

# THINKING INSIDE THE BOX: POLICIES TOWARDS FOOTLOOSE R&D INTENSIVE FIRMS

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## Abstract

We develop a model with a large R&D-intensive home firm that must decide whether to locate production domestically or to offshore it. Policymakers have an interest in the firm's profits, the local external benefits generated by the firm's R&D and the employment provided by the domestic production facility. We demonstrate that attempts to boost the firm's R&D can encourage the firm to offshore its production. Hence, we highlight a possible conflict between two policy objectives: encouraging local R&D and discouraging the offshoring of production. In addition, if the government is concerned about the employment large domestic firms create, its R&D policy could potentially harm future productivity growth.

*Keywords:* Corporate tax rates; Multinational firms; Offshoring; R&D subsidies.

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# 1 Introduction

In an era characterised by increasing globalisation, governments have often expressed concern about domestic firms offshoring production to destinations abroad. At the same time as articulating an uneasiness with the offshoring activities of their multinational enterprises (MNEs), policy makers are also often eager to implement policies that improve productivity in order to guarantee economic growth, often targeting research and development (R&D) intensive firms (OECD, 2008). Empirical evidence confirms that the vast majority of R&D is undertaken by large MNEs –the same firms that are responsible for most of the offshoring activity.<sup>1</sup> In fact, large R&D intensive MNEs have recently been described in the literature as ‘superstar firms’ (Mayer and Ottaviano (2007); Neary (2010)). There is an increased realisation, both in the academic community and among policy makers, that these corporate superstars, though only a small minority among all active firms, essentially drive the performance of some countries.<sup>2</sup> In addition, empirical studies also suggest that there are potential spillovers from R&D intensive MNEs to local firms; these tend to be largest if firms are geographically nearby and are operating in closely related sectors (Bloom, Schankerman and Van Reenen, 2005; Cassiman and Veugelers, 2002; Aldieri and Cincera, 2009).<sup>3</sup> It is therefore not surprising that policy makers are, both in terms of their rhetoric and actual policy stance, in favour of policies that are geared towards retaining domestic production of their large corporations and stimulating their R&D activities.

In this paper we derive the optimal package of direct and indirect R&D support policies when R&D intensive firms are footloose. While the optimal policy mix sometimes involves setting taxes and R&D subsidies to ensure retention of MNEs’ activities, this is not always the national welfare maximising policy. In particular, we examine the interdependence between the optimal R&D subsidy and the optimal effective corporate tax rate faced by R&D intensive corporations.

There is a good reason for looking at the interdependence between these two policy instruments. Apart from offering substantial direct government funding for R&D (OECD, 2017), several countries have –in an attempt to target activities of R&D intensive R&D- adopted (or are considering adopting) patent or innovation box regimes.<sup>4</sup> A patent box regime effectively reduces the corporate

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<sup>1</sup>It is a stylised fact that only a few firms are responsible for the bulk of R&D expenditures. According to a recent report by Booz and Company (2012), “The Global Innovation 1000”, the top 100 biggest R&D spenders worldwide accounted for 62% of total R&D spending. Computing and Electronics companies alone accounted for 28% of total R&D spending. Other big R&D spenders are the healthcare and automobile sectors. All these sectors are dominated by a few big players.

<sup>2</sup>The importance of large firms in international markets has also been discussed in the economic press (see, for instance, a relatively recent article in *The Economist* (“Big is Back”, August 27, 2009).

<sup>3</sup>However, there seems to be a wide variation in the estimates of the magnitude of these spillovers across host countries.

<sup>4</sup>This is true for several European countries. China also has a IP box regime. Other countries (e.g., US, Australia) are debating whether or not to adopt one.

tax rate on income earned from certain forms of intellectual property, in particular from patents.<sup>5</sup> In many cases, there is no requirement for R&D to be carried out locally or indeed by the company itself (the innovation may, for instance, have been acquired through a licensing agreement).<sup>6</sup> By contrast, direct R&D government support (such as R&D subsidies) typically is conditional on R&D being carried out in the subsidising jurisdiction and on the actual magnitude of the R&D that is locally undertaken.

Our paper adds to the literature on corporate taxation, R&D incentives and location decisions by MNEs.<sup>7</sup> While the academic literature has examined the effects of corporate tax rates and R&D incentives, it so far has not provided an insight into the characteristics of the optimal mix of corporate tax rate and R&D incentives governments should have in place. Our paper aims to offer a first step in answering this question, which –given that more countries are debating whether or not to adopt a IP box regime - is highly relevant in the current policy debate on corporate taxation.

Our basic model features a large firm that must decide whether to offshore its production to reap the benefits from a production cost advantage abroad or remain at home avoiding the relocation cost. Local production generates domestic employment, while local R&D may generate some local positive spillovers. The government of the firm’s domestic country aims to encourage local R&D by subsidising R&D. It may also attempt to retain the firm’s activities by setting a favourable corporate tax rate. In an extended version of the model, the firm’s R&D activities are also mobile and offshoring R&D also becomes a possibility. We examine how the optimal package of R&D subsidy and corporate tax rate is affected by the firm’s offshoring options.

In section 2 of the paper, the basic model is presented. Section 3 discusses the firm’s optimal output and R&D decisions. Section 4 deals with the firm’s location choice and the government’s optimal policy mix when the firm’s R&D is immobile. Section 5 extends the discussion by allowing for mobile R&D activities. Section 6 concludes.

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<sup>5</sup>Evers et al. (2014) conclude that the treatment of expenses related to intellectual property income is important in determining the effective tax burden.

<sup>6</sup>Most patent box countries allow acquired IP to qualify. So, if a firm licenses intellectual property from another organization and then generates income from that IP, it is taxed at the lower patent box rate. Exceptions are the IP box regimes in the Netherlands and Spain (Atkinson and Andes (2011)).

<sup>7</sup>Grüber (2003), investigating the link between intangible income, income-shifting and location choice for US parent manufacturing companies and their subsidiaries, finds that R&D intensive parent companies respond to opportunities for income-shifting. Ernst and Spengel (2011) found that the number of patent applications are negatively affected by the corporate tax rate but respond positively to R&D tax incentives. This finding is echoed in a comprehensive study on R&D tax incentives (EC, 2014). In fact, empirical work suggests that MNEs have an incentive to locate intangible assets, and patents in particular, in affiliates in low-tax locations to minimise tax payments (e.g., Dischinger and Riedel (2011), Karkinsky and Riedel (2012) and Griffith et al. (2014)).

## 2 The model

Consider a large and potentially multinational firm (MNE) that produces for an integrated market and engages in R&D to reduce its production cost or make its product more attractive to consumers. The firm has initially located both its production and R&D in the home country ( $h$ ) and is wholly owned by residents of that country. However, the firm must decide whether to continue to operate at home or to offshore some or all of its activities to another country ( $f$ ). We allow for it to choose where to locate its R&D and where to produce. If it decides to operate in the other country, then it will pay set up costs. The firm might decide to concentrate both its production and R&D activities in the same location and locate both activities either domestically or abroad. Alternatively, it might carry out one of the activities in  $h$  and the other one in  $f$ . For simplicity and to avoid the analysis becoming excessively taxonomical, we rule out locational fragmentation within an activity: the same activity, either production or R&D, is not spread across a domestic subsidiary and a subsidiary abroad.

The government in  $h$  wants to put in place a policy package aimed at influencing the firm's innovative activity and location decisions. The policy mix that it considers consists of a corporate profit tax rate,  $t$ , with  $0 \leq t < 1$  and a per unit R&D subsidy,  $s$ .<sup>8</sup> The government wishes to boost the firm's domestic R&D because of potential spillovers to the rest of the home economy. However, it faces the possibility that the MNE will offshore its production and/or its R&D. The loss of production activities may be costly particularly if there is significant domestic unemployment.

