii) The price level is unaffected by the number of haven-using firms,  $\frac{\partial \mathbf{P}}{\partial \bar{\theta}_j^h} = 0$  for  $j = d, f$ .

*Proof.* See the [Appendix](#).

### 3.2 | Optimal tax deductions for market entry and R&D

In the non-cooperative equilibrium, both countries set the deduction parameter  $\psi_i^e$  in order to maximise their representative household's utility. The first order condition is given by

$$\frac{dU_i}{d\psi_i^e} = -(\gamma - 1)t_i N_i F - \gamma t_i \left( \pi(\bar{\theta}_i^e) - \psi_i^e F \right) \frac{d\bar{\theta}_i^e}{d\psi_i^e} + \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{d\psi_i^e} = 0 \quad (16)$$

Note that  $\frac{d\mathbf{P}}{d\psi_i^e} < 0$  since  $\frac{\partial \bar{\theta}_i^e}{\partial \psi_i^e} < 0$  (see the [Appendix](#)). It follows that a country is willing to lose tax revenue with the entering firm, that is  $\pi(\bar{\theta}_i^e) - \psi_i^e F$  must be negative, if  $\gamma$  is sufficiently close to 1. How is the other country's representative household's utility affected by a small increase in  $\psi_i^e$ ?

$$\frac{dU_{-i}}{d\psi_i^e} = -\gamma t_{-i}(1 - r)\pi_{-i}(\theta) \frac{d\bar{\theta}_i^e}{d\psi_i^e} + \frac{dU_{-i}}{d\mathbf{P}} \frac{d\mathbf{P}}{d\psi_i^e} > 0 \quad (17)$$

Thus, in equilibrium, a small increase in  $\psi_i^e$  unambiguously increases welfare by exerting a positive externality on the foreign country.

A similar argument can be made for the nationally optimal R&D tax credits for R&D expenses. The first order condition for  $\psi_i^u$  is given by

$$\begin{aligned} \frac{dU_i}{d\psi_i^u} = & -(\gamma - 1)t_i n_i^u \Delta^u F - \gamma \left( (t_i + t^{\min} r^h) \left( \pi_{-i}^u(\bar{\theta}_i^u) - \pi_{-i}(\bar{\theta}_i^u) \right) - t_i \psi_i^u \Delta^u F \right) \frac{\partial \bar{\theta}_i^u}{\partial \psi_i^u} \\ & + \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{d\psi_i^u} = 0 \end{aligned} \quad (18)$$

Again, if the marginal value of public funds,  $\gamma$ , is close to 1, country  $i$  is willing to lose tax revenue with the marginal upgrading firm in order to increase consumer surplus ( $\frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{d\psi_i^u} > 0$ ).

What is the effect on the foreign country's representative household? A small increase in  $\psi_i^u$  affects  $U_{-i}$  as follows:

$$\frac{dU_{-i}}{d\psi_i^u} = -\gamma t_{-i}(1 - r^h) \left( \pi_{-i}^u(\bar{\theta}_i^u) - \pi_{-i}(\bar{\theta}_i^u) \right) \frac{d\bar{\theta}_i^u}{d\psi_i^u} + \frac{dU_{-i}}{d\mathbf{P}} \frac{d\mathbf{P}}{d\psi_i^u} > 0 \quad (19)$$

In equilibrium, a small increase in  $\psi_i^u$  unambiguously increases welfare by exerting a positive externality on the foreign household, via increased tax revenue and consumer surplus.

The following Proposition summarises these findings.

**Proposition 1.** In the policy competition equilibrium, nationally optimal tax credits for R&D and market entry are inefficiently low from a global perspective.

Tax credits for R&D (and market entry) are inefficiently low from a global perspective, because the positive cross-country externality resulting from R&D (or market entry) remains unaccounted for in the nationally optimal R&D (or market entry) incentives. Therefore, any increase in these incentives would make foreign countries better off.



The above Proposition holds independent of tax haven use. Tax havens reduce the tax burden on foreign income for all firms with tax haven access. As discussed above, if haven-using firms are a subset of upgrading firms, tax havens provide windfall profit for those already upgrading. In this case, tax havens are wasteful, since they imply a fixed cost and trigger costly profit shifting. However, if upgrading firms are a subset of haven-using firms, there is a trade-off. On the one hand, havens provide an additional incentive to engage in R&D; on the other hand, havens reduce tax revenue (which is a welfare loss as long as  $\gamma > 1$ ) and create cost (fixed access cost  $\Delta^h$  and concealment cost  $\alpha(r)$ ).<sup>11</sup>

For the following analysis, it is helpful to understand that the marginal firm's decision to use a tax haven has a negative externality on the foreign country (as long as there is profit shifting,  $r^h > r$ ):

$$\frac{\partial U_{-i}}{\partial \bar{\theta}_i^h} = \gamma t_{-i} (r^h - r) \pi_{-i} (\bar{\theta}_i^h) < 0 \quad (20)$$

The effect on the domestic representative household depends on the elasticity of profit shifting with respect to the marginal tax on foreign royalty fees:

$$\frac{\partial U_i}{\partial \bar{\theta}_i^h} = \gamma (t_i r - t^{\min} r^h) \pi_i (\bar{\theta}_i^h) \geq 0 \quad (21)$$

If  $r^h$  is much larger than  $r$ , the revenue effect may be positive (provided that  $t^{\min} > 0$ ). In this case, the domestic government has an interest in the marginal firm getting tax haven access, since it participates in the gains from profit shifting (via the minimum tax).

### 3.3 | Optimum minimum taxation

What is each country's optimal choice of the minimum tax rate? The first order condition is given by

$$\begin{aligned} \frac{dU_i}{dt_i^{\min}} = & (\gamma - 1)R_i + t^{\min} \gamma \frac{\partial R_i}{\partial t_i^{\min}} + \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{dt_i^{\min}} \\ & + \gamma (t_i r - t^{\min} r^h) \pi_{-i} (\bar{\theta}_i^u) \frac{d\bar{\theta}_i^h}{dt_i^{\min}} - \gamma \left( T_i^u (\bar{\theta}_i^u) - T_i^h (\bar{\theta}_i^u) \right) \frac{d\bar{\theta}_i^u}{dt_i^{\min}} = 0 \end{aligned} \quad (22)$$

where  $R_i = \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^{u,h}} r^h \pi_{-i} (\theta_i) d\theta + \int_{\bar{\theta}_i^{u,h}}^{\bar{\theta}_i^+} r^u \pi_{-i} (\theta_i) d\theta$  denotes royalty income from business abroad and

$\frac{\partial R_i}{\partial t_i^{\min}} = \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^{u,h}} \frac{\partial r^h}{\partial t_i^{\min}} \pi_{-i} (\theta_i) d\theta + \int_{\bar{\theta}_i^{u,h}}^{\bar{\theta}_i^+} \frac{\partial r^u}{\partial t_i^{\min}} \pi_{-i} (\theta_i) d\theta$  measures the response of royalty payments to a

small increase in  $t_i^{\min}$  (holding  $\bar{\theta}_i^{u,h}$  constant).  $T_i^u (\bar{\theta}_i^u) - T_i^h (\bar{\theta}_i^u) = t_i (\pi_i^u (\bar{\theta}_i^u) - \pi_i^h (\bar{\theta}_i^u)) + t^{\min} (r^u \pi_{-i}^u (\bar{\theta}_i^u) - r^h \pi_{-i}^h (\bar{\theta}_i^u)) - \psi_i^u \Delta^u F$  denotes the change in tax payments when the marginal firm upgrades its technology. In words, the optimum tax equates the marginal welfare effects of reallocating funds from the private to the public sector (first term), from affecting the firms' choices of royalty payments (second term), the price level (third term),

<sup>11</sup>Preferential tax regimes for returns to IP induce a similar trade-off although they have a higher fiscal cost, because they apply to domestic and foreign returns to IP.

the firms' decision to use a tax haven (fourth term) and the firms' decision to upgrade their technology (fifth term).

At first glance, it is unclear whether, at  $t_i^{\min} = 0$ , the marginal welfare effect is negative. In this case, a country would refrain from levying a minimum tax at all. The following Proposition establishes that, given the optimal choice of  $\psi_i^u$ , a country will always opt to levy strictly positive minimum taxes.

**Proposition 2.** Consider an uncoordinated competitive equilibrium with both countries optimally setting  $\psi_i^u$  and  $t_i^{\min}$ . Then, the following holds:

- (i) Each country sets a strictly positive minimum tax,  $t^{\min} > 0$ .
- (ii) If  $\gamma = 1$ , the minimum tax stays strictly below the local tax rate,  $t^{\min} < t_p$ , if royalty payments respond to a change in  $t^{\min}$  and equals the local tax rate,  $t^{\min} = t_p$ , if not.

