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Thinking inside the box: Optimal policy towards a footloose R&D-intensive firm

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Abstract
We derive the optimal policy mix of Research and Development (R&D)-subsidies and corporate tax rates towards a footloose R&D-intensive firm. Increasing R&D-subsidies strengthens the firm's incentive to offshore production. The firm's home government can offset this by offering an appropriate corporate tax concession. The optimal policy package exhibits a "Matthew principle": higher R&D-subsidies should typically be accompanied by lower tax rates. However, if the R&D-subsidy exceeds a crucial threshold, a tax concession can no longer prevent offshoring. We find that it is never optimal to raise tax rates as R&D-subsidies increase.

1 | INTRODUCTION

In an era characterized by increasing globalization, the threat of domestic firms offshoring production to lower-cost locations is a major concern of governments in developed countries. Another, and at first sight unrelated worry policy makers tend to have, is losing ground in innovation and Research and Development (R&D). When designing policy to address these issues, it is important to realize that offshoring production and investing in R&D are not unrelated. In fact, empirical work shows that offshoring firms also tend to be more R&D-intensive.[1] Successful innovation itself tends to make firms larger and more efficient and thus better able to reap the benefits of offshoring. In this paper, we start by showing that, for this reason, policies that raise the level of firm innovation can also have implications for its internationalization strategy. As a result, well-intended direct R&D-support may have

[1]Evidence is, for instance, provided by Dachs et al. (2015), who estimate the effects of production offshoring on R&D and innovation in the home country, using a data set of more than 3000 manufacturing firms from seven European countries.

unanticipated effects on domestic production and employment. We derive the optimal policy package towards an R&D-intensive firm with footloose production, with the package consisting of a combination of an R&D-subsidy and a corporate tax rate specifically targeted towards that type of firm. We argue that such a combined policy approach is necessary if the government wishes to take into account the implications of R&D-subsidization on potential offshoring of domestic production activities.

In recent years, several countries have tailored the effective corporate tax rates specifically to R&D-intensive firms by adopting patent or innovation box regimes.[2] A patent box regime effectively reduces the corporate tax rate on income earned from certain forms of IP, in particular from patents.[3] Empirical studies give us some further insights into real-world policies towards R&D-intensive firms. A detailed comparison of data from 2007 and 2011 for OECD-countries (Bellak & Leibrecht, 2016, table 4.1, p. 73) reveals that R&D-incentives as a percentage of gross domestic product (GDP) have gained in overall importance over that period in most countries. This suggests that countries are indeed targeting these firms to retain or attract them. However, the way in which countries have increased R&D-support varies. While one group of countries (among which Canada, Australia, and France) substituted direct financial incentives with increased fiscal support, another group (among which, the United States and the UK) complemented an increase in financial support with increased fiscal support, and yet another group, increased one component of R&D-support without changing the other. From this observation, it is far from obvious how an optimal R&D-support package, consisting of financial and fiscal incentives should be constructed.

Our basic model features a large firm that must decide whether to offshore its production to reap the benefits from advantages abroad, or remain at home, thus avoiding the relocation cost. We simplify our setup by assuming a single firm because we do not want to obscure our analysis with market structure issues. In our model, the home economy faces the possibility that its multinational may offshore production to a lower-cost foreign location. To bring out this scenario most sharply, we assume that only production is footloose, while the firm's R&D activities are immobile. The government of the firm's domestic country aims to encourage local R&D by subsidizing R&D. It can also fine-tune its tax regime by allowing a favorable effective corporate tax rate for an R&D-intensive corporation. We examine how the optimal package of R&D-subsidy and corporate tax rate is affected by the firm's option to offshore production. We discuss how the optimal policy may change if the government includes a special concern for domestic employment in its welfare function.

We find that if a firm sees its R&D-subsidy increase, its incentive to offshore its production to a lower-cost location abroad also increases. The reason for this lies in the fact that an increase in the R&D-subsidy magnifies the return to R&D more when the firm produces in the lower-cost location than when it produces at home. Furthermore, when the R&D-subsidy exceeds a particular threshold, the firm offshores its production, regardless of the tax rate differential between the home and foreign locations. That threshold level is lower if the fixed cost of setting

[2]This is true for several European countries. China also has an intellectual property (IP) box regime. Other countries (e.g., United States and Australia) are debating whether or not to adopt one.

[3]Unlike with direct R&D government support (e.g., R&D-subsidies), which is conditional on the magnitude of the R&D that is undertaken locally, there is in many cases no requirement for R&D to be carried out locally or indeed by the firm itself (the innovation may, for instance, have been acquired through a licensing agreement). Exceptions are the IP box regimes in the Netherlands and Spain (Atkinson & Andes, 2011). Evers et al. (2014) argue that the treatment of expenses related to IP income is important in determining the effective tax burden.

up a new plant abroad is lower, the production cost advantage of the foreign country is higher and the effectiveness of R&D is higher. These findings have normative implications.

First, governments that want to stimulate local R&D by increasing R&D-subsidies should bear in mind that this may lead to offshoring production. Out of a concern to safeguard tax revenue, such an increase in R&D-subsidization should be accompanied by a reduction in the corporate tax rate for this firm, with the tax rate of the foreign host country as a lower boundary. In other words, we find that it is not advisable to finance a higher R&D-subsidy through raising the corporate tax rate for R&D-intensive firms. Second, the accompanying tax reduction is also larger if the R&D-externality and thus the R&D-subsidy is large. Third, if the government has a special concern for local employment in the sector, it will want to boost the R&D-subsidy for low R&D-spillovers, while wanting to deter offshoring and thus safeguarding domestic employment by curtailing the R&D-subsidy for moderate to high R&D-spillovers. We find that in no case should an increase in the R&D-subsidy be accompanied by a fall in indirect R&D-support.

Our paper supplements the growing literature on corporate taxation, R&D-incentives, and location decisions of firms. Empirical work suggests that multinational firms have an incentive to locate intangible assets, and patents in particular, in affiliates in low-tax locations to minimize tax payments (e.g., Dischinger & Riedel, 2011; Ernst & Spengel, 2011; Griffith et al., 2014; Grubert, 2003; Karkinsky & Riedel, 2012). This finding is echoed in a comprehensive study on R&D tax incentives (European Commission, 2014). While there is a large body of work focusing on the effect of R&D-incentives on the location of patents, the relationship between R&D-incentives available in the home economy and firms' choice of production location is less clear. Our paper aims to provide a theoretical framework to investigate this link with the aim of providing an insight into the characteristics of the optimal mix of corporate tax rate and R&D-incentives governments should put in place. To our knowledge, this is the first paper to address theoretically the relationship between production offshoring on the one hand and R&D-incentives and corporate taxation on the other hand.

Our analysis also contributes to the literature on offshoring. Seminal theoretical contributions include Antras et al. (2006) and Grossman and Rossi-Hansberg (2008). Several authors have examined the effects of offshoring on the domestic labor market (e.g., Crinò, 2009; Ebenstein et al., 2014; Kovak et al., 2018; Mion & Zhu, 2013; Monarch et al., 2017; Wright, 2014). Most of this literature examines the effects of offshoring on production, exports and in particular on home labor market effects. However, it is the work that examines the effects of production offshoring on innovation that is most closely related to our analysis. Mazzanti et al. (2009), Crinò (2012), Fritsch and Görg (2015), and Dachs et al. (2015) provide evidence of a positive relationship between production offshoring and home innovation and R&D. Our paper provides a theoretical framework that links home R&D-policy to the offshoring of production activities.[4]

In Section 2, 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 Section 5 determines the government's optimal policy mix. Section 6 concludes and discusses possibilities for extensions in future work. All proofs are provided in the appendix.