We denote the firm's after-tax profits by  $\Pi^{ij}$  and its pre-tax profit as  $\pi^{ij}$ . Here and henceforth, when variables have double superscripts, the first superscript,  $i$  ( $i = h, f$ ), refers to the location of production and the second superscript,  $j$  ( $j = h, f$ ), is the location of R&D. When a firm locates its production and R&D activities in the same country ( $i = j$ ), it pays –by default– taxes in that country. Hence, after-tax profits can be written as  $\Pi^{hh} = (1 - t)\pi^{hh}$  when all the firms' activities are located in  $h$ , and as  $\Pi^{ff} = (1 - \tau)\pi^{ff}$  when all the firms' activities are located in  $f$ , with  $\tau$  denoting the corporate tax rate in  $f$ .

When a firm carries out its production activities in a different country from the country in which it sets up its R&D plant, it potentially pays taxes in both locations. Suppose the proportion  $\rho$  of a firm's pre-tax profit is subject to corporate tax in country  $h$  and the remainder,  $(1 - \rho)$ , in country  $f$ , then  $\Pi^{ij} = [(1 - t)\rho + (1 - \tau)(1 - \rho)]\pi^{ij}$ , where  $j \neq i$ . We assume that the firm can transfer-price between the two locations and will do so in an attempt to lower its tax burden as much as it can.<sup>9</sup> In doing so, it chooses  $\rho$ . Simplifying, we assume that the firm is unconstrained in setting  $\rho$  in the unit interval. This implies that it chooses  $\rho = 1$  if  $t < \tau$  and chooses  $\rho = 0$  if  $t > \tau$ . Hence, the expression for  $\Pi^{ij}$  simplifies to  $(1 - t)\pi^{ij}$  if  $t < \tau$  and  $(1 - \tau)\pi^{ij}$  if  $t > \tau$ . This is merely a simplifying assumption and, provided the firm has some ability to transfer price

<sup>8</sup>We do not consider negative corporate tax rates or negative R&D subsidies here.

<sup>9</sup>Davies et al. (2014) shows evidence that large MNEs engage in transfer pricing.

and can thus affect  $\rho$ , constraining the choice of  $\rho$  does not qualitatively alter our main results but does complicate the analysis considerably and reduces the transparency of the results.

It proves useful to abstract from domestic consumption and assume that the firm sells its output on an integrated export market. To obtain explicit solutions we assume that the firm faces a linear inverse demand:

$$p = a - q \quad (1)$$

where  $p$  is the price and  $q$  is the quantity sold. Marginal production costs are constant in output but depend on the production location. We can write it as  $c^i$ . One possibility is that R&D is cost reducing (i.e., process R&D) and we assume it affects costs in a simple linear way:  $c^{ij} = \bar{c}^i - x^{ij}$  where  $x^{ij}$  represents the reduction in marginal production cost generated by the R&D the firm undertakes. The superscripts indicate that this cost and cost reduction generated is specific to the firm's location choices. Alternatively, R&D might be demand enhancing when we can write the demand intercept as  $a^{ij} = \bar{a} + x^{ij}$ , where  $\bar{a}$  is a constant component. Writing the demand intercept as  $a^{ij}$  indicates that it depends on the level of product innovation which depends on where the firm's R&D and production activities are located. Henceforth, we will refer to  $x^{ij}$  as the level of innovation by the firm. R&D expenditure is represented by  $k^{ij}$ . To ensure an interior solution, R&D expenditure,  $k^{ij}$  is convex in  $x^{ij}$ , with  $k^{ij} = (x^{ij})^2/2\eta^j$ , hence  $x^{ij} = \sqrt{2\eta^j k^{ij}}$ , where  $\eta^j$  can be interpreted as the effectiveness of R&D.

The market potential of the firm depends positively on the demand intercept  $a$ , which is a measure of the market size, and negatively on marginal production costs. We can write  $A^i = a - \bar{c}^i$  and hence  $a^{ij} - c^{ij} = A^i + x^{ij}$ . Note that this way of writing the effect of innovation on the market potential of the firm is consistent with R&D being demand enhancing or cost reducing or both.

The pre-tax profits of a firm that produces in country  $i$  and carries out its R&D in country  $j$  ( $\pi^{ij}$ ) are given by:

$$\pi^{ij} = (p - c^i)q - (x^2/2\eta^j) + s^j x - \chi F - \psi G \quad (2)$$

where  $\chi$  and  $\psi$  are indicator variables with  $\chi = 0$  if  $i = h$  and  $\chi = 1$  if  $i = f$ , whereas  $\psi = 0$  if  $j = h$  and  $\psi = 1$  if  $j = f$ . This is the case because, since the MNE has not yet set up a production facility in country  $f$ , it will need to incur a fixed set-up cost of  $F$ , while it will incur a fixed set-up cost of  $G$  when it wants to set up R&D operations in country  $f$ .

The government of country  $h$  maximises welfare, which –for now– consists of the firm's post-tax profits ( $\Pi^{ij}$ ), tax revenue ( $t\pi^{ij}$ ) and the external social benefit from having R&D carried out in its territory minus the R&D subsidy cost. Hence, the expression for welfare in the different location combinations is given by:

|          |  |                               |
|----------|--|-------------------------------|
| $W^{ij}$ | $j = h$                                      | $j = f$                       |
| $i = h$  | $\Pi^{hh} + t\pi^{hh} + (\beta - s)x$        | $\Pi^{hf} + \theta t\pi^{hf}$ |
| $i = f$  | $\Pi^{fh} + \theta t\pi^{fh} + (\beta - s)x$ | $\Pi^{ff}$                    |

(3)

where  $\theta$  is an indicator variable with  $\theta = 1$  for  $t \leq \tau$  and  $\theta = 0$  otherwise;  $\beta$  is a non-negative parameter measuring the social benefit from a unit of local R&D (capturing, for instance, R&D spillovers from R&D to other local businesses or employment in the R&D sector).

The model consists of three stages. In the first stage, the government decides on its corporate tax rate and R&D subsidy. In the second stage, the firm decides whether to produce in  $h$  or abroad and it also decides whether to carry out its R&D in the domestic country or abroad. If it decides to carry out an activity abroad it must sink a fixed activity-specific investment cost. In the final stage, the firm decides how much output to produce and how much R&D to carry out.

### 3 The Firm's Output and R&D

The firm's first-order condition for output is:

$$A^i - 2q + x = 0 \quad (4)$$

Hence, output depends on both the level of innovation,  $x$ , and on the location of production which determines  $A^i$ . The first-order condition for R&D is:

$$q - \frac{x}{\eta^j} + s^j = 0 \quad (5)$$

where  $j$  is the R&D location and  $s^j$  is the R&D subsidy in location  $j$ . Combining expressions (4) and (5), we obtain:

$$q^{ij} = \frac{A^i + \eta^j s^j}{2 - \eta^j} \quad (6)$$

and

$$x^{ij} = \eta^j (q^{ij} + s^j) = \eta^j \frac{A^i + 2s^j}{2 - \eta^j} \quad (7)$$

where  $i$  is the location of production and  $j$  is the R&D location. To ensure that the second-order conditions hold, we impose  $\eta^j < 2$ .

Next, we use expressions (6) and (7) in the expression for pre-tax profits to obtain the maximised profits of the firm in each of the possible location constellations, resulting in:

$$\pi^{ij} = \frac{1}{(2 - \eta^j)} \left( \frac{(A^i)^2}{2} + \eta^j (A^i + s^j) s^j \right) - (\chi F + \psi \Phi) \quad (8)$$

Since we focus on the relationship between the two policy instruments of country  $h$ , we treat the policy variables of country  $f$  as exogenous. Having defined  $\tau$  as the corporate tax rate in  $f$ , we set the foreign R&D subsidy  $s^f$ —without loss of generality—equal to zero. This allows us to simply denote country  $h$ 's policy variables by  $s$  and  $t$ , respectively. In the next section we first determine the location pattern of the firm for different levels of country  $h$ 's R&D subsidy and corporate tax rate. We then discuss how country  $h$  can choose these to maximise welfare.