*Proof.* See the [Appendix](#). ■

The above Proposition is noteworthy (and not as unsurprising as it may seem), since it states that a minimum tax is desirable independent of how important the R&D margin is. The intuition can be understood assuming  $\gamma = 1$ . In this case, the optimal choice of  $\psi_i^u$  optimises the welfare effects of a change in  $\bar{\theta}_i^u$ , see [Equation \(18\)](#). The minimum tax can then be used to optimise profit shifting and tax haven use. Both activities redistribute income from the public to the private sector – which is irrelevant for welfare due to  $\gamma = 1$ . However, they also imply a resource cost. Reducing both activities, therefore, is a net gain in total. However, since the foreign country reaps part of the gain (because it sees its tax base increase), the optimum minimum tax is below  $t_i$  (i.e. below the point at which profit shifting and tax haven use are eliminated). Thus, each country allows its firms some extent of tax haven use in order to provide an R&D incentive. Lower minimum taxes imply larger net benefits from investment in R&D compared to the fixed investment cost. If the marginal value of public funds increases, that is if  $\gamma > 1$ , the case for minimum taxes becomes even stronger since they imply more tax revenue than reducing  $\psi_i^u$  (the reason being that minimum taxes also affect firms that do not engage in R&D).

**Corollary 1.** If royalty payments cannot be manipulated for profit shifting purposes, a complete shutdown of tax havens is optimal, that is  $t_i^{\min} = t_p$ .

The above Corollary states that tax havens are only attractive for the residence countries if there is profit shifting at the intensive margin. The reason is that this makes the foreign country (involuntarily) contribute to the R&D incentive, because any reduction in the minimum tax implies an increase in the proportion of MNE profits that is shifted out of the country. In this case, the optimal minimum tax trades off reduced R&D incentives versus higher tax revenue. If there is no profit shifting in the narrow sense, a reduction in  $t_i^{\min}$  results solely in reduced tax revenue, therefore,  $t_i^{\min} = t_p$ .

In the setting considered here, the minimum tax has ambiguous effects on welfare: it reduces profit shifting and the firm's incentive to engage in R&D. The following Proposition clarifies how a small increase in the minimum tax affects the other country's welfare.

**Proposition 3.** In the competitive equilibrium, a small increase in the minimum tax rate has an ambiguous impact on the other country's welfare.



- (i) If upgrading is sufficiently ineffective (i.e. if  $\lambda^{\varepsilon-1}$  is sufficiently close to 1), the equilibrium minimum tax rates are inefficiently low.
- (ii) If the marginal cost of profit shifting is strongly increasing (i.e. if  $\alpha''(r)$  is sufficiently large), the equilibrium minimum tax rates are inefficiently high.

*Proof.* See the [Appendix](#). ■

The above Proposition reflects the welfare ambiguity of minimum taxation in the framework considered here. Minimum taxes curb profit shifting (thus increasing tax revenue and saving on concealment as well as fixed cost of tax haven use) but reduce R&D activities and, therefore, consumer surplus as well as tax revenue. The welfare properties of minimum taxation thus crucially depend on the relative strength of each of these channels. If upgrading is ineffective, for instance if  $\lambda = 1$ , a complete shutdown of tax havens would be desirable from a global point of view. However, by Proposition 2, each country allows some extent of tax haven use, because it increases its firm's net profit. Therefore, the foreign country would find a higher minimum tax desirable. In the latter case, profit shifting is relatively unpronounced and the positive R&D externality remains largely unaccounted for. Then, if R&D subsidies are set optimally (from the host countries perspective), the country has little incentive to provide additional R&D incentives via tax havens, resulting in excessively high minimum taxes, especially if upgrading has a strong effect on firm productivity.

The question arises, though, whether there are better instruments to foster R&D than letting firms use a tax haven. In principle, the same effect could be reached by offering a tax rebate for foreign royalty income, which would in effect imply that the MNE's host country becomes tax haven. In most countries, however, there are rules in place that stipulate the equal treatment of foreign and domestic income.

### 3.4 | IP boxes

In the following, I will explore the introduction of IP boxes, which serve as on-shore tax havens for royalty income from both, foreign and domestic sources. IP boxes can provide additional R&D incentives for MNEs by sheltering the returns to IP from taxation. In the policy debate, IP boxes are considered harmful due to their role as 'on-shore tax havens'. In this section, I investigate whether IP boxes can be welfare beneficial, in a sense similar to tax havens, that is by correcting the externality generated by positive cross-country spillovers. I find that, interestingly, IP boxes can be welfare enhancing, even in presence of minimum taxes.

I model IP boxes compliant with the criteria stated in Action 5 of the OECD's BEPS proposals. This is, preferential tax regimes can only be offered for own-developed IP and apply exclusively to direct returns to the exploitation of it.<sup>12</sup> After-tax profit of an upgrading firm is given by

$$\Pi_i = \sum_{j=df} \pi_j^u (1 - (1 - r^{IP,u})t_j - r^{IP,u}t_i^{IP} - \alpha(r^{IP,u})) - F(1 - \psi_i^e t_i) - (1 - \psi_i^u t_i)\Delta^u F \quad (23)$$

<sup>12</sup>IP boxes that only apply to foreign returns to R&D would effectively take the role of tax havens.

For now, I assume that IP boxes *replace* tax havens, that is a country has no interest in offering IP boxes *and* letting its firms use tax havens. This raises the question how the allocation with tax haven access differs from the allocation with IP boxes.

As it turns out, this question is not easily answered. A firm without tax haven access has a gain of  $\pi_i(t_i - \tau_i^{IP})$  with  $\tau_i^{IP} = (1 - r^{IP})t_i + r^{IP}t_i^{IP} + \alpha(r^{IP})$ ; the domestic government has an associated loss of  $-(t_i - t_i^{IP})r^{IP}\pi_i$  and the foreign government of  $-t_{-i}(r^{IP} - r)\pi_{-i}$ . A firm with tax haven access sees its after-tax profit change according to

$$\pi_i(t_i - \tau_i^{IP}) + \pi_{-i}(\tau_{-i}^h - \tau_{-i}^{IP}) + \Delta^h F \quad (24)$$

whereas, for the government, the difference is

$$-(t_i - t_i^{IP})r^{IP}\pi_i + (t^{IP}r^{IP} - t^{\min}r^h)\pi_{-i} \quad (25)$$

and for the foreign government this is  $-t_{-i}(r^{IP} - r^h)\pi_{-i}$ .<sup>13</sup> Due to saving the fixed setup cost associated with tax haven use, the firm may gain from the IP box (compared to using the tax haven), even if its tax payments increase compared to the situation with tax havens.

The first order condition for the tax on IP income within the box is

$$\begin{aligned} \frac{dU_i}{dt_i^{IP}} &= (\gamma - 1)(R_i^{IP} + R_{-i}^{IP}) + \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{dt_i^{IP}} \\ &+ \gamma \left( t^{IP} \frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} - (t_i - t^{IP}) \frac{\partial R_i^{IP}}{\partial t_i^{IP}} \right) - \gamma \left( T_i^{IP,u}(\bar{\theta}_i^u) - T_i^{IP}(\bar{\theta}_i^u) \right) \frac{d\bar{\theta}_i^u}{dt_i^{IP}} = 0 \end{aligned} \quad (26)$$

with

$$R_i^{IP} = \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^+} r\pi(\theta_i)d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^+} r^u\pi(\theta_i)d\theta \quad \text{and}$$

$T_i^{IP,u}(\bar{\theta}_i^u) - T_i^{IP}(\bar{\theta}_i^u) = \pi_i(\bar{\theta}_i^u) \left( ((1 - r^{IP,u})t_i + 2r^{IP,u}t_i^{IP}) - \pi_i(\bar{\theta}_i^u) \left( (1 - r^{IP})t_i + 2r^{IP}t_i^{IP} \right) - t_i\psi_i^u\Delta^u F \right)$ . I can now state the following Proposition.

**Proposition 4.** Consider the symmetric uncoordinated equilibrium with both countries optimally setting  $\psi_i^u$  and  $t_i^{IP}$ . Then, the following holds:

- (i) Each country sets a strictly positive tax on royalty income within the IP box,  $t^{IP} > 0$ .
- (ii) If  $\gamma = 1$  and if royalty shares respond to changes in the tax differential  $t_i - t_i^{IP}$ , the IP tax stays strictly below the local tax rate,  $t^{IP} < t_i$ . Under symmetry, the optimal  $t^{IP}$  equals  $\frac{t_i}{2}$ .
- (iii) If royalty payments do not respond to changes in the tax differential  $t_i - t_i^{IP}$ , there is no positive welfare effect of preferential tax treatments for royalty income within the IP box.