[4]Iida and Mukherjee (2020) have, in a different context but in a similar spirit, argued that certain tax/subsidy policies affect firms' incentive to outsource activities; they show that international tax cooperation can encourage outsourcing.

2 | THE MODEL

Consider a large and potentially multinational firm that exports its production; it faces the following inverse demand:

$$p = a - q, \tag{1}$$

where p is the price, q is the quantity sold, and a is a constant.[5] The firm also invests in R&D and has initially located both its production and R&D in the home country, denoted by h. However, the firm must now decide whether to continue to operate exclusively at home or to offshore its production to a foreign host country, denoted by f. R&D is maintained in the home country and is cost-reducing.[6] We have

$$c^i = \bar{c}^i - x, \tag{2}$$

where c^i denotes the marginal production cost in location i $(i = h, f)$; c^i is constant in output, thereby ruling out locational fragmentation of production: production is not spread across a domestic subsidiary and a subsidiary abroad. The firm's marginal production cost without R&D $(\bar{c}^i)$ is location-specific because of international differences in factor prices. Note that trade cost associated with serving the market from location i is taken into account and subsumed into $\bar{c}^i$; thus, c^i includes any trade costs. The reduction in marginal production cost generated by the R&D the firm undertakes is represented by x. Henceforth, we will simply refer to x as the firm's R&D. To ensure that offshoring production is a possibility, we assume henceforth that, when offshoring production abroad, the firm has a marginal production cost advantage compared with when it produces at Home.

> **Assumption 1.** At a given level of R&D, the firm's marginal production cost at Home exceeds its marginal production cost in Foreign, or, $\bar{c}^h > \bar{c}^f$.

The cost of R&D is represented by k. To ensure an interior solution, k is convex in x, with $k = x^2/2\eta$; hence, $x = \sqrt{2\eta k}$, where η can be interpreted as the effectiveness of R&D. Because of the public-good character of knowledge, R&D generates, in addition to the benefits to the firm itself, some external benefits to other local firms and the wider local community. So, the private return to R&D is lower than its social rate of return.[7] To correct for this, the Home government considers a per-unit R&D-subsidy, s, with $s \geq 0$.

The firm is wholly owned by residents of the Home country. Pretax profits of the firm producing in location i $(i = h, f)$, denoted by π^i, are given by

$$\pi^i = (p - c^i)q - (x^2/2\eta) + sx - F^i. \tag{3}$$

[5]Although it is straightforward to generalize the demand, the linear functional form allows us to obtain explicit solutions for profits and welfare, enabling us to compare different cases.

[6]Alternatively, R&D might be demand-enhancing. In that case, R&D will shift the demand to the right. Whether R&D is cost-reducing or demand-enhancing does not qualitatively change our results.

[7]See, for instance, Griliches (1992), Griffith (2000), and Bloom et al. (2013).

Here and henceforth, superscript i refers to the firm's *production* location. Since the firm has not yet set up a production facility in Foreign, it will need to incur a fixed setup cost of $F^f > 0$ if it chooses to produce abroad but not if it decides to keep production at Home ($F^h = 0$).

We denote the firm's after-tax profits by Π^i. Let t and $\hat{t}$ represent the Home and Foreign corporate tax rate (with $0 \leq t < 1$ and $0 \leq \hat{t} < 1$), respectively. Naturally, when a firm decides to keep its production at Home, hence in the same country as its R&D, it only has a presence at Home and hence pays—by default—taxes in Home. After-tax profits can therefore be written as $\Pi^h = (1 - t)\pi^h$ when all the firms' activities are located in h. When a firm offshores its production activities while carrying out its R&D at Home, it becomes a multinational corporation that operates in two locations. It can then engage in transfer pricing, which allows it to effectively shift its profits to the location in which corporate taxes are lowest and pay its taxes there.[8] This can, for instance, be done by allocating assets to low-tax locations and generating royalties or license fees from high-tax locations. While these profit-shifting mechanisms are important to carry out transfer pricing in practice, we do not model them as the aim of our paper is not to analyze the theoretical aspects of these mechanisms. Instead, we simply assume that, in line with the empirical evidence, these mechanisms are available.[9]

Assumption 2. When a firm offshores production and hence operates in two locations, it can perfectly transfer price to minimize tax liabilities.

From Assumption 2, an offshoring firm's after-tax profit, Π^f, simplifies to $(1 - t)\pi^f$ if $t \leq \hat{t}$ and $(1 - \hat{t})\pi^f$ if $t > \hat{t}$.[10]

The model is set up as a two-stage game. The sequence of decisions is illustrated in Figure 1. In the first stage, the Home government decides on its corporate tax rate and R&D-subsidy. In doing so, it aims to maximize welfare, denoted by W (the Home government's welfare function will be discussed in Section 5), with W^i denoting welfare when the firm produces in location i. Since we wish to focus on the relationship between the two policy instruments of the Home country (s and t), we treat the policy variables of the Foreign as exogenous.[11] In the second stage, the firm decides whether to produce in h or in f. It also decides how much output to produce and how much R&D to carry out.

3 | THE FIRM'S OUTPUT AND R&D

As usual, solving by backward induction, we first solve the firm's output and R&D decision. The firm's first-order condition for output is

$$A^i - 2q + x = 0, \tag{4}$$

[8]Davies et al. (2018) show evidence that large multinationals engage in transfer pricing. For evidence on transfer pricing in the United States, see Clausing (2009).

[9]Examples are Dischinger and Riedel (2011) and Dudar, Spengel and Voget (2015). Provided the firm has some ability to transfer price, constraining its ability to do so does not qualitatively alter our main results, but does complicate the analysis considerably and reduces the transparency of the results

[10]Assumption 2 is merely a simplifying one and, provided the firm has some ability to transfer price, constraining its ability to do so does not qualitatively alter our main results, but does complicate the analysis considerably and reduces the transparency of the results.

[11]For a survey on tax competition, see Baskaran and Lopes da Fonseca (2013).

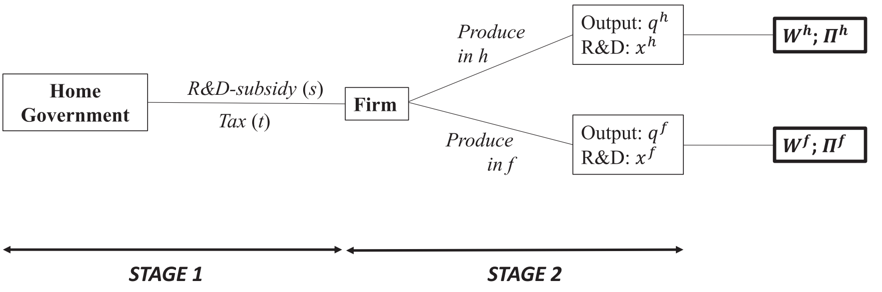

FIGURE 1 Sequence of the game

where $A^i \equiv a - \bar{c}^i$. As is clear from expression (4), output depends on both the innovation level (x) and on the location of production (which determines A^i). The firm's first-order condition for R&D is

$$q - \frac{x}{\eta} + s = 0. \tag{5}$$

Combining expressions (4) and (5), we obtain the firm's optimal location-specific output and R&D:

$$\tilde{q}^i = \frac{A^i + \eta s}{2 - \eta} \tag{6}$$

and

$$\tilde{x}^i = \eta(\tilde{q}^i + s) = \eta \frac{A^i + 2s}{2 - \eta}. \tag{7}$$

Here and henceforth, the tilde notation on the firm variables denotes profit-maximizing levels of those variables, given government policy and location. To ensure that the second-order conditions hold, we limit the value of the relative effectiveness of R&D and impose $\eta < 2$. R&D, although always taking place in Home, is superscripted ($i = h, f$) because its optimal level depends on whether or not the firm offshores production.