## 4 Footloose Production but Immobile R&D

For expositional clarity, we first assume that the MNE's R&D activities are immobile (hence,  $j = h$ ). This could, for instance, be the case when the firm feels the intellectual property rights system in  $f$  is inadequate or R&D is much more effective at home than abroad. Still, while the firm will not relocate its R&D activity in this section, it does consider offshoring its production.

### 4.1 The Firm's Location Decision

The firm will offshore production if doing so means that its after-tax profits are higher, that is, if  $\Pi^{fh} - \Pi^{hh} > 0$ . Clearly, the sign of this difference depends on the differences in corporate tax rates and pre-tax profits. When comparing pre-tax profits, the firm does not only compare the difference in operating profits but also takes into account the fixed cost of setting up a plant in the foreign country. Operating profits are affected by marginal costs. We will focus on a scenario that is usually the most policy relevant case in the sense that it tends to generate a considerable political and policy angst: the home economy faces the possibility that its multinational may offshore production to a lower-cost foreign location.<sup>10</sup> Given that the firm must pay a fixed cost to offshore production, it may consider to do so if the prospective host country has a low marginal production cost. Hence, we assume  $\bar{c}^h > \bar{c}^f$ .

Figure 1 represents the location decision of the firm in  $(s, t)$ -space with  $\bar{c}^h > \bar{c}^f$ . We start the exposition of Figure 1 at the point where the government of country  $h$  does not intervene (i.e., at  $t = 0$  and  $s = 0$ ). At  $t = 0$  and  $s = 0$ , the firm does not consider relocating production. In fact, the fixed cost of setting up a plant in  $f$  is high enough for the firm to keep producing in  $h$  in spite of the fact that there is a marginal cost advantage when producing in  $f$ . Suppose now that the government of  $h$  wants to encourage R&D in its jurisdiction by subsidising R&D. Then, there exists a critical R&D subsidy, denoted by  $\bar{s}$ , at which the firm's pre-tax profits in  $fh$  and  $hh$  are equal ( $\pi^{fh} = \pi^{hh}$ ). Since its R&D stays in  $h$ , the firm can –even if it produces abroad– shift its profits to  $h$  for tax purposes by engaging in transfer pricing, and will do so as long as  $t \leq \tau$ . Thus, at  $\bar{s}$ , for  $t \leq \tau$ , not only pre-tax but also after-tax profits are equal ( $\Pi^{fh} = \Pi^{hh}$ ), implying that the firm is indifferent between maintaining production at home or offshoring. Since R&D is always carried out in  $h$ , an increase in the R&D subsidy encourages innovation and raises pre-tax profit whether the firm offshores production or not. However, it raises pre-tax profit more if the firm offshores as the return to innovation is higher in that case because of the lower production cost abroad.<sup>11</sup> So, when the R&D subsidy is relatively low ( $s < \bar{s}$ ), an increase in the R&D subsidy raises both the firm's local

<sup>10</sup>Obviously, if the home economy has a marginal production cost advantage over other location, there is no cost incentive for the firm to relocate abroad.

<sup>11</sup>Lower marginal production costs imply a higher price to cost margin and hence the increased output resulting from the innovation is more profitable to the firm. Thus the return to innovation is larger when the underlying marginal costs are lower.

R&D and local production ( $\pi^{fh} < \pi^{hh}$ ), but once the R&D subsidy exceeds a critical level,  $\bar{s}$ , the firm will, while further increasing local R&D, offshore its production ( $\pi^{fh} > \pi^{hh}$ ), even if the tax rate in  $h$  lies below the one abroad. Importantly, when domestic R&D subsidy levels are high ( $s > \bar{s}$ ), the level of the domestic corporate tax rate cannot influence the firm's production location choice.

[Figure 1 about here]

By contrast, the relative domestic tax rate does affect the firm's decision whether or not to offshore production when the domestic R&D subsidy is relatively low ( $s < \bar{s}$ ). In that case, the firm will not want to offshore production ( $\Pi^{fh} < \Pi^{hh}$ ), thereby also automatically foregoing the opportunity to transfer price, but only when the domestic tax rate is not too high. More specifically, when  $s < \bar{s}$ , there exists a critical threshold, denoted by  $\bar{t}$ , for which  $(1 - \bar{t})\pi^{hh} = (1 - \tau)\pi^{fh}$  holds; it is thus given by:

$$\bar{t} = 1 - (1 - \tau) \frac{\pi^{fh}}{\pi^{hh}} \quad (9)$$

Provided  $t < \bar{t}$ , the firm will not offshore production, but will do so for  $t > \bar{t}$ . Since both  $\pi^{fh}$  and  $\pi^{hh}$  increase in the R&D subsidy  $s$ ,  $\bar{t}$  also depends on  $s$ . In fact, since  $s$  raises pre-tax profit more if the firm offshores than when it keeps production in  $h$ , the critical home tax rate  $\bar{t}$  is falling in  $s$ .

In short, an attempt by the government of  $h$  to support innovation makes it harder to retain production and encourages the firm to become footloose. Note that in Figure 1 we depict the interesting case in which  $\bar{s}$  is positive, giving raise to the area  $hh$ . It should be pointed out that if the cost advantage of the offshore location is large enough, the threshold  $\bar{s}$  is no longer positive and the area  $hh$  vanishes (i.e.,  $\pi^{fh} > \pi^{hh}$  is always the case).

## 4.2 Optimal Policy Mix

Given that, in this section, the firm is assumed to always carry out his R&D activities in  $h$  ( $j = h$ ), country  $h$ 's government only needs to determine the optimal policy mix when production is retained ( $hh$ ) and when it is not ( $fh$ ). The government will then compare welfare levels,  $W^{hh}$  and  $W^{fh}$ , choosing the higher one of the two. When doing so, it needs to bear in mind that the subsidy-tax combination can, when critical thresholds are crossed, affect the firm's production location decision and its decision where to pay its taxes.

The corporate tax does *directly* affect the jurisdiction in which taxes are paid. It is optimal for the government in  $h$  to set the tax rate so that the firm will not declare and pay its taxes in  $f$ . Given that the firm pays its taxes in  $h$ , the firm's tax payments and government's tax revenues cancel, implying that welfare can be written as:

$$W^{ih} = \pi^{ih} + (\beta - s)x^{ih} \quad (10)$$

Using expression (10) for welfare, the first-order condition for the  $h$ 's optimal R&D subsidy is:

$$\frac{dW^{ih}}{ds} = \frac{d\pi^{ih}}{ds} + (\beta - s) \frac{dx^{ih}}{ds} - x^{ih} = 0 \quad (11)$$

Since  $\frac{d\pi^{ih}}{ds} = \pi_s^{ih} + \pi_q^{ih} \frac{dq^{ih}}{ds} + \pi_x^{ih} \frac{dx^{ih}}{ds}$ , where subscripts denote partial derivatives,  $\pi_q^{ih} = 0$  and  $\pi_x^{ih} = 0$  from the final stage and  $\pi_s^{ih} = x^{ih}$ . The optimal subsidy (denoted by an asterisk) for location combination  $hh$  and  $fh$  is the same and is given by:

$$s^{hh*} = s^{fh*} = \beta \quad (12)$$

So, regardless of whether country  $h$  retains the MNE's production or not, the optimal R&D subsidy in the absence of a government concern for employment, is fully determined by the level of the local R&D spillover.