*Proof.* See the [Appendix](#). ■

The above proposition shows that countries find it optimal to levy a strictly positive tax on returns to R&D, regardless of how important R&D is in terms of welfare. However, especially if the

<sup>13</sup>To be precise, the changes in profit and tax revenue depend on whether the firm upgrades its technology. If the firm upgrades, the effective tax rate is  $\tau_i^{IP,u} = (1 - r^{IP,u})t_i + r^{IP,u}t_i^{IP} + \alpha(r^{IP,u})$  with  $r^{IP,u} \geq r^{IP}$ .





marginal value of public funds is low, countries find it desirable to offer preferential tax regimes for returns to R&D, if royalty shares can be manipulated. If royalty shares respond to changes in  $t^{IP}$ , a reduction in  $t^{IP}$  reduces tax revenue but increases R&D incentives. The increase in royalty shares in response to the reduced tax rate forces the foreign country to carry a fraction of the R&D incentives fiscal cost. If royalty shares are fixed, the optimal choice of  $\psi_i^u$  ensures that R&D incentives are set optimally from the host country's point of view. Preferential IP regimes only benefit the foreign country. The following proposition clarifies the effect of a small increase in  $t_i^{IP}$  on the foreign countries welfare.

**Proposition 5.** In the competitive equilibrium, a small increase in the IP tax rate has an ambiguous impact on the other country's welfare.

- (i) If upgrading is sufficiently ineffective (i.e. if  $\lambda^{\varepsilon-1}$  is sufficiently close to 1), the equilibrium IP tax rates are inefficiently low.
- (ii) If the marginal cost of profit shifting is strongly increasing (i.e. if  $\alpha''(r)$  is sufficiently large), the equilibrium IP tax rates are inefficiently high.

*Proof.* See the [Appendix](#). ■

These findings resemble my insights on the minimum tax. In the first case, the MNEs host country effectively becomes a tax haven itself, that is it chooses low IP tax rates to shelter domestic profit from foreign taxation. In the latter case, profit shifting is not sufficiently pronounced to incentivise the MNE's host country to provide additional R&D incentives.

It is not straightforward to compare the tax haven regime with the IP box regime. The IP box creates profit-shifting incentives at two margins instead of just one. In addition, due to the missing fixed cost of IP box use, more firms are attracted to this tax saving opportunity. Using the symmetry property, I can make the following statement.

**Corollary 2.** In the symmetric equilibrium, the average tax rate on royalty income is lower with IP boxes than with tax havens.

*Proof.* Proposition 2 has shown that  $t^{\min} > 0$ . Proposition 4 has shown that  $t^{IP} = \frac{t_i}{2}$ .

The average tax rate on royalty income is, thus,  $\frac{t_i + t^{\min}}{2}$  under tax havens and  $\frac{t_i}{2}$  with IP boxes. ■

Note, though, that the above Corollary does not necessarily imply that there is more technological upgrading in IP boxes. For more upgrading, it would be required that  $t_i + \tau_i^h > 2\tau_i^{IP}$ . Without profit shifting (in the sense of manipulating  $r$ ), this is implied by  $t^{IP} = \frac{t_i}{2}$ . With strong profit shifting, it is not.

### 3.5 | Coexistence of tax havens and IP boxes

So far, I have assumed that both countries' governments shut down tax havens (by setting  $t^{\min} = t_i$ ) when introducing an IP box. In this subsection, I discuss the *coexistence* of tax havens and IP boxes. Starting from  $t_i^{IP} = t_i$ , a small reduction in  $t^{IP}$  increases the after-tax profit of all

firms with royalty income,  $\theta > \bar{\theta}_i^0$ , which do not use the tax haven and lures some firms out of the tax haven. The resulting savings of fixed and concealment cost  $\alpha(r^h)$  may compensate for the loss in tax revenue. To be precise, a small increase in  $t_i^{IP}$  in the range where the marginal upgrading firm still chooses the tax haven has the following effect on utility  $U_i$ :

$$\int_{\bar{\theta}_i^0}^{\bar{\theta}_i^h} \left[ (\gamma - 1)r^{IP}(\pi_i + \pi_{-i}) - \gamma \frac{\partial r^{IP}}{\partial t^{IP}}(t - t^{IP})(\pi_i + \pi_{-i}) \right] d\theta \\ + \gamma((t - t^{\min})r^h \pi_{-i} - (t - t^{IP})r(\pi_i + \pi_{-i})) \frac{\partial \bar{\theta}_i^h}{\partial t^{IP}} \quad (27)$$

where  $(t - t^{\min})r^h \pi_{-i} - (t - t^{IP})r(\pi_i + \pi_{-i}) = \alpha(r^h)\pi_{-i} + \Delta^h F - \alpha(r)(\pi_i + \pi_{-i})$ , that is the difference in concealment cost. At  $t_i^{IP} = t_i$ , I have

$$\int_{\bar{\theta}_i^0}^{\bar{\theta}_i^h} [(\gamma - 1)r^{IP}(\pi_i(\theta_i) + \pi_{-i}(\theta_i))] d\theta + \gamma(t - t^{\min})r^h \pi_{-i}(\bar{\theta}_i^h) \frac{\partial \bar{\theta}_i^h}{\partial t^{IP}} \quad (28)$$

which is negative if  $\gamma - 1$  is sufficiently small. In this case, the government wants to introduce an IP box. If Equation (27) holds with equality for some  $\bar{\theta}_i^h < \bar{\theta}_i^u$ , IP boxes and tax havens coexist in the equilibrium. In this case, IP boxes are not intended to increase R&D, but rather to mitigate the private cost from using a tax haven.

Now, consider the case in which the IP box is attractive enough such that the marginal upgrading firm is in it. In this case, the tax haven threshold is above the upgrading threshold,  $\bar{\theta}_i^h > \bar{\theta}_i^u$ . In this case, a small increase in  $t_i^{IP}$  has the following effect on utility:

$$\frac{dU_i}{dt^{IP}} = (\gamma - 1)(R_i^{IP} + R_{-i}^{IP}) + \gamma \left( t^{IP} \frac{\partial R_{-i}^{IP}}{\partial t^{IP}} - (t_i - t^{IP}) \frac{\partial R_i^{IP}}{\partial t^{IP}} \right) \\ + \gamma \left( (t - t^{\min})r^{u,h} \pi_{-i}(\bar{\theta}_i^h) - (t - t^{IP})r^u \left( \pi_i(\bar{\theta}_i^h) + \pi_{-i}(\bar{\theta}_i^h) \right) \right) \frac{\partial \bar{\theta}_i^h}{\partial t^{IP}} \\ - \gamma \left( T^u(\bar{\theta}_i^u) - T^h(\bar{\theta}_i^u) \right) \frac{d\bar{\theta}_i^u}{dt^{IP}} + \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{dt^{IP}} \quad (29)$$

with  $R_i^{IP} = \int_{\bar{\theta}_i^0}^{\bar{\theta}_i^u} r^{IP} \pi_i(\theta_i) d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^h} r^{IP,u} \pi_i(\theta_i) d\theta$  and  $R_{-i}^{IP} = \int_{\bar{\theta}_i^0}^{\bar{\theta}_i^u} r^{IP} \pi_{-i}(\theta_i) d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^h} r^{IP,u} \pi_{-i}(\theta_i) d\theta$ . If

the above equation holds with equality for some  $\bar{\theta}_i^h < \theta^+$ , coexistence of IP box and tax haven exists if the optimal minimum tax satisfies the following condition for some  $t_i^{\min} < t_i$ :

$$\frac{dU_i}{dt^{\min}} = (\gamma - 1)R_i^h + t^{\min} \gamma \frac{\partial R_i^h}{\partial t^{\min}} \\ + \gamma \left( (t - t^{\min})r^{u,h} \pi_{-i}(\bar{\theta}_i^h) - (t - t^{IP})r^u \left( \pi_i(\bar{\theta}_i^h) + \pi_{-i}(\bar{\theta}_i^h) \right) \right) \frac{d\bar{\theta}_i^h}{dt^{\min}} = 0 \quad (30)$$

with  $R_i^h = \int_{\bar{\theta}_i^h}^{\theta^+} r^h \pi_{-i}(\theta_i) d\theta$  and  $\frac{\partial R_i^h}{\partial t^{\min}} = \int_{\bar{\theta}_i^h}^{\theta^+} \frac{\partial r^h}{\partial t^{\min}} \pi_{-i}(\theta_i) d\theta$ . In this case, tax havens are not intended

to foster R&D, but rather to mitigate the public cost from offering IP boxes. As in the initial setting,



this implies that tax havens serve as a means of incentivising R&D at the expense of foreign tax revenue. Whether or not tax havens are beneficial in this case is ambiguous, depending on the welfare effects of R&D.