Lemma 1. *For a given R&D-subsidy, the firm's output and R&D are larger when it produces in Foreign than when it produces at Home.*

In Section 4, we determine the production location pattern of the firm for different levels of the R&D-subsidy and corporate tax rate.

4 | THE FIRM'S LOCATION DECISION

Whether the firm will offshore production or not depends on both the locational differences in corporate tax rates and pretax profits. It will offshore production if doing so means that its posttax profits are higher. Leaving corporate tax rates aside for the moment, it will prove useful to turn our attention first to pretax profits (Section 4.1). After examining this, we include corporate tax rates and determine the location choices of the firm (Section 4.2).

4.1 | R&D-subsidy and pretax profits

Substituting the firm's optimal output and R&D (expressions 6 and 7, respectively) into expression (3) yields maximized pretax profits of the firm for production location i, given by

$$\tilde{\pi}^i = \frac{1}{(2-\eta)}\left(\frac{(A^i)^2}{2} + \eta(A^i + s)s\right) - F^i. \tag{8}$$

Figure 2a depicts maximized pretax profits as a function of the Home R&D-subsidy, s, when the firm offshores production ($\tilde{\pi}^f$) and when it does not ($\tilde{\pi}^h$). If the firm offshores production, it incurs a fixed cost $F^f > 0$, but it has a marginal production cost advantage relative to producing in Home (see Assumption 1). We will assume that the fixed cost of setting up a plant in foreign is sufficiently high, such that $\tilde{\pi}^h > \tilde{\pi}^f$ at $s = 0$. Assumption 3 specifies the necessary parameter restrictions for this.

Assumption 3. $F^f > \frac{1}{2(2-\eta)}((A^f)^2 - (A^h)^2)$.

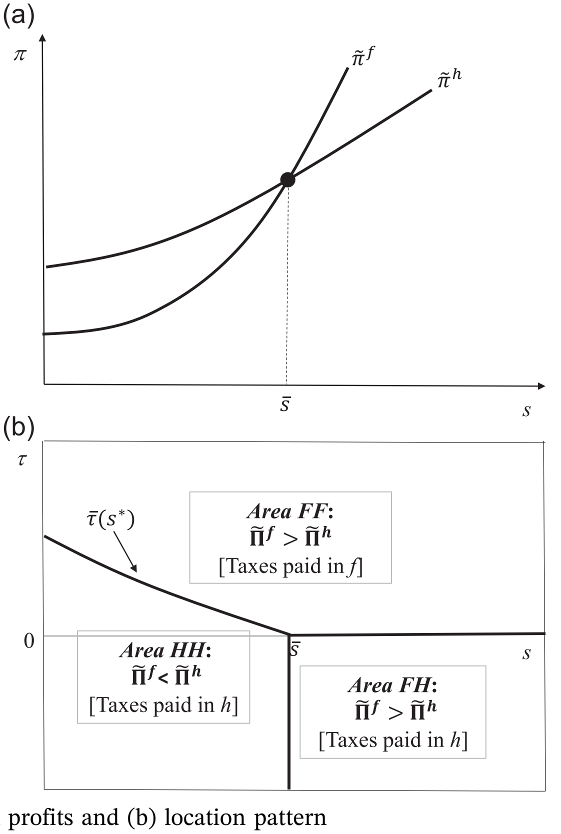

FIGURE 2 (a) Pretax profits and (b) location pattern

So, in spite of the fact that there is a marginal cost advantage when producing in f, pretax profits at $s = 0$ are higher when production is retained in h than when production is offshored (see Figure 2a). This means that, for some levels of s, pretax profits are higher when the firm stays at Home.

Suppose now that the government of h wants to encourage R&D in its jurisdiction by subsidizing it. Since $A^h > A^f$ and from expression (8), profits increase faster in the R&D-subsidy when the firm offshores production than when it produces in Home. Offshoring production implies that the return to innovation is higher: the lower production cost abroad results in a higher price to cost margin and hence the increased output generated by the innovation is more profitable to the firm.

Lemma 2. *There exists a critical R&D-subsidy,* $\bar{s} = \frac{(2-\eta)F^f - \frac{1}{2}((A^f)^2 - (A^h)^2)}{(A^f - A^h)\eta}$, *at which* $\tilde{\pi}^h(\bar{s}) = \tilde{\pi}^f(\bar{s})$. *For* $s < \bar{s}$, $\tilde{\pi}^h(s) > \tilde{\pi}^f(s)$ *and for* $s > \bar{s}$, $\tilde{\pi}^h(s) < \tilde{\pi}^f(s)$.

The critical threshold R&D-subsidy is a function of firm-specific characteristics. If a firm's fixed offshoring costs, F^f, are not very large, its critical R&D-subsidy threshold above which it will always offshore production ($\bar{s}$) will be low. Relatively low underlying preinvestment marginal cost of production advantages abroad, captured by a high value for A^f, or a relatively high marginal production cost at Home, reflected in a low value for A^h, affect $\bar{s}$ in a similar way. Importantly, the R&D intensity, indicated by parameter η, magnifies the attractiveness of low-cost locations abroad.

Proposition 1. *The threshold R&D-subsidy,* $\bar{s}$, *is increasing in* F^f *and* A^h, *but decreasing in* A^f *and* η.

4.2 | Posttax profits and the location decision

Naturally, a firm's location decision is ultimately determined not by pretax profits but by after-tax profits, which also depend on corporate tax rates. Figure 2b represents the location decision of the firm in (s, τ)-space where τ denotes the corporate tax differential between the two locations; specifically, $\tau \equiv t - \hat{t}$. Without loss of generality and to economize on notation (since Foreign's corporate tax rate is assumed to be exogenous), we normalize $\hat{t}$ at zero. From Section 4.1, for $s < \bar{s}$, maximized pretax profit when producing in Home is larger than when production is offshored ($\tilde{\pi}^h > \tilde{\pi}^f$). Hence, if corporate tax rates in both locations are the same ($\tau = 0$), posttax profits are also higher at Home ($\tilde{\Pi}^h > \tilde{\Pi}^f$). In fact, for $s < \bar{s}$, producing at Home continues to yield higher posttax profits than producing abroad for small enough corporate tax rate differences. More specifically, this is the case up to the critical threshold $\bar{\tau}$ (area *HH* in Figure 2b), which is given by

$$\bar{\tau} = \frac{(\tilde{\pi}^h - \tilde{\pi}^f)}{\tilde{\pi}^h} = \frac{2F^f(2-\eta) - (\bar{c}^h - \bar{c}^f)(A^f + A^h + 2\eta s)}{(A^h)^2 + 2\eta(A^h + s)}. \tag{9}$$