Since,  $s^{ih*} = \beta$ , maximised welfare, using expression (12), reduces to  $W^{ih*} = \pi^{ih}$ . Hence, it follows that  $W^{hh} = W^{fh}$  will occur at the same R&D subsidy threshold at which  $\pi^{hh} = \pi^{fh}$  (i.e., at  $s = \bar{s}$ ). So, when the optimal subsidy is  $\bar{s}$ , we have  $W^{hh}(\bar{s}) = W^{fh}(\bar{s})$ . The spillover value for which  $\bar{s}$  is the optimal subsidy is  $\beta'$ . This case is shown in Figure 2(b). For relatively high R&D spillover values ( $\beta > \beta'$ ),  $W^{fh} > W^{hh}$  (see Figure 2(c)) and hence the government accommodates the firm's decision to produce in  $f$ , setting its R&D subsidy equal to the R&D spillover and undercutting country  $f$ 's corporate tax rate ( $t \leq \tau$ ) (as shown in the lower panel of Figure 2(c)) to capture the firm's tax payments. If the subsidy is small, which will occur when the R&D spillover is small ( $\beta < \beta'$  as is the case in Figure 2(a)), the firm wishes to maintain its production in  $h$ . Locating both R&D and production in  $h$  implies that the firm cannot use transfer pricing to shift profits across different locations and the government can now set a higher corporate tax rate than the one prevailing in  $f$ . In fact, for  $\beta < \beta'$ , the government of  $h$  can set a  $t \leq \bar{t}$ , where  $\bar{t}$  is the tax rate at which the firm is indifferent between the two locations. Note that as  $\beta$  gets closer to  $\beta'$ , the R&D subsidy increases too, increasing the potential operating profits in  $f$  faster than the ones in  $h$ , and hence decreasing  $h$ 's government ability to extract rent from the firm: the optimal corporate tax rate in  $h$  decreases as the R&D spillover, and hence the R&D subsidy, rises.

[Figure 2 about here]

## 5 Mobile R&D and Production

So far we have assumed R&D is immobile. Indeed, if the fixed cost of setting up a R&D facility,  $G$ , is relatively high and there is no or only a very small countervailing relative marginal cost advantage of doing R&D abroad ( $\eta^f - \eta^h > 0$ , but small), the MNE will always choose to carry out his R&D domestically and a location pattern like the one discussed in section 4 will emerge, implying a qualitatively identical optimal policy mix. However, there is an increasing trend

in some sectors to source R&D abroad. In this section, we extend our analysis to allow for this possibility. This would occur if the fixed cost of setting up a R&D facility abroad is sufficiently low, while the relative effectiveness of R&D is sufficiently higher abroad than in the domestic location. As in the previous section, we first determine the firm's location pattern and subsequently discuss country  $h$ 's optimal policy mix when there is full employment and when there is considerable unemployment in the country.

### 5.1 The Firm's Location Decision

The MNE's location pattern for parameters that allow the representation of all four location combinations on one diagram is depicted in Figure 3. In particular, we assume  $\eta^f > \eta^h$  in the figure. It proves convenient to start explaining this figure at high R&D-subsidy levels, i.e., for  $s > \tilde{s}$ . For this range of subsidy, the pre-tax profit of a firm that produces in  $f$  is higher when it does its R&D in home than when it offshores its R&D ( $\pi^{fh} > \pi^{ff}$ ). As we assume, the subsidy in  $f$  is exogenous (and set equal to zero without loss of generality) the difference ( $\pi^{fh} - \pi^{ff}$ ) increases in  $s$ . The location choice  $ff$  is never chosen above  $\tilde{s}$  as it is dominated there. In the figure the vertical locus at  $\tilde{s}$  separates area IVb in which the firm chooses  $ff$  from area I in which  $fh$  is the location choice. Just below  $\tilde{s}$ , the firm's choice reduces to locating both activities in  $h$  or in  $f$ . Since  $\pi^{hh}$  falls as the subsidy falls, while  $\pi^{ff}$  remains constant, the critical tax rate in home  $\tilde{t}$  at which the firm is indifferent between  $ff$  and  $hh$  is positively related to  $s$ . This is represented by the upward sloping  $\tilde{t} - \tau$  locus in the figure. There is another critical subsidy level in the figure,  $\underline{s}$ , at which  $\pi^{hf} = \pi^{hh}$ . Below  $\underline{s}$ , the pre-tax profits at location choice  $hf$  are higher than those at  $hh$  and the firm will never choose  $hh$ . The choice is then between  $hf$  and  $ff$  when the firm always does its R&D abroad but chooses to locate production at home if the corporate tax is low enough (below  $\underline{t}$ ). In the figure, the operating profit at  $ff$  is higher than that at  $hf$ , so the critical tax at which the firm is indifferent is below  $\tau$ , which is the tax in  $f$ . Also, since neither  $\pi^{ff}$  nor  $\pi^{hf}$  depend on  $s$ , the critical  $t$  at which the firm is indifferent between the locations,  $\underline{t}$ , is independent of the R&D subsidy. This threshold is represented in the figure by the horizontal  $\underline{t} - \tau$  boundary between region I and II.

[Figure 3 about here]

### 5.2 Optimal Policy Mix with Mobile R&D

As in the case in which R&D is not mobile the the optimal policy mix still depends on  $\beta$ . Figure 4 shows welfare as a function of the subsidy for various values of the R&D spillover. For small R&D spillovers ( $\beta < \beta''$ ), the benefits from having the MNE's R&D activity carried out locally are lower than the benefit of having them carried out abroad. This is due to the higher R&D effectiveness of foreign R&D. So, the government sets a zero subsidy and allows R&D to be done abroad. The tax is set no higher than the level  $\underline{t} - \tau$ ; that

would encourage the firm to produce abroad and so pay its tax there. When the R&D spillover is higher than  $\beta''$  the optimal subsidy is as derived in subsection 4.2. and given by  $s^* = \beta$  as indicated in the upper panel of 4(a). The actual location outcome is then  $hh$  when the spillover does not exceed  $\beta'$ . However if the spillover is above this level the government's optimal subsidy induces the firm to relocate production abroad while maintaining R&D at home. This choice is accommodated by  $h$ 's government as, for those spillover values,  $W^{fh} > W^{hh}$  and the optimal optimal subsidy remains  $s^* = \beta$  as indicated in the upper panel of 4(b).

[Figure 4 about here]

## 6 Extensions

Governments typically have concerns in addition to those we have already included in the welfare function in expression (3). In this extension we discuss the inclusion of domestic consumer interests (subsection 6.1) and a concern for domestic employment generated by the MNE (subsection 6.2). Naturally, both these concerns may enter the government's welfare function at the same time, but we disentangle them here for expositional clarity. Aiming to convey the key message in the simplest and clearest way, we also return to our basic model and assume, as we did in section 4, that R&D is immobile and always carried out in country  $H$ .

### 6.1 Optimal Policy Mix with Concern for Domestic Consumers

Some output of the MNE may be consumed domestically, and thus should be included in domestic welfare. This is captured by including consumer surplus ( $CS$ ) with a weight ( $\delta$  with  $\delta < 1$ ) in the welfare function, or:

$$W^{ih} = \Pi^{ih} + \theta t \pi^{ih} + (\beta - s)x^{ih} + \delta CS^{ih} \quad (13)$$

In line with earlier usage  $\theta = 1$  when  $i = h$  or  $i = f$  and  $t \leq \tau$  and  $\theta = 0$  if  $i = f$  and  $t > \tau$ . A natural interpretation of  $\delta$  would be to indicate the share of the MNE's production that is consumed domestically. Given the MNE's production location decision, taxes are chosen to ensure that they are paid in the home country and the optimal subsidy is now:

$$s^* = \frac{\beta + (\delta/2) \frac{A^i}{2-\eta}}{1 - (\delta/2) \frac{\eta}{2-\eta}} \quad (14)$$

Figure 5 depicts the optimal subsidy as a function of the local spillover, beta. The 45°-line shows the optimal subsidy as a function of beta when delta is zero. When the local R&D spillover is low ( $\beta < \beta^{CS}$ ), the R&D subsidy tracks the spillover parameter but is higher than the spillover; since a higher R&D subsidy

lowers local production cost and hence increases output and lowers the price, local consumers benefit from this. In fact, from the moment the local R&D spillover is large enough ( $\beta = \underline{\beta}^{CS}$ ), the government wants to encourage the MNE to locate its production to  $f$ , where it is cheaper to produce, implying a discrete jump in the R&D subsidy<sup>12</sup>. When the subsidy is large enough ( $s = \bar{s}$ ), the firm wants to produce in  $f$ . Beyond  $\bar{\beta}^{CS}$ , as domestic consumers gain from low production cost in  $f$ , the government's optimal R&D subsidy continues to exceed  $\beta$  and increases as  $\beta$  itself increases.