## 4 | CONCLUSION

In the above analysis, I considered optimal minimum taxation and optimal taxation of IP income (within boxes) in a setting, in which R&D is suboptimally low. The foreign country benefits from R&D investments made by domestic MNEs. Due to this externality, R&D and market entry incentives set by the countries are inefficiently low in equilibrium. Tax havens are a tool to make the foreign country contribute to the R&D incentive. Therefore, shutting down tax havens completely may reduce welfare. Interestingly, tax havens and IP boxes are only interesting as a policy instrument if the firm shifts profit at the intensive margin (i.e. if it manipulates royalty shares). This forces the foreign country to involuntarily contribute to the R&D incentive. In this setting, I show that, despite the reduction in R&D incentives and independent of the relative strength of the R&D and the profit-shifting channel, the optimal minimum tax is strictly positive. I find that uncoordinated minimum taxes on MNE profits may be excessively high, especially if R&D activity by MNEs has a strong impact on productivity.

In practice, IP boxes often serve as on-shore tax havens. In this paper, I show that, as tax havens, IP boxes can be beneficial in presence of positive cross-country spillovers. In fact, IP boxes may be welfare enhancing substitutes for tax havens, because they are better targeted towards firms that actually invest in R&D. In this restricted sense, I suggest that IP boxes and minimum taxes may be complementary, because preferential tax regimes for returns to IP are a tool to mitigate the reduction in investment incentives resulting from a crackdown on tax havens. However, IP boxes may be inferior to tax havens due to their higher fiscal cost (more firms are eligible, and both, foreign and domestic IP income benefit from the preferential tax treatment). As tax havens, IP boxes are only interesting for the government as a policy instrument, if they attract tax base from the foreign country.

My model is built upon the assumption that tax havens only attract foreign profit. I relax this assumption in the analysis of IP boxes, which apply to all returns to R&D. I show that, under certain circumstances, policymakers still find preferential tax regimes for MNEs desirable. Whilst there are some structural differences between tax havens and IP boxes, this allows me to conclude that my results remain intact if domestic profit can be shifted to tax havens.

This paper analyses a setting in which R&D incentives for MNEs are inefficiently low resulting from positive cross-country spillovers of R&D by MNEs. In this scenario, tax havens (and IP boxes) are only beneficial, because they internalise the R&D externality as they force foreign countries to contribute to the R&D incentive. Other mechanisms, for instance coordinated international subsidies for R&D by MNEs, would also be suited to overcome the inefficiency. However, this requires a high level of cooperation between countries and is, therefore, unlikely to be sustainable. Additionally, there is a number of concerns to the political feasibility of direct subsidies to foreign MNEs. I argue that tax havens and preferential tax treatments of returns to IP can serve as a feasible and easy to enforce second best solution to overcome existing inefficiencies in the provision of R&D incentives for MNEs.

## ACKNOWLEDGEMENTS

I thank Johannes Becker and participants at the 2022 ZEW Public Finance Conference, 2022 Mannheim Taxation Conference, the 2023 Ghent Conference on International Taxation, the 2023 IIPF Annual Congress, the 2024 PET conference and research seminars at the universities of Münster and Tübingen for their valuable feedback. I declare no conflict of interest. The usual disclaimer applies. Open Access funding enabled and organized by Projekt DEAL.

## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

## ORCID

Malte Lüttmann  <https://orcid.org/0000-0003-2081-336X>

## REFERENCES

- Baumann, M., Boehm, T., Knoll, B., & Riedel, N. (2020). Corporate taxes, patent shifting, and anti-avoidance rules: Empirical evidence. *Public Finance Review*, 48(4), 467–504.
- Becker, J., & Riedel, N. (2012). Cross-border tax effects on affiliate investment—Evidence from European multinationals. *European Economic Review*, 56(3), 436–450.
- Beer, S., de Mooij, R., & Liu, L. (2020). International corporate tax avoidance: A review of the channels, magnitudes and blind spots. *Journal of Economic Surveys*, 34(3), 660–688.
- Bustos, P. (2011). Trade liberalization, exports, and technology upgrading: Evidence on the impact of MERCOSUR on Argentinian firms. *The American Economic Review*, 101(1), 304–340.
- de Mooij, R. A., & Liu, L. X. (2020). At a cost: The real effects of transfer pricing regulations. *IMF Economic Review*, 68, 268–306.
- Desai, M. A., Foley, C. F., & Hines, J. R. (2006). The demand for tax haven operations. *Journal of Public Economics*, 90(3), 513–531.
- Desai, M. A., Foley, C. F., & Hines, J. R. (2009). Domestic effects of the foreign activities of US multinationals. *American Economic Journal: Economic Policy*, 1(1), 181–203.
- Dowd, T., Landefeld, P., & Moore, A. (2017). Profit shifting of U.S. multinationals. *Journal of Public Economics*, 148, 1–13.
- Dyrda, S., Hong, G., & Steinberg, J. B. (2022). *A macroeconomic perspective on taxing multinational enterprises*. University of Toronto Working Paper.
- Hebous, S., & Keen, M. (2023). Pareto-improving minimum corporate taxation. *Journal of Public Economics*, 225, 104952.
- Heckemeyer, J. H., & Overesch, M. (2017). Multinationals' profit response to tax differentials: Effect size and shifting channels. *Canadian Journal of Economics/Revue Canadienne d'économique*, 50(4), 965–994.
- Helpman, E., Melitz, M. J., & Yeaple, S. R. (2004). Export versus FDI with heterogeneous firms. *American Economic Review*, 94(1), 300–316.
- Hindriks, J., & Nishimura, Y. (2021). *Why minimum corporate income taxation can make the high-tax countries worse off: The compliance dilemma*. Discussion Papers in Economics and Business 21-10, Osaka University, Graduate School of Economics.
- Hong, Q., & Smart, M. (2010). In praise of tax havens: International tax planning and foreign direct investment. *European Economic Review*, 54(1), 82–95.
- Johannessen, N. (2010). Imperfect tax competition for profits, asymmetric equilibrium and beneficial tax havens. *Journal of International Economics*, 81(2), 253–264.
- Johannessen, N. (2022). The global minimum tax. *Journal of Public Economics*, 212(104709), 1–8.
- Keen, M. (2001). Preferential regimes can make tax competition less harmful. *National Tax Journal*, 54(4), 757–762.
- Kiss, Á. (2012). Minimum taxes and repeated tax competition. *International Tax and Public Finance*, 19(5), 641–649.



- Köthenbürger, M., Liberini, F., & Stimmelmayer, M. (2018). *Is it just luring reported profit? The case of European patent boxes*. CESifo Working Papers No 7061.
- Kovak, B. K., Oldenski, L., & Sly, N. (2021). The labor market effects of offshoring by U.S. multinational firms. *The Review of Economics and Statistics*, 103(2), 381–396.
- Marceau, N., Mongrain, S., & Wilson, J. D. (2010). Why do most countries set high tax rates on capital? *Journal of International Economics*, 80(2), 249–259.
- Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6), 1695–1725.
- Mohnen, P., Vankan, A., & Verspagen, B. (2017). Evaluating the innovation box tax policy instrument in The Netherlands, 2007–13. *Oxford Review of Economic Policy*, 33(1), 141–156.
- Mongrain, S., Oh, D., & van Ypersele, T. (2020). Tax competition in presence of profit shifting. *SSRN Electronic Journal*.
- Mongrain, S., & Wilson, J. D. (2018). Tax competition with heterogeneous capital mobility. *Journal of Public Economics*, 167, 177–189.
- Mutti, J., & Grubert, H. (2009). The effect of taxes on royalties and the migration of intangible assets abroad. In M. Reinsdorf & M. J. Slaughter (Eds.), *International trade in services and intangibles in the era of globalization*. University of Chicago Press.
- Peralta, S., & van Ypersele, T. (2006). Coordination of capital taxation among asymmetric countries. *Regional Science and Urban Economics*, 36(6), 708–726.
- Schwab, T., & Todtenhaupt, M. (2021). Thinking outside the box: The cross-border effect of tax cuts on R&D. *Journal of Public Economics*, 204, 104536.
- Slemrod, J., & Wilson, J. D. (2009). Tax competition with parasitic tax havens. *Journal of Public Economics*, 93(11), 1261–1270.
- Suárez Serrato, J. C. (2018). *Unintended consequences of eliminating tax havens*. National Bureau of Economic Research Working Paper Series, No. 24850.
- Tørsløv, T., Wier, L., & Zucman, G. (2022). The missing profits of nations. *The Review of Economic Studies*, 90(3), 1499–1534.