Following convention, we will here and henceforth assume that the firm will only offshore production if its posttax profits from doing so are *strictly* higher than those from staying at

Home. Thus, the firm will keep producing at Home for $\tau \leq \bar{\tau}$. However, a corporate tax rate difference higher than $\bar{\tau}$ will reverse the firm's posttax profit ranking ($\widetilde{\Pi}^h < \widetilde{\Pi}^f$) and it will then offshore its production. As the R&D-subsidy increases, the difference between pretax profits in the two locations ($\widetilde{\pi}^h - \widetilde{\pi}^f$) shrinks and the critical τ-threshold ($\bar{\tau}$) falls, reaching zero when the pretax profit gap between the two locations is zero ($\widetilde{\pi}^h - \widetilde{\pi}^f = 0$). From Section 4.1, pretax profits in the two locations are equal ($\widetilde{\pi}^h = \widetilde{\pi}^f$) when $s = \bar{s}$. Thus, from expression (9), $\bar{\tau} = 0$ at $s = \bar{s}$.

When $s > \bar{s}$, pretax profits are largest when the firm produces abroad (as we have shown in Section 4.1). Thanks to the ability to transfer price, the firm will enjoy higher posttax profits by offshoring production *regardless* of the corporate tax rate set by the Home government and hence will produce in Foreign; it will then pay taxes in Home when $\tau < 0$ and in Foreign when $\tau > 0$. So, when the firm is operating in two locations, it can use the fact that it can transfer price to pay its taxes where these are lowest (in Foreign in area *FF* and in Home in area *FH* in Figure 2b), while enjoying the production cost benefits of producing abroad. The results in this subsection are summarized in Proposition 2.

Proposition 2. *The firm will offshore production (i) if $s > \bar{s}$, regardless of the level of τ, or (ii) if $s \leq \bar{s}$ and $\tau > \bar{\tau}$; otherwise, it will produce domestically.*

5 | GOVERNMENT POLICY

We now discuss the Home government's policy. We first construct a benchmark welfare function (see Section 5.1) in which the government is only concerned with the profits of its national firm, tax revenue, and the R&D-spillover to the rest of the economy. This case provides a "clean" point of reference in the sense that the government will only want to use its R&D-subsidy in the Pigovian sense to internalize the R&D-externality and not to interfere with the firm's decision whether or not to offshore. However, the government may want to include additional specific concerns in its welfare function, which warrant manipulation of the firm's offshoring decision. We will show that when the government is concerned with domestic employment provided by the firm, then it will—unlike in the benchmark case—sometimes keep the R&D-subsidy low to deter offshoring (see Section 5.2). For ease of exposition, Table 1 summarizes the notation used in the remainder of the paper.

5.1 | Optimal policy mix in the benchmark case

As discussed above, the social return of R&D exceeds the private return to the firm. The knowledge created spills over to the wider economy. This external social benefit from a unit of local R&D is captured by parameter β, with $\beta \geq 0$. The benchmark welfare function consists of after-tax profits, tax revenue ($t\pi^i$), and the external benefit of R&D to the economy net of the subsidy cost, that is, $(\beta - s)x$. So, the welfare function in the benchmark case is given by

$$W^i = \Pi^i + \theta t \pi^i + (\beta - s)x^i, \tag{10}$$

where θ is an indicator variable, which takes the value of one when the corporate tax is paid in the Home country and zero when it is paid abroad. Importantly, here too superscript i refers to

TABLE 1 Welfare parameter and policy variables—summary of notation and thresholds

Notation		Explanation
s	$s \geq 0$	Home R&D-subsidy
$\hat{s}$	$\hat{s} = 0$	Foreign R&D-subsidy
t	$t \geq 0$	Home tax rate
$\hat{t}$	$\hat{t} = 0$	Foreign tax rate
τ	$\tau = t - \hat{t}$	Tax rate differential
β	$\beta \geq 0$	Local R&D-spillover
λ	$\lambda \geq 0$	Weight of employment in Home welfare
Superscript $i = h, f$		Refers to firm's production location
Variable with ~		Indicates profit-maximized level
Variable with i*		Indicates welfare-maximized level in Home, conditional on production in location i
Variable with *		Indicates welfare-maximized level in Home

Thresholds	Definition	Comment
$\bar{s}$	$\tilde{\pi}^h(\bar{s}) = \tilde{\pi}^f(\bar{s})$	Above $\bar{s}$, pretax profits in Foreign are higher than pretax profits at Home
$\bar{\tau}$	$\frac{\tilde{\pi}^h - \tilde{\pi}^f}{\tilde{\pi}^h}$	Above $\bar{\tau}$, after-tax profits in Foreign are higher than after-tax profits at Home
$\lambda = 0$		***Without*** **concern for employment:**
β'	$W^{h*}(s^{h*}(\beta')) = W^{f*}(s^{f*}(\beta'))$	R&D-spillover above which production offshoring is optimal
$\lambda > 0$		***With*** **concern for employment:**
$\underline{\beta}^e$	$W^{h*}(s^{h*}(\underline{\beta}^e), \underline{\beta}^e, \lambda) = W^h(\bar{s}, \underline{\beta}^e, \lambda)$	R&D-spillover below which production offshoring is never welfare maximizing
$\bar{\beta}^e$	$W^{f*}(s^{f*}(\bar{\beta}^e)) = W^h(\bar{s}, \bar{\beta}^e, \lambda)$	R&D-spillover above which production offshoring is welfare maximizing
$\underline{\beta}^e < \beta < \bar{\beta}^e$		R&D-spillover range for which deterrence of production offshoring is welfare maximizing

the production location of the firm (e.g., W^f is Home welfare when the firm offshores production to Foreign).

Given this welfare function, we now determine the optimal corporate tax and R&D-subsidy package. Note that the taxes paid by the firm will cancel in the welfare function with the Home government's tax revenues if the firm pays taxes at Home. Since the Home government cares about its tax revenues, welfare will, ceteris paribus, always be higher if the firm pays its taxes at

Home, even if it produces in Foreign.[12] Hence, regardless of where the firm decides to produce, it is always optimal for the government to set the tax rate so that the firm will declare and pay its taxes in h. Given such tax setting, welfare reduces to

$$W^i = \pi^i + (\beta - s)x^i. \tag{11}$$

Although the government is aware that its choice of R&D-subsidy could affect the firm's production location, for a *given* location choice by the firm, the first-order condition for the optimal R&D-subsidy is

$$\frac{dW^i}{ds} = \frac{d\tilde{\pi}^i}{ds} + (\beta - s)\frac{d\tilde{x}^i}{ds} - \tilde{x}^i = 0. \tag{12}$$

We have $\frac{d\tilde{\pi}^i}{ds} = \pi_s^i + \pi_q^i \frac{d\tilde{q}^i}{ds} + \pi_x^i \frac{d\tilde{x}^i}{ds}$, where subscripts denote partial derivatives, with $\pi_q^i = 0$ and $\pi_x^i = 0$ from the final stage and $\pi_s^i = \tilde{x}^i$. Henceforth, we use starred variables when they maximize Home welfare. Denoting the optimal Home government's R&D-subsidy when the firm produces in location i as s^{i*}, expression (12) reduces to

$$s^{i*} = \beta. \tag{13}$$

So, irrespective of the production location chosen by the firm, the optimal R&D-subsidy is exclusively determined by the level of the local R&D-spillover and is used to fully internalize the positive externality of the firm's R&D to the Home economy; it is not used to affect the firm's offshoring decision (unlike in Section 5.2 where domestic employment is a concern).