So, when local residents consume a significant fraction of the firm's production, the government will, through a generous domestic R&D subsidy policy, actively encourage the MNE to set up production abroad if production costs are lower there.

[Figure 5 about here]

## 6.2 Optimal Policy Mix with Concern for Employment

We now include a concern for domestic employment in expression (3). This may be of particular relevance when the country is characterised by high unemployment or the labour unions in a sector are especially powerful and the government is under political pressure to protect employment in that sector. We assume a simple input-output technology given by  $L^{ih} = q^{ih}$ , where  $L^{ih}$  denotes the labour required to produce one unit of output when production occurs in location  $i$ . The welfare function when  $j = h$  can then be written as:

$$W^{ih} = \Pi^{ih} + \theta t \pi^{ih} + (\beta - s)x^{ih} + \lambda q^{ih} \quad (15)$$

where  $\lambda$  ( $\lambda > 0$ ) captures the extra weight of employment. The optimal subsidy, given that the MNE produces in  $h$ , is then equal to:

$$s^{hh*} = \beta + \lambda/2 \quad (16)$$

Figure 6 shows the relationship between  $\beta$  and the optimal R&D subsidy when the government's welfare function includes a concern for employment. At very low spillover values ( $\beta < \underline{\beta}^e$ ), the government sets a R&D subsidy that exceeds the spillover. The higher R&D subsidy will raise production by the MNE, thereby creating more local employment. Because it now cares about employment, the government is now more concerned about the firm offshoring its production, implying that there is a range of  $\beta$  ( $\underline{\beta}^e \leq \beta \leq \bar{\beta}^e$ ) for which the government keeps the subsidy at a level just below  $\bar{s}$  to deter offshoring. When the spillover is very high ( $\beta > \bar{\beta}^e$ ), the government will find the optimal policy involves letting the MNE offshore production and, once again, the optimal R&D subsidy simply tracks the R&D-spillover.

<sup>12</sup>For some parameter values it will prefer to do this by pushing the tax above  $\tau$ . This leads to a loss of tax revenue as the firm pays taxes abroad and requires  $\tau$  to be low and the required increase in subsidy to be large.

It is noteworthy that, compared to when the government does not take employment into account, the optimal subsidy picture that emerges shows that attaching an additional weight to employment provided by the MNE will raise R&D in sectors with low R&D spillovers, whereas it will dampen R&D in sectors with high R&D spillovers. While such a policy stance may mitigate unemployment in the short-run, it may slow down future productivity growth.

[Figure 6 about here]

## 7 Conclusion

In this paper we examined the optimal mix of policies, consisting of a R&D subsidy and a (potentially favourable) corporate tax rate, targeted at R&D intensive corporations that consider offshoring their production and/or R&D activities. One way countries can set a tax rate favourable to R&D intensive firms is by adopting a patent box or innovation box regime we have shown that the relationship between the optimal R&D subsidy and the optimal corporate tax rate stipulated for R&D intensive firms is far from trivial.

If the firm's R&D is effectively immobile, any attempt to boost local R&D by increasing the R&D subsidy, may –while encouraging local R&D– facilitate the offshoring of the MNE's production activities to a lower production cost location. However, provided that the R&D subsidy is not too high, offshoring of production may be prevented by lowering the corporate tax rate R&D intensive firms are subject to. Nevertheless, if the R&D subsidy is very high, offshoring of production to a lower production cost location will be inevitable. While this may be welfare improving for an economy with very low unemployment, it may be undesirable for a government of a country with a high rate of unemployment. In fact, we find that the latter type of government will tend to under-subsidise R&D (relative to a government that has no additional special interest in keeping domestic employment high) to keep multinationals' production at home and may, by doing so, hinder future innovation and growth. By contrast, we find that a government of an economy with near full employment but a particular concern for consumer welfare or a high level of consumption of the MNE's products will over-subsidise R&D (relative to a government that is only interested in tax revenues) in order to encourage the MNE to produce abroad where production cost are lower, thus guaranteeing a higher return to R&D.

Determining the optimal combination of R&D subsidy and corporate tax rate becomes more complex when R&D activities too are effectively footloose. Then, when all MNE activities are footloose, there exists an intermediate range of R&D subsidies, for which the optimal corporate tax rate for R&D intensive corporations increases in the R&D subsidy until the R&D subsidy is high enough to make R&D effectively immobile. Any further increase in the R&D subsidy needs to be accompanied by a reduction in the corporate tax rate to prevent offshoring of MNE production. However, like in the case when R&D is immobile, if the optimal R&D subsidy becomes very high, offshoring of production will become inevitable.

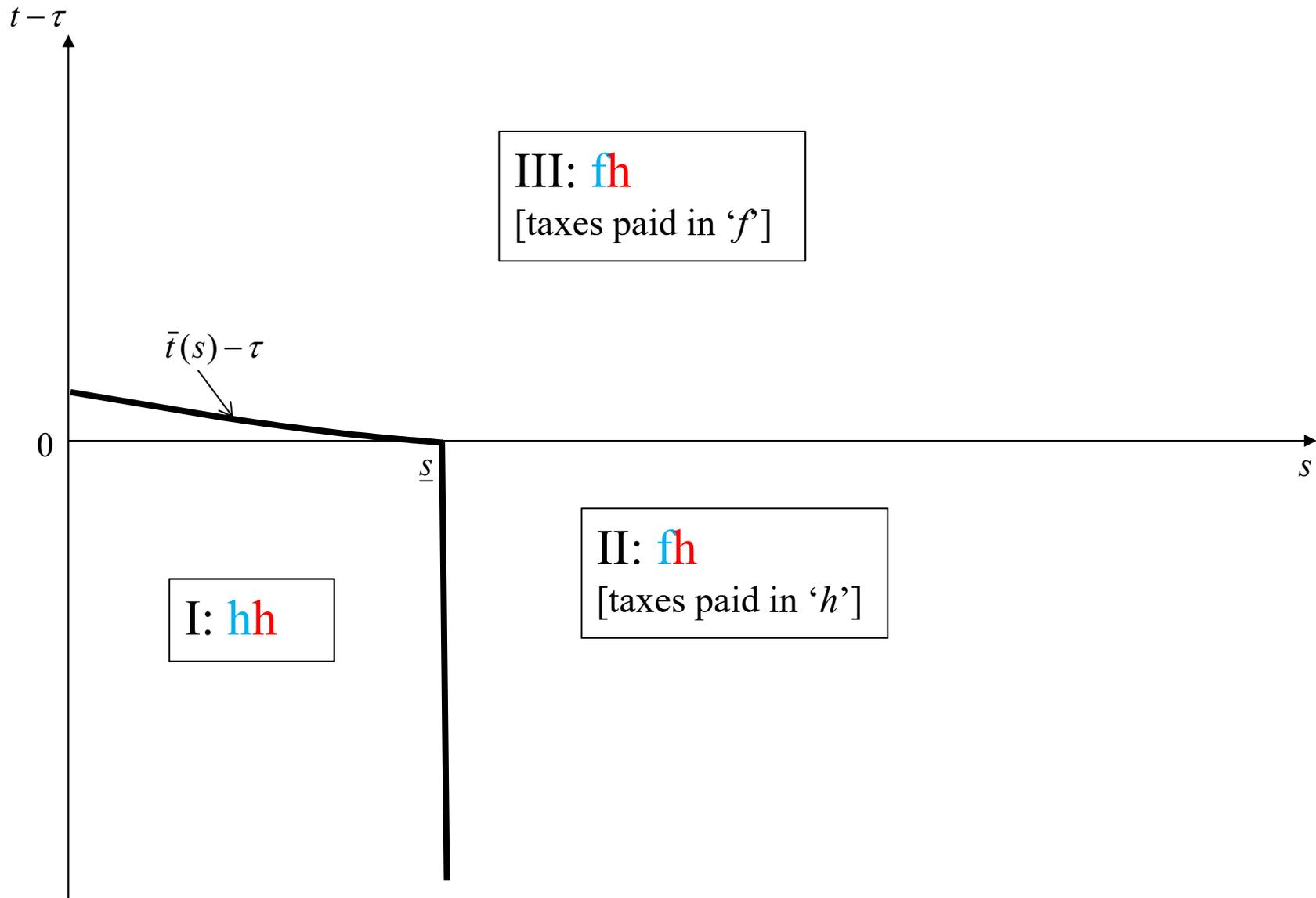
Our findings suggest that policy makers should be cautious when setting corporate tax rates for R&D intensive firms and would be wise to examine the entire package of policies geared towards retaining activities of R&D-intensive multinationals in order to achieve the desired effects of their policies.