**How to cite this article:** Lüttmann, M. (2024). Taxation of MNE profits in an R&D driven economy: Beneficial tax havens and minimum taxes. *The World Economy*, 47, 4061–4087. <https://doi.org/10.1111/twec.13621>

## APPENDIX

### Expressions for $B_i$ and $\Pi_i$

Tax revenue in country  $i$  is given by

$$\begin{aligned}
 B_i = & t_i \left( \int_{\bar{\theta}_i^e}^{\bar{\theta}_i^u} \pi_i(\theta_i) d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \pi_i^u(\theta_i) d\theta - \psi_i^e N_i F - n_i^u \psi_i^u \Delta F \right) \\
 & + t_i r \int_{\bar{\theta}_i^e}^{\bar{\theta}_i^h} \pi_{-i}(\theta_i) d\theta + t^{\min} r^h \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} \pi_{-i}(\theta_i) d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \pi_{-i}^u(\theta_i) d\theta \right) \\
 & + t_i (1-r) \int_{\bar{\theta}_i^e}^{\bar{\theta}_{-i}^h} \pi(\theta_{-i}) d\theta + t_i (1-r^h) \left( \int_{\bar{\theta}_{-i}^h}^{\bar{\theta}_{-i}^u} \pi_i(\theta_{-i}) d\theta + \int_{\bar{\theta}_{-i}^u}^{\bar{\theta}^+} \pi_i^u(\theta_{-i}) d\theta \right)
 \end{aligned}$$

With  $\pi = (1 - \sigma)(p(\omega))^{1-\varepsilon} \mathbf{P}^{\varepsilon - \frac{1}{1-\beta}}$ , I can write, using symmetry,

$$B = t_i(1 - \sigma)\mathbf{P}^{-\frac{\beta}{1-\beta}} - (t_i - t^{\min})r^h \left( \int_{\bar{\theta}^h}^{\bar{\theta}^u} \pi_i(\theta)d\omega + \int_{\bar{\theta}^u}^{\bar{\theta}^+} \pi_i^u(\theta)d\omega \right) - t_i(\psi^e N_i + n_i^u \psi^u \Delta)F$$

where  $N_i$  denotes the domestic number of firms in the market and  $n_i^u$  the number of firms with upgrades.

Total net profit of domestic firms is

$$\begin{aligned} \Pi_i = (1 - t_i) & \left( \int_{\bar{\theta}_i^e}^{\bar{\theta}_i^u} \pi_i(\theta_i)d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^+} \left( \pi_i^u(\theta_i) - \left( \frac{1 - t_i \psi_i^u}{1 - t_i} \right) \Delta^u F \right) d\theta \right) - (1 - \psi_i^e t_i) N_i F \\ & + (1 - \tau_i) \left( \int_{\bar{\theta}_i^e}^{\bar{\theta}_i^u} \pi_{-i}(\theta_i)d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^+} \pi_{-i}^u(\theta_i)d\theta \right) - n_i^h \Delta^h F \end{aligned}$$

which can be expressed (under symmetry) as

$$\begin{aligned} \Pi_i = (1 - t_i)(1 - \sigma)\mathbf{P}^{-\frac{\beta}{1-\beta}} & - (1 - \psi_i^e t_i) N_i F + (1 - \psi_i^u t_i) n_i^u \psi^u \Delta^u F \\ & + ((t_i - t^{\min})r^h - \alpha(r^h)) \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} \pi_{-i}(\theta_i)d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^+} \pi_{-i}^u(\theta)d\theta \right) - n_i^h \Delta^h F \end{aligned}$$

where  $n_i^h$  denotes the number of firms with tax haven access.

### Proof of Lemma 1

Under symmetry,

$$U_i = 1 + \Pi_i + \frac{1 - \beta}{\beta} \mathbf{P}_i^{-\frac{\beta}{1-\beta}} + \gamma B_i$$

i.e.

$$\begin{aligned} U_i = 1 + (1 + (\gamma - 1)t_i)(1 - \sigma)\mathbf{P}^{-\frac{\beta}{1-\beta}} & - (1 + (\gamma - 1)\psi_i^e t_i) N_i F - (1 + (\gamma - 1)\psi_i^u t_i) n_i^u \Delta^u F \\ & - \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} [(\gamma - 1)(t_i - t^{\min})r^h + \alpha(r^h)] \pi_{-i}(\theta_i)d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^+} [(\gamma - 1)(t_i - t^{\min})r^u + \alpha(r^u)] \pi_{-i}^u(\theta)d\theta \right) \\ & - n_i^h \Delta^h F + \frac{1 - \beta}{\beta} \mathbf{P}_i^{-\frac{\beta}{1-\beta}} \end{aligned}$$



Now, consider an exogenous increase in the price level  $\mathbf{P}$ . The price level affects utility directly and indirectly via the threshold  $\bar{\theta}_i^e$ ,  $\bar{\theta}_i^h$  and  $\bar{\theta}_i^u$ . The effect of is given by

$$\begin{aligned} \frac{\partial U_i}{\partial \mathbf{P}} = & -\left(1 + (\gamma - 1)t_i\right) \frac{\beta}{1 - \beta} \mathbf{P}^{-\frac{1}{1-\beta}} \\ & - \left(\varepsilon - \frac{1}{1 - \beta}\right) \mathbf{P}^{-1} \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} [(\gamma - 1)(t_i - t^{\min})r^h + \alpha(r^h)] \pi(\theta_i) d\theta \right. \\ & \left. + \int_{\bar{\theta}_i^e}^{\bar{\theta}_i^u} [(\gamma - 1)(t_i - t^{\min})r^u + \alpha(r^u)] \pi^u(\theta_i) d\theta \right) \\ & + \frac{\partial U_i}{\partial \bar{\theta}_i^e} \frac{\partial \bar{\theta}_i^e}{\partial \mathbf{P}} + \frac{\partial U_i}{\partial \bar{\theta}_i^h} \frac{\partial \bar{\theta}_i^h}{\partial \mathbf{P}} + \frac{\partial U_i}{\partial \bar{\theta}_i^u} \frac{\partial \bar{\theta}_i^u}{\partial \mathbf{P}} - \mathbf{P}^{-\frac{1}{1-\beta}} \end{aligned}$$

with

$$\begin{aligned} \frac{\partial U_i}{\partial \bar{\theta}_i^e} &= (1 + (\gamma - 1)\psi_i^e t_i) F > 0 \\ \frac{\partial U_i}{\partial \bar{\theta}_i^h} &= \Delta^h F + [(\gamma - 1)(t_i - t^{\min})r^h + \alpha(r^h)] \pi_{-i}(\bar{\theta}_i^h) \\ \frac{\partial U_i}{\partial \bar{\theta}_i^u} &= (1 + (\gamma - 1)\psi_i^u t_i) \Delta^u F + \left( \begin{aligned} & [(\gamma - 1)(t_i - t^{\min})r^u + \alpha(r^u)] \pi_{-i}^u(\bar{\theta}_i^u) - \\ & [(\gamma - 1)(t_i - t^{\min})r^h + \alpha(r^h)] \pi_{-i}(\bar{\theta}_i^u) \end{aligned} \right) \end{aligned}$$

With  $\pi_{-i}((t_{-i} - t^{\min})r^h - \alpha(r^h)) = \Delta^h F$  and  $(1 - \psi_i^u t_i) \Delta^u F = (\pi_i^u - \pi_i)(1 - t_i) + [(1 - \tau_i^u) \pi_{-i}^u - (1 - \tau_i) \pi_{-i}]$  follows

$$\begin{aligned} \frac{\partial U_i}{\partial \bar{\theta}_i^h} &= [\gamma(t_i - t^{\min})r^h] \pi_{-i}(\bar{\theta}_i^h) > 0 \\ \frac{\partial U_i}{\partial \bar{\theta}_i^u} &= \gamma \psi_i^u t_i \Delta^u F + \left( \pi_i^u(\bar{\theta}_i^u) - \pi_i(\bar{\theta}_i^u) \right) (1 - t_i) + \left[ \begin{aligned} & (1 - t_i + \gamma(t_i - t^{\min})r^u) \pi_{-i}^u(\bar{\theta}_i^u) \\ & - (1 - t_i + [\gamma(t_i - t^{\min})r^h]) \pi_{-i}(\bar{\theta}_i^u) \end{aligned} \right] > 0 \end{aligned}$$

With all three thresholds decreasing in  $\mathbf{P}$ , I may conclude that an increase in  $\mathbf{P}$  unambiguously drives down welfare.