Proposition 3. *The optimal R&D-subsidy*, s^*, *and corporate tax differential*, τ^*, *are*

(i) $s^*(\beta) = \beta$;
(ii) $\tau^*(\beta) = \max\{\bar{\tau}(s^*(\beta)), 0\}$.

We now determine how the two components of this optimal policy package (s and τ) change as the spillover parameter changes; in addition, we will discuss its implications for the firm's location decision. It proves convenient to first define a specific spillover threshold, β'.

Definition 1. Let $\beta' \equiv \frac{(2-\eta)F^f - \frac{1}{2}((A^f)^2 - (A^h)^2)}{(A^f - A^h)\eta}$ be the spillover such that $s^*(\beta') = \bar{s}$.

At the spillover level β', the optimal subsidy is just at the threshold R&D-subsidy level, $\bar{s}$, beyond which the firm will offshore its production. Proposition 3 then has an immediate implication for the firm's production location decision, which is formulated in Corollary 1.

Corollary 1. *When policy is optimal, offshoring occurs if and only if* $\beta > \beta'$.

[12] Since we assume a costless transfer between domestic agents and an equal weight on domestic profits and government revenue, it could be argued that, strictly speaking, any tax differential between zero and $\bar{\tau}$ is optimal. To simplify the exposition without affecting any other results, we will follow standard practice and assume that, when indifferent between tax rates, the tie-break will be that the government chooses the largest one.

Using Figure 3, we now provide an intuitive explanation of how the optimal R&D-subsidy and tax rate differential change as the spillover parameter increases. First, consider the optimal policy bundle for relatively low spillover levels ($\beta < \beta'$) in Figure 3a. Since here the optimal subsidy is smaller than $\bar{s}$ ($s^* < \bar{s}$), the tax differential at the optimal subsidy is $\bar{\tau}(s^*) > 0$. Setting the tax rate so that the tax differential does not exceed $\bar{\tau}(s^*)$ not only safeguards Home tax revenue, but also prevents offshoring. An increase in β when β remains below β', leads to an increase in the optimal R&D-subsidy and a fall in the optimal corporate tax. Importantly, the tax rate concession depends on the direct R&D-support: the higher the R&D-subsidy, the greater the optimal tax rate concession, resulting in keeping both the firm's production and tax payments at Home.

In Figure 3b, the spillover is relatively high ($\beta > \beta'$). The government is aware that, here, the high R&D-subsidy leads the firm to offshore its production (as $s^* = \beta > \beta' = \bar{s}$), but it has—given the welfare function in our benchmark case—no special preference for the firm's production location. To fully benefit from the high spillover, the government subsidizes R&D optimally, accepting that the firm will offshore. As the firm can now transfer price and the government does care about tax revenue, the government must match the tax abroad (i.e., $\tau = 0$) to retain the tax revenue.

Figure 3c depicts the knife-edge situation in which $\beta = \beta'$. Since, at β', $\bar{s}$ is optimal, the tax cannot be set above the one set in the offshore location as that would lead to a loss of tax revenue as the firm would ensure its taxes were paid abroad. Corollary 2 summarizes these results.

Corollary 2. *When policy is optimal,*

(i) *an increase in β lowers the optimal tax differential if $\beta \leq \beta'$: $\tau^* = \bar{\tau}(s^*(\beta))$ with $\frac{d\tau^*}{d\beta} < 0$;*
(ii) *the optimal tax differential is independent of β if $\beta > \beta'$: $\tau^* = 0$.*

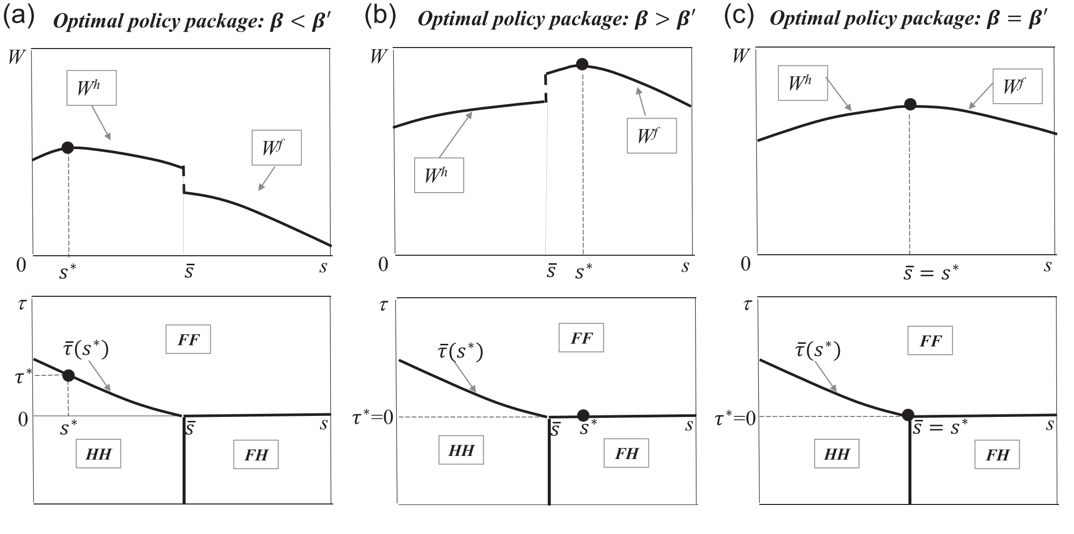

FIGURE 3 Welfare and optimal policy. Optimal policy package: (a) $\beta < \beta'$, (b) $\beta > \beta'$, and (c) $\beta = \beta'$

From the firm's perspective, the optimal policy package of R&D-subsidy and corporate tax implies a 'Matthew effect' of accumulated advantage. In general, the Matthew effect refers to the idea that those who already have advantages of some kind often gain other advantages.[13] Here, the optimal policy package requires that an increase in the R&D-subsidy should never be accompanied by an increase but should typically be combined with a decrease in the corporate tax rate.

While the government is indifferent to the production location of the firm in our benchmark case, this is typically not the case in practice. The reason for this is that governments tend to have concerns, such as employment, in addition to those we have already included in the welfare function in expression (3). In Section 5.2, we discuss the optimal policy mix when a concern for domestic employment generated by the firm is included in the welfare function.

5.2 | Optimal policy with concern for employment

We now include a concern for domestic employment in the government's objective function. This may be of particular relevance when Home is characterized by high unemployment and the government is under political pressure to protect employment (L^h) in that sector. The government's objective function in expression (10) can then be expanded and rewritten as

$$W^i = \Pi^i + \theta t\pi^i + (\beta - s)x^i + \lambda^i L^i, \tag{14}$$

where $\lambda^i \geq 0$, with $\lambda^h > 0$ capturing the extra weight of employment provided by the firm if it produces at Home and $\lambda^f = 0$, reflecting that, if the firm offshores production, the Home government does not care about the employment the firm provides abroad. We assume a simple input–output technology, given by $L^i = q^i$. As in the case without a concern for employment, given optimal tax setting, the firm will always pay its taxes in h and, given our input–output technology, expression (14) reduces to

$$W^i = \pi^i + (\beta - s)x^i + \lambda^i q^i. \tag{15}$$

Before examining the optimal subsidy, consider what happens to domestic employment as the subsidy rises. When $s < \bar{s}$, domestic production and hence employment is increasing in the R&D-subsidy, but when the subsidy rises above $\bar{s}$, domestic production, and hence domestic employment, abruptly falls to zero as the firm offshores.