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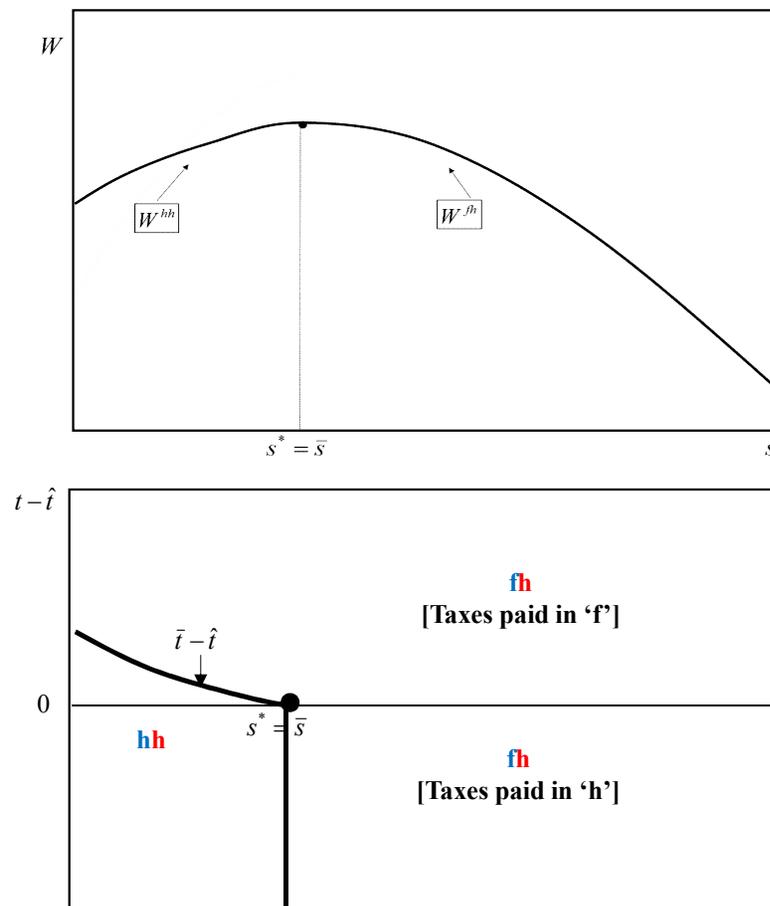
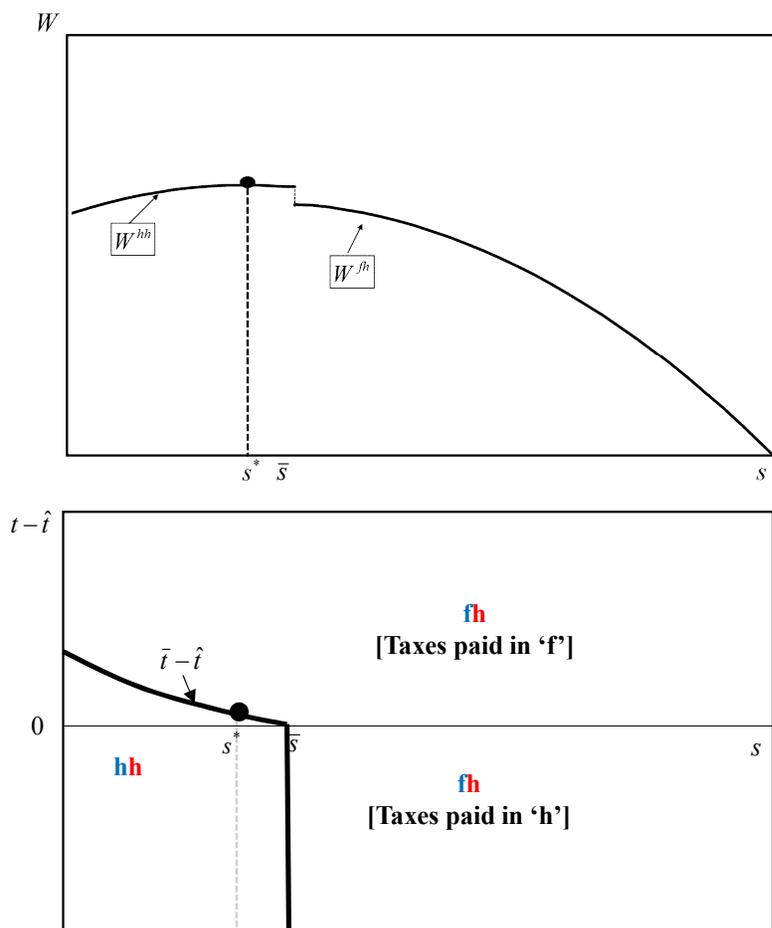
*Figure 1: Location pattern – Immobile R&D*



## Figure 2: Welfare – Immobile R&D

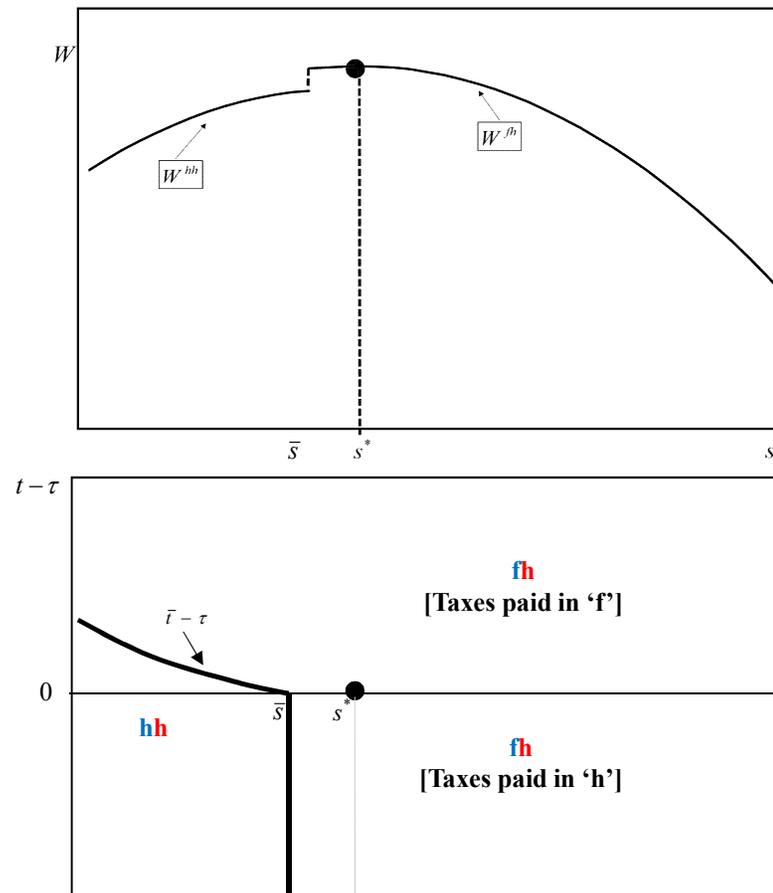
(a) Optimal policy package:  $\beta < \beta'$