## Proof of Lemma 2

The price level is a function of individual prices and thresholds  $\bar{\theta}_i^e$  and  $\bar{\theta}_i^u$ :

$$\mathbf{P} = \left( \sum_i \left( \int_{\bar{\theta}_i^e}^{\bar{\theta}_i^u} p(\theta)^{1-\varepsilon} d\omega + \int_{\bar{\theta}_i^u}^{\bar{\theta}_i^+} p(\theta)^{1-\varepsilon} d\omega \right) \right)^{\frac{1}{1-\varepsilon}}$$



with  $\bar{\theta}_i^e = \frac{1}{\sigma} \left( \frac{F \frac{1-\psi_i^e t_i}{1-t_i}}{2(1-\sigma) \mathbf{P}^{\epsilon-1-\beta}} \right)^{\frac{1}{\epsilon-1}}$  and  $\bar{\theta}_i^u = \left[ \frac{\frac{2(1-t_i)}{1-t_i+1-\tau_i} \frac{1-\psi_i^u t_i}{1-\psi_i^e t_i} \Delta^u}{\lambda^{\epsilon-1}-1} \right]^{\frac{1}{\epsilon-1}} \bar{\theta}_i^e$ . Total differentiation with respect to

all variables and some domestic variable  $x^u$  and  $x^e$ :

$$\begin{aligned} d\bar{\theta}_d^{u,h} &= \frac{\partial \bar{\theta}_d^u}{\partial x^u} dx^u + \frac{\bar{\theta}_d^u}{\bar{\theta}_d^e} d\bar{\theta}_d^e \quad \text{and} \quad d\bar{\theta}_f^{u,h} = \frac{\bar{\theta}_f^u}{\bar{\theta}_f^e} d\bar{\theta}_f^e \\ d\bar{\theta}_d^e &= -\frac{1}{\epsilon-1} \bar{\theta}_d^e \frac{1}{\mathbf{P}} \left( \epsilon - \frac{1}{1-\beta} \right) d\mathbf{P} + \frac{\partial \bar{\theta}_d^e}{\partial x^e} dx^e \\ d\bar{\theta}_f^e &= -\frac{1}{\epsilon-1} \bar{\theta}_f^e \frac{1}{\mathbf{P}} \left( \epsilon - \frac{1}{1-\beta} \right) d\mathbf{P} \\ d\mathbf{P} &= \frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^u)^{1-\epsilon} (\lambda^{\epsilon-1}-1) d\bar{\theta}_i^u + \frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^e)^{1-\epsilon} d\bar{\theta}_i^e \end{aligned}$$

It follows

$$d\bar{\theta}_d^{u,h} = \left[ 1 - \frac{\frac{1}{\epsilon-1} \mathbf{P}^{\epsilon-1} \frac{\epsilon-1}{\epsilon-1} p(\bar{\theta}_d^u)^{1-\epsilon} (\lambda^{\epsilon-1}-1) \bar{\theta}_d^u}{1 + \frac{1}{\epsilon-1} \mathbf{P}^{\epsilon-1} \frac{\epsilon-1}{\epsilon-1} \left( \sum_i p(\bar{\theta}_i^u)^{1-\epsilon} (\lambda^{\epsilon-1}-1) \bar{\theta}_i^u + p(\bar{\theta}_i^e)^{1-\epsilon} \bar{\theta}_i^e \right)} \right] \frac{\partial \bar{\theta}_d^u}{\partial x^u} dx^u$$

Note that  $x^u$  and  $x^e$  may be identical (e.g.  $x^u = x^e = F$ ) or different. It follows

$$\begin{aligned} d\mathbf{P} &= \frac{1}{\epsilon-1} \mathbf{P}^\epsilon p(\bar{\theta}_d^u)^{1-\epsilon} (\lambda^{\epsilon-1}-1) \frac{\partial \bar{\theta}_d^u}{\partial x} dx^u + \frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^e)^{1-\epsilon} \frac{\partial \bar{\theta}_i^e}{\partial x^e} dx^e \\ &+ \frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^u)^{1-\epsilon} (\lambda^{\epsilon-1}-1) \frac{\bar{\theta}_i^u}{\bar{\theta}_i^e} d\bar{\theta}_i^e + -\frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^e)^{1-\epsilon} \frac{1}{\epsilon-1} \bar{\theta}_i^e \frac{1}{\mathbf{P}} \left( \epsilon - \frac{1}{1-\beta} \right) d\mathbf{P} \end{aligned}$$

and

$$\begin{aligned} d\mathbf{P} &= \frac{1}{\epsilon-1} \mathbf{P}^\epsilon p(\bar{\theta}_d^u)^{1-\epsilon} (\lambda^{\epsilon-1}-1) \frac{\partial \bar{\theta}_d^u}{\partial x} dx^u + \frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^e)^{1-\epsilon} \frac{\partial \bar{\theta}_i^e}{\partial x^e} dx^e \\ &+ \frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^u)^{1-\epsilon} (\lambda^{\epsilon-1}-1) \frac{\bar{\theta}_i^u}{\bar{\theta}_i^e} \frac{\partial \bar{\theta}_i^e}{\partial x^e} dx^e \\ &- \frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^u)^{1-\epsilon} (\lambda^{\epsilon-1}-1) \frac{\bar{\theta}_i^u}{\bar{\theta}_i^e} \frac{1}{\epsilon-1} \bar{\theta}_i^e \frac{1}{\mathbf{P}} \left( \epsilon - \frac{1}{1-\beta} \right) d\mathbf{P} \\ &- \frac{1}{\epsilon-1} \mathbf{P}^\epsilon \sum_i p(\bar{\theta}_i^e)^{1-\epsilon} \frac{1}{\epsilon-1} \bar{\theta}_i^e \frac{1}{\mathbf{P}} \left( \epsilon - \frac{1}{1-\beta} \right) d\mathbf{P} \end{aligned}$$

which can be summarised as



$$d\mathbf{P} = \frac{\frac{1}{\varepsilon-1} \mathbf{P}^\varepsilon p(\bar{\theta}_d^u)^{1-\varepsilon} (\lambda^{\varepsilon-1} - 1) \frac{\partial \bar{\theta}_d^u}{\partial x} dx^u + \frac{1}{\varepsilon-1} \mathbf{P}^\varepsilon \left( \sum_i p(\bar{\theta}_i^e)^{1-\varepsilon} \left( 1 + (\lambda^{\varepsilon-1} - 1) \frac{\bar{\theta}_i^u}{\bar{\theta}_i^e} \right) \right) \frac{\partial \bar{\theta}_d^e}{\partial x^e} dx^e}{1 + \frac{1}{\varepsilon-1} \mathbf{P}^\varepsilon \frac{1}{\mathbf{P}} \frac{1}{\varepsilon-1} \left( \varepsilon - \frac{1}{1-\beta} \right) \left( \sum_i \left( p(\bar{\theta}_i^u)^{1-\varepsilon} (\lambda^{\varepsilon-1} - 1) \bar{\theta}_i^u + p(\bar{\theta}_i^e)^{1-\varepsilon} \bar{\theta}_i^e \right) \right)}$$

Thus, if  $x^u \neq x^e$  affects  $\bar{\theta}_d^u$ , but not  $\bar{\theta}_d^e$ ,

$$\begin{aligned} \frac{d\mathbf{P}}{dx^u} &= \text{sign} \left( \frac{\partial \bar{\theta}_d^u}{\partial x^u} \right) \quad \text{if } x^u \neq x^e \\ \frac{d\mathbf{P}}{dx^e} &= \text{sign} \left( \frac{\partial \bar{\theta}_d^e}{\partial x^e} \right) \quad \text{if } x^u \neq x^e \end{aligned}$$

If  $x^u = x^e = x$ ,  $\frac{d\mathbf{P}}{dx}$  has the same sign as  $\frac{\partial \bar{\theta}_d^u}{\partial x}$  and  $\frac{\partial \bar{\theta}_d^e}{\partial x}$ , provided that the latter two have the same sign (e.g.  $x^u = x^e = F$ ).