Figure 4 shows the relationship between β and the optimal R&D-subsidy (Figure 4a) and tax (Figure 4b) when the government has an additional concern for domestic employment, represented by the bold curves. The dashed curves represent the optimal R&D-subsidy and corporate tax in the benchmark case when the government has no special concern for employment (i.e., $\lambda^h = \lambda^f = 0$). To explain the optimal policy package for different spillover levels, it is convenient to define two spillover thresholds.

Definition 2. $\underline{\beta}^e \equiv \beta' - \frac{1}{2}\lambda^h$.

[13] The Matthew effect has been discussed widely in the social sciences. For an example from economics, see Neary (2015).

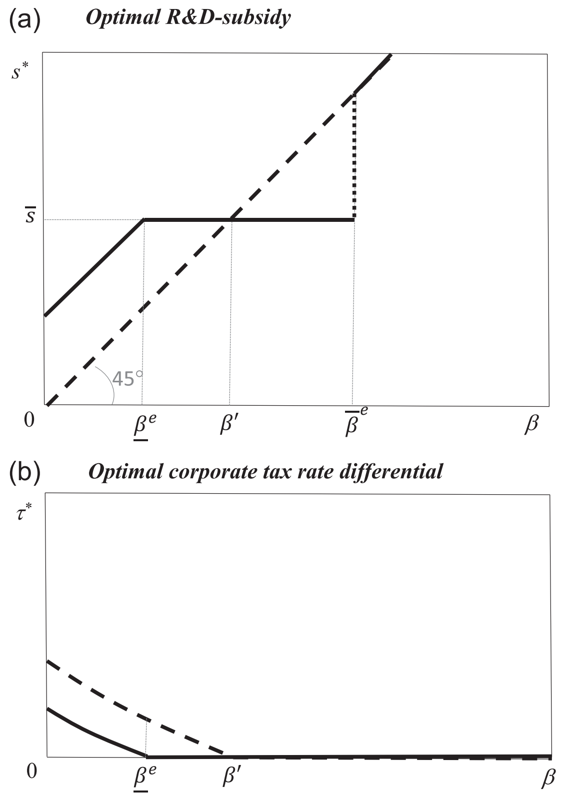

FIGURE 4 Optimal policy package with concern for domestic employment. (a) Optimal R&D-subsidy and (b) optimal corporate tax rate differential. R&D, Research and Development

Definition 3. $\overline{\beta}^e \equiv \beta' + \frac{1}{2}\left(\sqrt{(A^f - A^h)^2 + 4\lambda h\frac{1}{\eta}(A^h + \eta\beta')} - (A^f - A^h)\right)$.

In qualitative terms, $\underline{\beta}^e$ is the minimum spillover level at which the government wants to limit the subsidy to deter offshoring, while $\overline{\beta}^e$ is the maximum spillover level at which deterring offshoring is the optimal policy stance. These thresholds $\underline{\beta}^e$ and $\overline{\beta}^e$ are formally derived in the appendix in the proof of Proposition 4; $\underline{\beta}^e < \beta' < \overline{\beta}^e$ follows from these derivations.

Intuitively, at low spillover values ($\beta < \underline{\beta}^e$), the government sets an R&D-subsidy that exceeds the spillover. The R&D-subsidy, now being higher for a given level of R&D-spillover than in the benchmark case, will boost the firm's production, thereby creating more local employment (see Figure 4a). Since it now cares about employment, the government is, even at relatively high levels of the R&D-spillover, keen to retain the firm's production at Home, implying that there is a range of β ($\beta \in [\underline{\beta}^e, \overline{\beta}^e]$) for which the government keeps the subsidy at the critical level that deters offshoring, that is, $s^* = \bar{s}$. Importantly, the maximum level of the spillover parameter at which the government wants to retain the firm, $\overline{\beta}^e$, is higher than in the benchmark case in which government policy was not driven by concerns for domestic employment (i.e., $\overline{\beta}^e > \beta'$, as is illustrated in Figure 4a). Only when the spillover is sufficiently high ($\beta > \overline{\beta}^e$), does the Pigovian argument for internalizing the incentive to do the socially optimal amount of R&D dominate the argument for preserving domestic employment; the optimal policy then involves letting the firm offshore production and, like in the benchmark case, the optimal R&D-subsidy simply tracks the R&D-spillover ($s^* = \beta$).

Figure 4b shows the corporate tax rate differential that the government can afford to set at various levels of the spillover parameter. As the gap between the solid and dashed curves shows, at a given level of β, for $\beta < \beta'$, the government must now set lower corporate taxes to retain production than in the benchmark. The reason for this lies in the fact that, at given β, it is giving higher R&D-subsidies, which—ceteris paribus—makes offshoring more attractive. Since the R&D-subsidy is now also being used to manipulate the firm's production location choice, it is not tailored specifically to correct the R&D-externality but is chosen to retain production at Home. Proposition 4 summarizes these results.

Proposition 4. *With a special concern for employment* ($\lambda^h > 0$), *the optimal R&D-subsidy and optimal tax rate are*

(i) $s^* = \beta + \lambda^h/2$ *and* $\tau^* = \bar{\tau}(s^*(\beta, \lambda^h)) > 0$ *for* $\beta < \underline{\beta}^e$;
(ii) $s^* = \bar{s}$ *and* $\tau^* = \bar{\tau}(\bar{s}) = 0$ *for* $\underline{\beta}^e \leq \beta \leq \overline{\beta}^e$;
(iii) $s^* = \beta > \bar{s}$ *and* $\tau^* = 0$ *for* $\beta > \overline{\beta}^e$.

Note that, compared with when the government does not take employment into account, the optimal subsidy picture that emerges shows (in Figure 4a) that attaching an additional weight to domestic employment increases the R&D-subsidy in sectors with low R&D-spillovers (i.e., between 0 and β') and also lowers the associated tax rate in these sectors (if s^* increases, then $\bar{\tau}(s^*)$ falls to retain production at Home). However, it will dampen the R&D-subsidy—and consequently R&D—in sectors with high R&D-spillovers (i.e., between β' and $\overline{\beta}^e$) since the R&D-subsidy is curbed at $\bar{s}$ in this range of spillover values; the tax rate is the same as in the benchmark (since at $\bar{s}$, the corresponding optimal tax rate differential is zero).

6 | CONCLUSION AND EXTENSIONS

In this paper we have examined optimal policy towards an R&D-intensive firm that considers offshoring its production activities. The policy consists of a mix of direct R&D-subsidies and a favorable corporate tax rate. We have shown that an attempt by a government to boost local innovation by increasing the direct R&D-subsidy, will—while encouraging local R&D—also increase the incentive to offshore production activities to a lower-cost location. The reason for this lies in the fact that the return to R&D expenditure is higher for low-cost firms and so, to maximize the return to R&D, firms have an incentive to move production to where marginal costs are lower. This result has several important policy implications.