(b) Optimal policy package:  $\beta = \beta'$

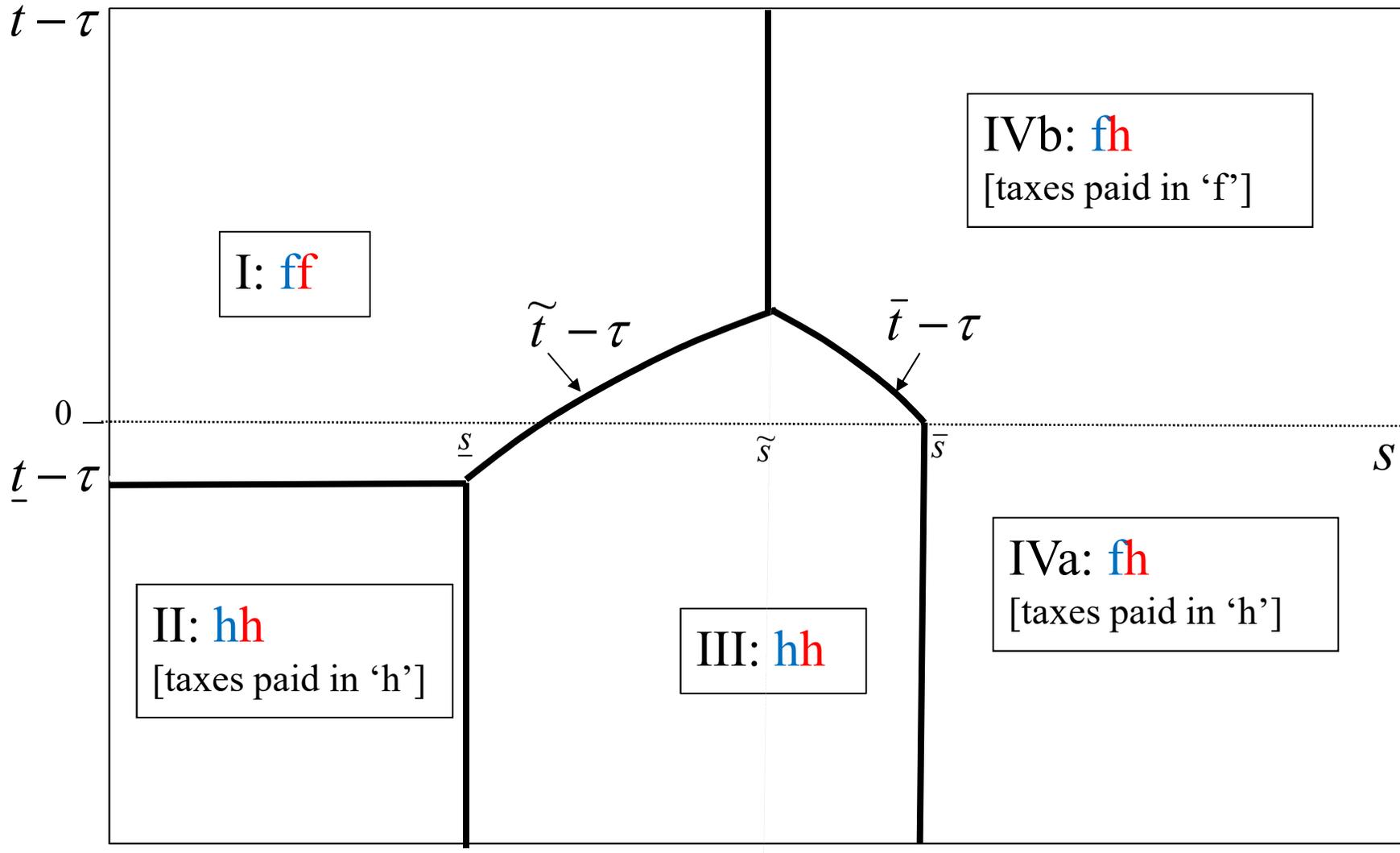


**Figure 2: Welfare – Immobile R&D**

(c) Optimal policy package:  $\beta > \beta'$

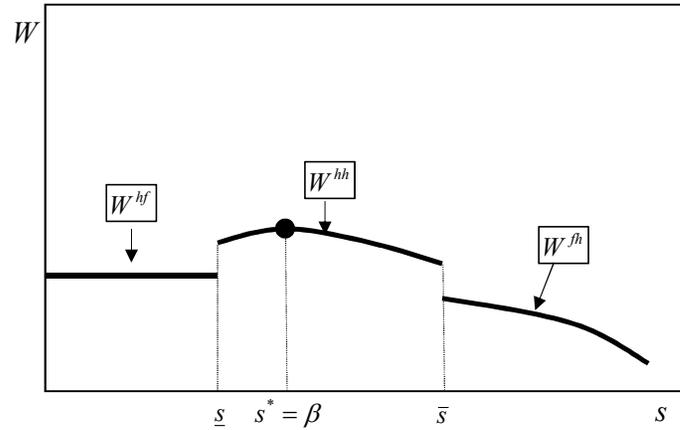


*Figure 3: Location pattern – Mobile R&D*

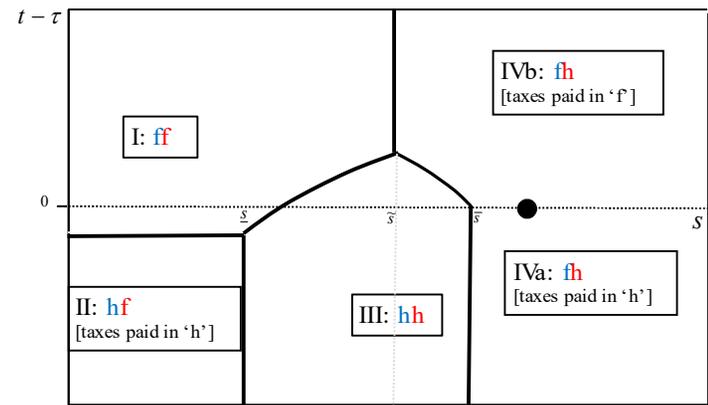
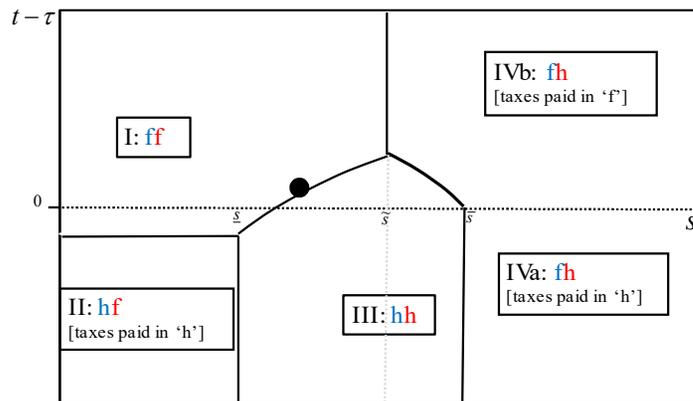
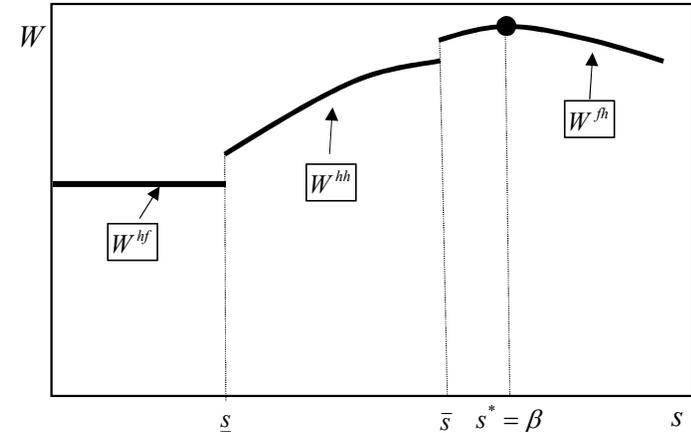