Thus, it follows that

$$\frac{d\mathbf{P}}{d\psi_i^u} = \frac{\frac{\partial \bar{\theta}_d^u}{\partial \psi_i^u}}{\frac{\partial \bar{\theta}_d^u}{\partial t_i^{\min}}} \frac{d\mathbf{P}}{dt_i^{\min}}$$

## Proof of Proposition 2

*Proof.* The first order condition with respect to  $\psi_i^u$  is

$$\begin{aligned} \frac{dU_i}{d\psi_i^u} &= -(\gamma-1)t_i \Delta^u F \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} d\theta + \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{d\psi_i^u} \\ &\quad - \gamma \left( (t_i + t^{\min} r^h) \left( \pi_i^u(\bar{\theta}_i^u) - \pi_i(\bar{\theta}_i^u) \right) - t_i \psi_i^u \Delta^u F \right) \frac{d\bar{\theta}_i^u}{d\psi_i^u} = 0 \end{aligned}$$

From  $\frac{\partial \bar{\theta}_i^u}{\partial \psi_i^u} = -\frac{t_i}{1-\psi_i^u t_i} \bar{\theta}_i^u$  and  $\frac{\partial \bar{\theta}_i^u}{\partial t_i^{\min}} = \frac{\lambda^{\varepsilon-1} r^u - r^h}{(1-t_i)(\lambda^{\varepsilon-1}-1) + (1-\tau_i^u)\lambda^{\varepsilon-1} - (1-\tau_i)} \bar{\theta}_i^u$  follows

$$\frac{d\bar{\theta}_i^u}{d\psi_i^u} = -\frac{t_i}{(1-\psi_i^u t_i)} \frac{(1-t_i)(\lambda^{\varepsilon-1}-1) + (1-\tau_i^u)\lambda^{\varepsilon-1} - (1-\tau_i)}{\lambda^{\varepsilon-1} r^u - r^h} \frac{d\bar{\theta}_i^u}{dt_i^{\min}}.$$

Using this and  $\frac{d\mathbf{P}}{d\psi_i^u} = \frac{\frac{\partial \bar{\theta}_d^u}{\partial \psi_i^u}}{\frac{\partial \bar{\theta}_d^u}{\partial t_i^{\min}}} \frac{d\mathbf{P}}{dt_i^{\min}} = -\frac{t_i}{(1-\psi_i^u t_i)} \frac{(1-t_i)(\lambda^{\varepsilon-1}-1) + (1-\tau_i^u)\lambda^{\varepsilon-1} - (1-\tau_i)}{\lambda^{\varepsilon-1} r^u - r^h} \frac{d\mathbf{P}}{dt_i^{\min}}$ , it

follows for the above equation

$$\begin{aligned} & - (1-\psi_i^u t_i) \frac{\lambda^{\varepsilon-1} r^u - r^h}{(1-t_i)(\lambda^{\varepsilon-1}-1) + (1-\tau_i^u)\lambda^{\varepsilon-1} - (1-\tau_i)} (\gamma-1) \Delta^u F \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} d\theta \\ & = \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{dt_i^{\min}} - \gamma \left( (t_i + t^{\min} r^h) \left( \pi_i^u(\bar{\theta}_i^u) - \pi_i(\bar{\theta}_i^u) \right) - t_i \psi_i^u \Delta^u F \right) \frac{d\bar{\theta}_i^u}{dt_i^{\min}} \end{aligned}$$

Plug the right hand side into the first order condition for the minimum tax in Equation (22):

$$\begin{aligned} \frac{dU_i}{dt_i^{\min}} = & \left[ (\gamma - 1)r^h + t^{\min} \gamma \frac{\partial r^h}{\partial t_i^{\min}} \right] \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} \pi_{-i}(\theta_i) d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \pi_{-i}^u(\theta_i) d\theta \right) + \gamma (t_i r - t^{\min} r^h) \pi_{-i}(\bar{\theta}_i^h) \frac{d\bar{\theta}_i^h}{dt_i^{\min}} \\ & - (1 - \psi_i^u t_i) \frac{\lambda^{\varepsilon-1} r^u - r^h}{(1 - t_i)(\lambda^{\varepsilon-1} - 1) + (1 - \tau_i^u) \lambda^{\varepsilon-1} - (1 - \tau_i)} (\gamma - 1) \Delta^u F \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} d\theta \\ & = 0 \end{aligned}$$

and rewrite:

$$\begin{aligned} \frac{dU_i}{dt_i^{\min}} = & (\gamma - 1) \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} r^h \pi_{-i}(\theta_i) d\theta + r^u \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \left[ \pi_{-i}^u(\theta_i) - \frac{\lambda^{\varepsilon-1} - \frac{r^h}{r^u} (1 - \psi_i^u t_i) \Delta^u F}{(1 - t_i)(\lambda^{\varepsilon-1} - 1) + (1 - \tau_i^u) \lambda^{\varepsilon-1} - (1 - \tau_i)} \right] d\theta \right) \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} d\theta \\ & + t^{\min} \gamma \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} \frac{\partial r^h}{\partial t_i^{\min}} \pi_{-i}(\theta_i) d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \frac{\partial r^u}{\partial t_i^{\min}} \pi_{-i}^u(\theta_i) d\theta \right) + \gamma (t_i r - t^{\min} r^h) \pi_{-i}(\bar{\theta}_i^h) \frac{d\bar{\theta}_i^h}{dt_i^{\min}} = 0 \end{aligned}$$

From the indifference condition for  $\bar{\theta}_i^u$  follows:

$$[(\lambda^{\varepsilon-1} - 1)(1 - t_i) + (1 - \tau_i^u) \lambda^{\varepsilon-1} - (1 - \tau_i)] \pi_i(\bar{\theta}_i^u) = (1 - \psi_i^u t_i) \Delta^u F$$

Replacing  $(1 - \psi_i^u t_i) \Delta^u F$  above gives:

$$\begin{aligned} \frac{dU_i}{dt_i^{\min}} = & (\gamma - 1) \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} r^h \pi_{-i}(\theta_i) d\theta + r^u \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \left[ \pi_{-i}^u(\theta_i) - \left( \lambda^{\varepsilon-1} - \frac{r^h}{r^u} \right) \pi_i(\bar{\theta}_i^u) \right] d\theta \right) \\ & + t^{\min} \gamma \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} \frac{\partial r^h}{\partial t_i^{\min}} \pi_{-i}(\theta_i) d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \frac{\partial r^u}{\partial t_i^{\min}} \pi_{-i}^u(\theta_i) d\theta \right) + \gamma (t_i r - t^{\min} r^h) \pi_{-i}(\bar{\theta}_i^h) \frac{d\bar{\theta}_i^h}{dt_i^{\min}} = 0 \end{aligned}$$

The expression in the first line is positive as long as  $\gamma > 1$ . Therefore, consider the case of  $\gamma = 1$ . Then, at  $t^{\min} = 0$ , the marginal welfare impact of increasing the minimum rate equals

$t_i r \pi_{-i}(\bar{\theta}_i^h) \frac{d\bar{\theta}_i^h}{dt_i^{\min}} > 0$ . (ii) At  $\gamma = 1$  and  $t_i^{\min} = t_i$ , the first order condition reads

$t_i \frac{\partial r^h}{\partial t_i^{\min}} \left( \int_{\bar{\theta}_i^h}^{\bar{\theta}_i^u} \pi_{-i}(\theta_i) d\theta + \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \pi_{-i}^u(\theta_i) d\theta \right) < 0$ . With  $\frac{\partial r^h}{\partial t_i^{\min}} = 0$ , this expression is zero, from

which follows that  $t_i^{\min} = t_i$  is optimal. ■

### Proof of Proposition 3

*Proof.* A small increase of the minimum tax has the following effect on the other country's welfare:



$$\begin{aligned} \frac{dU_{-i}}{dt_{i,\min}^h} = & -\gamma t_{-i} \frac{\partial R_i}{\partial t_{i,\min}^h} + \frac{dU_{-i}}{d\mathbf{P}} \frac{d\mathbf{P}}{dt_{i,\min}^h} + \gamma t_{-i} (r^h - r) \pi_{-i}(\bar{\theta}_i^h) \frac{d\bar{\theta}_i^h}{dt_{i,\min}^h} \\ & - \gamma t_{-i} \left( (1 - r^u) \pi_{-i}^u(\bar{\theta}_i^u) - (1 - r^h) \pi_{-i}(\bar{\theta}_i^u) \right) \frac{d\bar{\theta}_i^u}{dt_{i,\min}^h} \end{aligned}$$

(i) If  $\lambda^{\varepsilon-1}$  is sufficiently close to 1,  $\bar{\theta}_i^u > \theta^+$ , there is no firm opting for upgrades (in this sense, the R&D channel is shut down). Then,  $\pi_i^u(\theta) = \pi_i(\theta)$  and  $\frac{d\mathbf{P}}{dt_{i,\min}^h} = 0$ . The remaining parts of the right hand side of the above equation are unambiguously positive. (ii) If  $\alpha''(r)$  is sufficiently large,  $\frac{\partial r^h}{\partial t_{i,\min}^h} = -\frac{1}{\alpha''}$  as well as  $r^h - r$  are small. For  $\alpha''(r) \rightarrow \infty$ , both expressions approach zero. In this case, remaining parts of the right hand side of the above equation are unambiguously negative. ■

## Proof of Proposition 4

*Proof.* The first order condition with respect to  $\psi_i^u$  is

$$\frac{dU_i}{d\psi_i^u} = -(\gamma - 1)t_i \Delta^u F \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} d\theta + \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{d\psi_i^u} - \gamma \left( T^{IP,u}(\bar{\theta}_i^u) - T^{IP}(\bar{\theta}_i^u) \right) \frac{d\bar{\theta}_i^u}{d\psi_i^u} = 0$$