First, when the local R&D-spillover is relatively low, the optimal R&D-subsidy will also be low. Then, provided that pretax net-benefits from offshoring are sufficiently low, production offshoring can be prevented by complementing any increase in the R&D-subsidy with a tailored corporate tax rate reduction. Without offshoring its production, the firm cannot transfer price and will pay taxes at home. Importantly, even though an increase in the R&D-subsidy should be accompanied by a reduction in the corporate tax rate, the corporate tax rate at home can still exceed the one abroad.

Second, the prevention of production offshoring will no longer be possible when the R&D-subsidy raises the return to R&D sufficiently, since then the firm will offshore production regardless of the corporate tax rate it faces at home. In that case, pretax net-benefits from offshoring are high enough for the firm never to want to maintain production at home. Transfer pricing then enables the firm to pay taxes where the corporate tax rate is lower. This implies that the government, can—at best—ensure that the firm pays its taxes at home by simply matching the effective corporate tax rate to the foreign one.

Third, from our analysis, it is clear that, regardless of the welfare function adopted by the government, the optimal policy package towards R&D-intensive firms never involves an increase in the R&D-subsidy being accompanied by an increase in the corporate tax rate. Thus, it is not a good idea to recover the cost of R&D-subsidization by increasing the tax bill for R&D-intensive firms. The common idiom that one should "give with one hand and take away with the other" does not hold. In fact, if anything, the converse, implying that one should "give with one hand and do the same with the other," typically applies.

In our welfare benchmark, the home government uses the R&D-subsidy for Pigovian reasons only. It therefore yields a "clean" point of reference against which to compare cases in which the government does have specific concerns that lead to policies that aim to manipulate these firms' production location decisions. Compared with the government in our benchmark, a government that is also concerned with domestic employment will use the R&D-subsidy to manipulate the location decision of the firm. Compared with the benchmark subsidy, the R&D-subsidy will now be used to boost domestic production and hence domestic employment and will therefore be higher when the local R&D-spillover is low. It also implies that, when the R&D-spillover is high enough, the government will keep the R&D-subsidy below the critical threshold to prevent the firm from relocating production abroad. So, because the government now also uses the R&D-subsidy to augment domestic employment, it overstimulates R&D for low spillovers and understimulates it for high R&D-spillovers, relative to the benchmark case.

One increasingly popular way of achieving lower corporate tax rates for R&D-intensive firms in practice is the implementation of a patent box or innovation box. Our analysis suggests that policy makers should be cautious when adopting IP boxes. We show that ignoring direct R&D-support when setting the tax rate concession can have negative implications for a country's welfare. Given the level of R&D-subsidization, a tax rate concession that is too small, implying an effective tax rate that is too high, will lead to offshoring of production and a loss of tax revenues, while a tax rate concession that is too large will lead to tax revenue losses. While it is not always necessary to match the tax rate to that of competing jurisdictions, it is essential to examine the entire package of domestic policies towards R&D-intensive firms.

Our study naturally has some limitations, which point to possible extensions for future research. For instance, it is straightforward to incorporate the cost of public funds into our welfare function. It is often argued that, when considering government expenditure programs, such as R&D-support, the actual level of spending is an underestimate of the true opportunity cost since taxation, needed to raise the required funds, tends to be distortionary.[14] If the social costs of funds are taken account of, the R&D-subsidy will be lower than in the benchmark case for every level of the spillover, simply because it is now more costly to subsidize R&D. Another possible extension with similar implications for the resulting optimal policy involves allowing for the multinational firm to be partially foreign owned. Since home subsidies are then going to a firm that is not fully domestically owned and corporate taxes are coming from profits that are partially foreign, the incentive to subsidize decreases, while the incentive to tax increases. In each of these extensions, the qualitative result of our basic model—increasing R&D-subsidies may need to be complemented by a lower but never a higher corporate tax rate—should remain.

[14]For early work, see Browning (1976).

We did not include consumer surplus in the welfare function. While this is a reasonable approach if the home economy is a small open economy and exports most of its production, a large economy may consume a substantial share of the R&D-intensive firm's production. In that case, consumers at home will be better off if production is offshored to a lower-cost location. Naturally, goods sold at home would have to be imported from the foreign production location, bearing trade costs; hence, both production and trade costs would have to be taken into account when assessing the relative cost of offshoring. If the foreign marginal production cost and the cost of importing the final product is sufficiently low, the optimal policy package would in some circumstances involve inducing production offshoring. Of course, in practice, encouraging firms to offshore production is not part of the rhetoric employed by policy makers.

Our model could also be extended to include more firms. An oligopolistic setup would introduce the possibility of strategic location or policy decisions in our framework, whereas a monopolistically competitive setup could provide insights into the sorting effects of a package of direct and indirect R&D-support. Another worthwhile though considerably complex extension may be to endogenize the policy of the foreign government. Allowing for offshoring of R&D is another interesting avenue for future research; firms may consider investing in R&D-centers abroad to source technology or conducting R&D locally to adapt the generic product to local markets, thus choosing to offshore their R&D as well as production activities. Finally, it would be interesting to add a dynamic dimension to our model. Our result that a government that cares particularly about domestic employment will oversubsidize R&D in sectors with low spillovers and do the opposite in sectors with high spillovers, is bound to have implications for long-run growth that deserves further investigation.

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APPENDIX A: PROOFS OF LEMMAS AND PROPOSITIONS

A.1 | Proof of Lemma 1

Since $\bar{c}^h > \bar{c}^f$ from Assumption 1, $A^f > A^h$. Then, from (6), $\tilde{q}^f > \tilde{q}^h$ follows and $\tilde{x}^f > \tilde{x}^h$ follows from (7). □

A.2 | Proof of Lemma 2

From Assumption 3, $\tilde{\pi}^h(s) > \tilde{\pi}^f(s)$ at $s = 0$ and since $A^f > A^h$ from Assumption 1, it follows from (8) that $\tilde{\pi}^f(s)$ increases faster in s at every s than $\tilde{\pi}^h(s)$. Hence, the $\tilde{\pi}^f(s)$ locus cuts the $\tilde{\pi}^h(s)$ locus once from below at $\bar{s}$. Using (8) and $\tilde{\pi}^h(\bar{s}) = \tilde{\pi}^f(\bar{s})$ yields $\bar{s} = \frac{1}{(A^f - A^h)\eta}\left((2-\eta)F^f - \frac{1}{2}((A^f)^2 - (A^h)^2)\right)$. Since $(A^f - A^h)\eta = (\bar{c}^h - \bar{c}^f)\eta > 0$ from Assumption 1 and $(2-\eta)F^f - \frac{1}{2}((A^f)^2 - (A^h)^2) > 0$ from Assumption 3, $\bar{s} > 0$. Since the $\tilde{\pi}^f(s)$-locus cuts the $\tilde{\pi}^h(s)$-locus once from below at $\bar{s}$, $\tilde{\pi}^f(s) > \tilde{\pi}^h(s)$ for $s > \bar{s}$ and $\tilde{\pi}^f(s) < \tilde{\pi}^h(s)$ for $s < \bar{s}$. □