**Figure 4: Welfare – Mobile R&D**

(a) Optimal policy package:  $\beta'' < \beta < \beta'$

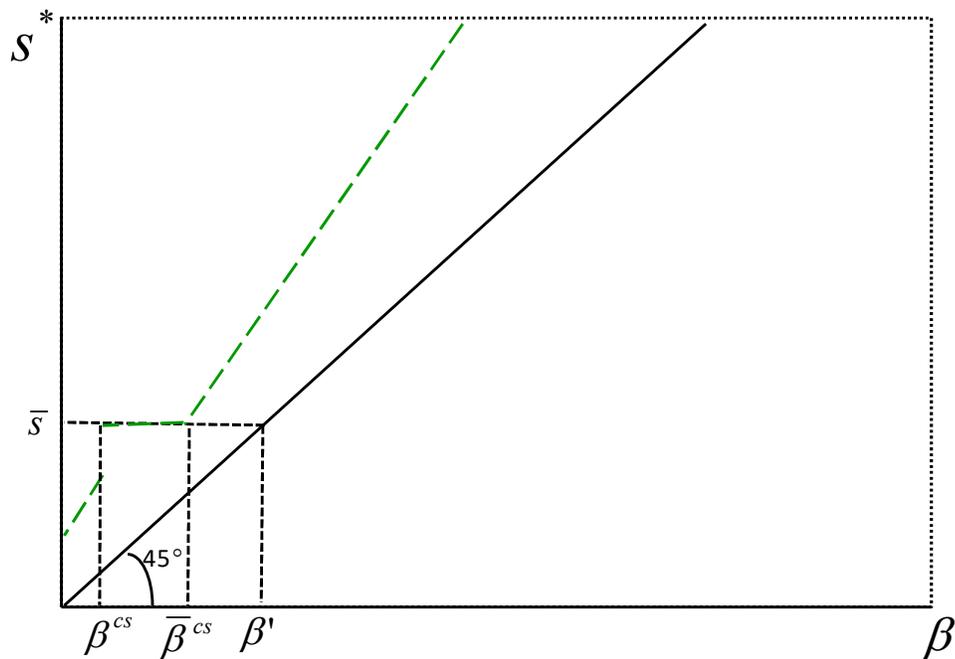


(b) Optimal policy package:  $\beta > \beta'$

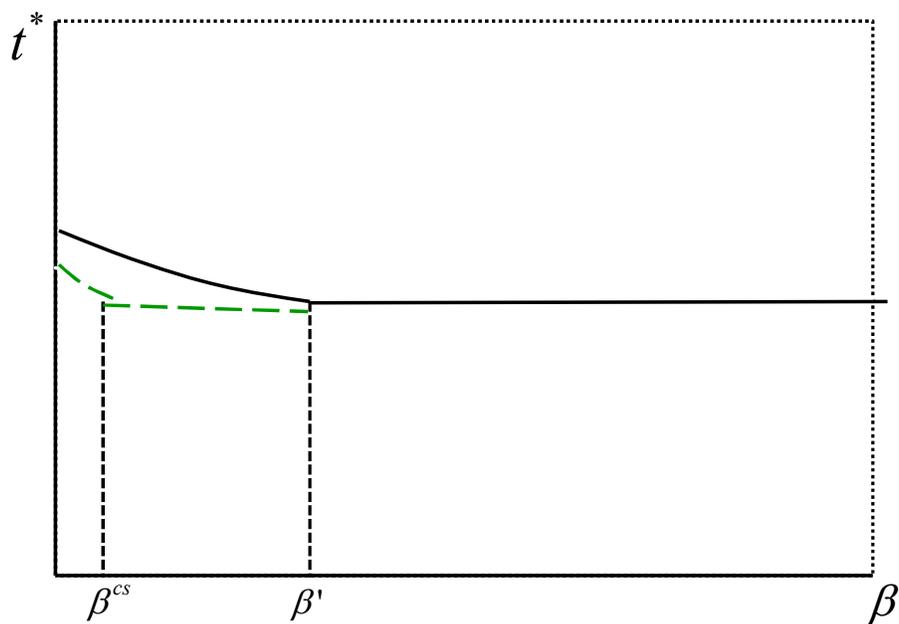


**Figure 5: Optimal policy package with concern for consumers (Immobile R&D)**

*(a) Optimal R&D subsidy*

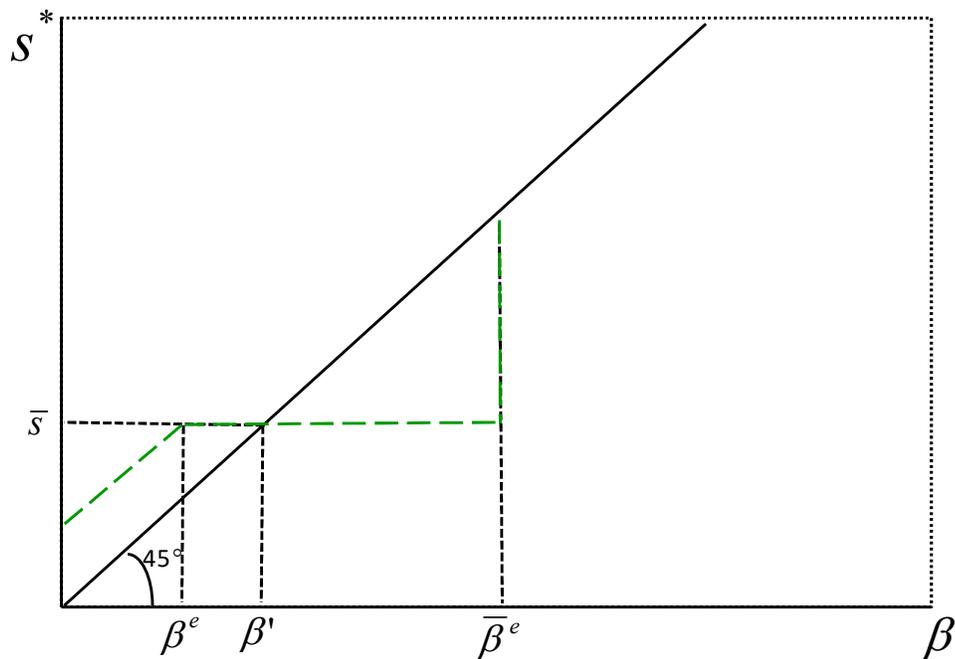


*(b) Optimal corporate tax rate*



**Figure 6: Optimal policy package with concern for employment (Immobile R&D)**

(a) Optimal R&D subsidy



(b) Optimal corporate tax rate