With IP boxes, the R&D threshold is  $\bar{\theta}_i^u = \left[ \frac{(1-t_i) \left( \frac{1-\psi_i^u t_i}{1-\psi_i^{\varepsilon} t_i} \right) \Delta^u}{(1-\tau_i^{IP,u}) \lambda^{\varepsilon-1} - (1-\tau_i^{IP})} \right]^{\frac{1}{\varepsilon-1}} \bar{\theta}_i^e$ . From

$$\frac{\partial \bar{\theta}_i^u}{\partial \psi_i^u} = -\frac{1}{\varepsilon-1} \frac{t_i}{1-\psi_i^u t_i} \bar{\theta}_i^u \quad \text{and} \quad \frac{\partial \bar{\theta}_i^u}{\partial t_i^{IP}} = \frac{1}{\varepsilon-1} \frac{\lambda^{\varepsilon-1} r^{IP,u} - r^{IP}}{(1-\tau_i^{IP,u}) \lambda^{\varepsilon-1} - (1-\tau_i^{IP})} \bar{\theta}_i^u \quad \text{follows}$$

$$\frac{d\bar{\theta}_i^u}{d\psi_i^u} = -\frac{t_i}{(1-\psi_i^u t_i)} \frac{\left( (1-\tau_i^{IP,u}) \lambda^{\varepsilon-1} - (1-\tau_i^{IP}) \right)}{\lambda^{\varepsilon-1} r^{IP,u} - r^{IP}} \frac{d\bar{\theta}_i^u}{dt_i^{IP}}. \quad \text{Using this and}$$

$$\frac{d\mathbf{P}}{d\psi_i^u} = \frac{\frac{\partial \bar{\theta}_i^u}{\partial \psi_i^u} \frac{d\mathbf{P}}{d\bar{\theta}_i^u}}{\frac{\partial \bar{\theta}_i^u}{\partial t_i^{IP}} \frac{d\mathbf{P}}{dt_i^{IP}}} = -\frac{t_i}{(1-\psi_i^u t_i)} \frac{\left( (1-\tau_i^{IP,u}) \lambda^{\varepsilon-1} - (1-\tau_i^{IP}) \right)}{\lambda^{\varepsilon-1} r^{IP,u} - r^{IP}} \frac{d\mathbf{P}}{dt_i^{IP}}, \quad \text{it follows for the above}$$

equation

$$\begin{aligned} & - (1-\psi_i^u t_i) \frac{\lambda^{\varepsilon-1} r^{IP,u} - r^{IP}}{\left( (1-\tau_i^{IP,u}) \lambda^{\varepsilon-1} - (1-\tau_i^{IP}) \right)} (\gamma - 1) \Delta F \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} d\theta \\ & = \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{dt_i^{IP}} - \gamma \left( T^{IP,u}(\bar{\theta}_i^u) - T^{IP}(\bar{\theta}_i^u) \right) \frac{\partial \bar{\theta}_i^u}{dt_i^{IP}} = 0 \end{aligned}$$

Plug the right hand side into the first order condition in Equation (26):

$$\frac{dU_i}{dt_i^{IP}} = (\gamma - 1)(R_i^{IP} + R_{-i}^{IP}) - \frac{\lambda^{\varepsilon-1} r^{IP,u} - r^{IP}}{\left( (1 - \tau_i^{IP,u}) \lambda^{\varepsilon-1} - (1 - \tau_i^{IP}) \right)} (\gamma - 1) (1 - \psi_i^u t_i) \Delta^u F \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} d\theta \\ + \gamma \left( t_i^{IP} \frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} - (t_i - t^{IP}) \frac{\partial R_i^{IP}}{\partial t_i^{IP}} \right) = 0$$

and rewrite:

$$\frac{dU_i}{dt_i^{IP}} = (\gamma - 1) \left( \int_{\bar{\theta}_i^0}^{\bar{\theta}_i^u} r^{IP} \pi_i(\theta_i) d\theta \right. \\ \left. + r^{IP,u} \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \left[ \pi_i^u(\theta_i) - \frac{\lambda^{\varepsilon-1} - \frac{r^{IP}}{r^{IP,u}}}{\left( (1 - \tau_i^{IP,u}) \lambda^{\varepsilon-1} - (1 - \tau_i^{IP}) \right)} (1 - \psi_i^u t_i) \Delta^u F \right] d\theta + R_i^{IP} \right) \\ + \gamma \left( t_i^{IP} \frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} - (t_i - t^{IP}) \frac{\partial R_i^{IP}}{\partial t_i^{IP}} \right) = 0$$

From the indifference condition for  $\bar{\theta}_i^u$  follows:

$$2 \left[ (1 - \tau_i^{IP,u}) \lambda^{\varepsilon-1} - (1 - \tau_i^{IP}) \right] \pi_i(\bar{\theta}_i^u) = (1 - \psi_i^u t_i) \Delta^u F$$

Replacing  $(1 - \psi_i^u t_i) \Delta^u F$  above gives:

$$\frac{dU_i}{dt_i^{IP}} = (\gamma - 1) \left( \int_{\bar{\theta}_i^0}^{\bar{\theta}_i^u} r^{IP} \pi(\theta_i) d\theta + r^{IP,u} \int_{\bar{\theta}_i^u}^{\bar{\theta}^+} \left[ \pi^u(\theta_i) - \left( \lambda^{\varepsilon-1} - \frac{r^{IP}}{r^{IP,u}} \right) 2\pi_i(\bar{\theta}_i^u) \right] d\theta + R_i^{IP} \right) \\ + \gamma \left( t_i^{IP} \frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} - (t_i - t^{IP}) \frac{\partial R_i^{IP}}{\partial t_i^{IP}} \right) = 0$$

The expression in the first line is positive as long as  $\gamma > 1$ . Therefore, consider the case of  $\gamma = 1$ . Then, at  $t^{IP} = 0$ , the marginal welfare impact of increasing the tax rate equals

$-t_i \frac{\partial R_i^{IP}}{\partial t_i^{IP}} > 0$ . At  $\gamma = 1$  and  $t^{IP} = t_i$ , the first order condition reads  $t_i \frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} = 0 < 0$ . With

$\frac{\partial R_i^{IP}}{\partial t_i^{IP}}, \frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} = 0$ , this expression is zero, from which follows that the introduction of the IP

box has no welfare effect. If  $\frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} = \frac{\partial R_i^{IP}}{\partial t_i^{IP}}$ , optimality implies  $t^{IP} = \frac{t_i}{2}$ . ■

## Proof of Proposition 5

*Proof.* A small increase of the IP tax has the following effect on the other country's welfare:

$$\frac{dU_{-i}}{dt_i^{IP}} = \frac{dU_i}{d\mathbf{P}} \frac{d\mathbf{P}}{dt_i^{IP}} - \gamma \left( T_{-i}^{IP,u}(\bar{\theta}_i^u) - T_{-i}^{IP}(\bar{\theta}_i^u) \right) \frac{d\bar{\theta}_i^u}{dt_i^{IP}} - \gamma t_{-i} \frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} \quad (31)$$



$$T_{-i}^{IP,u}(\bar{\theta}_i^u) - T_{-i}^{IP}(\bar{\theta}_i^u) = t_{-i}((1-r^u)\pi_{-i}^u - (1-r)\pi_{-i}) > 0 \quad \text{and} \quad \frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}} = \int_{\bar{\theta}_i^0}^{\bar{\theta}_i^{u,h}}$$

$\frac{\partial r^{IP}}{\partial t_i^{IP}} \pi(\theta_i) d\theta + \int_{\bar{\theta}_i^{u,h}}^{\bar{\theta}_i^+} \frac{\partial r^{IP,u}}{\partial t_i^{IP}} \pi^u(\theta_i) d\theta < 0$ . (i) If  $\lambda^{\varepsilon-1}$  is sufficiently close to 1,  $\bar{\theta}_i^u > \theta^+$ , there is no firm opting for upgrades (in this sense, the R&D channel is shut down). Then,  $T_{-i}^{IP,u}(\bar{\theta}_i^u) = T_{-i}^{IP}(\bar{\theta}_i^u)$  and  $\frac{dP}{dt_i^{IP}} = 0$ . The remaining parts of the right hand side of the above equation are unambiguously positive. (ii) If  $\alpha''(r)$  is sufficiently large,  $\frac{\partial r^{IP}}{\partial t_i^{IP}} = -\frac{1}{\alpha''}$  as well as  $\frac{\partial R_{-i}^{IP}}{\partial t_i^{IP}}$  are small. For  $\alpha''(r) \rightarrow \infty$ , both expressions approach zero. In this case, remaining parts of the right hand side of the above equation are unambiguously negative. ■