A.3 | Proof of Proposition 1

From $\bar{s} = \frac{1}{(A^f - A^h)\eta}\left((2-\eta)F^f - \frac{1}{2}((A^f)^2 - (A^h)^2)\right)$, it is clear that $\frac{\partial \bar{s}}{\partial F^f} > 0$. Also, we have $\frac{\partial \bar{s}}{\partial A^h} = \frac{1}{(A^f - A^h)^2\eta}\left((2-\eta)F^f - \frac{1}{2}(A^f - A^h)^2\right)$. Note that $(2-\eta)F^f - \frac{1}{2}(A^f - A^h)^2$ can be written as $(2-\eta)F^f - \frac{1}{2}((A^f)^2 - (A^h)^2) + A^h(A^f - A^h)$. Since $F^f > \frac{1}{2(2-\eta)}((A^f)^2 - (A^h)^2)$ from Assumption 3, we have $(2-\eta)F^f - \frac{1}{2}((A^f)^2 - (A^h)^2) > 0$; also, $A^h(A^f - A^h) = A^h(c^h - c^f) > 0$ from Assumption 1; hence, $\frac{\partial \bar{s}}{\partial A^h} > 0$. Furthermore, $\frac{\partial \bar{s}}{\partial A^f} = -\frac{1}{(A^f - A^h)^2\eta}\left((2-\eta)F^f + \frac{1}{2}(A^f - A^h)^2\right) < 0$. In addition $\frac{\partial \bar{s}}{\partial \eta} = \frac{-1}{(A^f - A^h)\eta^2}\left(2F^f - \frac{1}{2}((A^f)^2 - (A^h)^2)\right)$; from $F^f > \frac{1}{2(2-\eta)}((A^f)^2 - (A^h)^2)$ (Assumption 3), we have $F^f > \frac{1}{4}((A^f)^2 - (A^h)^2)$ and $\frac{\partial \bar{s}}{\partial \eta} < 0$. □

A.4 | Proof of Proposition 2

(i) From Assumption 2, offshoring production allows the firm to perfectly transfer price and, from Lemma 2, $\tilde{\pi}^f > \tilde{\pi}^h$ for $s > \bar{s}$. So, for $s > \bar{s}$, $\tilde{\Pi}^f > \tilde{\Pi}^h$ regardless of the level of τ. (ii) From Lemma 2, $\tilde{\pi}^h \geq \tilde{\pi}^f$ for $s \leq \bar{s}$. So, $\tilde{\Pi}^f = \tilde{\Pi}^h$ at $\tau = \bar{\tau}$ and $\tilde{\Pi}^f > \tilde{\Pi}^h$ if and only if $\tau > \bar{\tau}$. □

A.5 | Proof of Proposition 3

(i) First, we derive maximized welfare *given* the location of production ($W^{i*}(\beta)$). Combining (13) and (11) yields $W^{i*}(\beta) = \tilde{\pi}^i(s^{i*}(\beta))$, which depends positively on β. Second, evaluating $W^{i*}(\beta)$ for $i = h, f$, we have $W^{h*}(\beta) = \tilde{\pi}^h(s^{h*}(\beta))$ and $W^{f*}(\beta) = \tilde{\pi}^f(s^{f*}(\beta))$, respectively; at

$\beta = \beta' = \bar{s}$, $W^{h*}(\beta') = \widetilde{\pi}^h(\bar{s}) = \widetilde{\pi}^f(\bar{s}) = W^{f*}(\beta')$ (since $\widetilde{\pi}^h(\bar{s}) = \widetilde{\pi}^f(\bar{s})$ from the definition of $\bar{s}$ in Lemma 2). For $\beta < \beta'$, $s^{i*}(\beta) < \bar{s}$, and $W^{h*}(\beta) = \widetilde{\pi}^h(s^{h*}(\beta)) > \widetilde{\pi}^f(s^{f*}(\beta)) = W^{f*}(\beta)$ with $s^{h*} = s^{f*} = \beta$. Clearly, any deviation from $s^{i*}(\beta) = \beta$, including deviating to slightly above $\bar{s}$ and inducing offshoring, lowers welfare. Hence, $s^* = s^{h*} = \beta$ for $\beta < \beta'$. For $\beta > \beta'$, $s^{i*}(\beta) = \beta > \bar{s}$; so, $W^{h*}(\beta) = \widetilde{\pi}^h(s^{h*}(\beta)) < \widetilde{\pi}^f(s^{f*}(\beta)) = W^{f*}(\beta)$ and deviations in the subsidy (in this case downwards to $\bar{s}$ to prevent offshoring) must lower welfare. Thus, $s^*(\beta) = \beta$.

(ii) For any s, welfare is at least as high when taxes are paid in h rather than in f. For $\beta \le \beta'$, $s^*(\beta) = \beta \le \beta' = \bar{s}$; hence, $\widetilde{\pi}^h(s^*) \ge \widetilde{\pi}^f(s^*)$; the firm only offshores and pays taxes in f for $\tau > \bar{\tau}(s^*) = \frac{2F^f(2-\eta) - (\bar{c}^h - \bar{c}^f)(A^f + A^h + 2\eta s^*)}{(A^h)^2 + 2\eta(A^h + s^*)} \ge 0$. Using $s^*(\beta) = \beta$, we have

$$\tau^*(\beta) = \bar{\tau}(s^*(\beta)) = \frac{2F^f(2-\eta) - (\bar{c}^h - \bar{c}^f)(A^f + A^h + 2\eta\beta)}{(A^h)^2 + 2\eta(A^h + \beta)}$$

for $\beta \le \beta'$. For $\beta > \beta'$, $s^*(\beta) > \bar{s}$, and $\bar{\tau}(s^*(\beta)) < 0$. However, since now $\widetilde{\pi}^f(s^*(\beta)) > \widetilde{\pi}^h(s^*(\beta))$ and the firm always offshores regardless of τ, $\tau^* = 0 > \bar{\tau}(s^*(\beta))$ for $\beta > \beta'$. Hence, $\tau^*(\beta) = \max\{\bar{\tau}(s^*(\beta)), 0\}$. □

A.6 | Proof of Corollary 1

This follows from a combination of Proposition 1, Proposition 3, and Definition 1. Given $\tau^*(\beta)$ and $s^*(\beta) = \beta$, $\widetilde{\Pi}^f > \widetilde{\Pi}^h$ iff $s^*(\beta) > \bar{s}$ from Proposition 1; $s^*(\beta) > \bar{s}$ iff $\beta > \beta'$ from Proposition 3 and Definition 1. □

A.7 | Proof of Corollary 2

From Proposition 3, $s^*(\beta) = \beta$.

(i) For $\beta \le \beta'$, $s^*(\beta) \le \bar{s}$ and, as shown in the proof of Proposition 3,

$$\tau^*(\beta) = \frac{2F^f(2-\eta) - (\bar{c}^h - \bar{c}^f)(A^f + A^h + 2\beta\eta)}{(A^h)^2 + 2\eta(A^h + \beta)}.$$

From this it is easy to see that $\bar{\tau}^*(\beta)$ falls in β.

(ii) For $\beta > \beta'$, $s^*(\beta) > \bar{s}$ and, as shown in the proof of Proposition 3, the optimal tax differential is $\tau^* = 0$ which is independent of β. □

A.8 | Proof of Proposition 4

Using expression (15), we obtain the first-order condition for s:

$$\frac{dW^i}{ds} = \frac{d\widetilde{\pi}^i}{ds} + (\beta - s)\frac{d\widetilde{x}^i}{ds} - \widetilde{x}^i + \lambda^i\frac{d\widetilde{q}^i}{ds} = 0. \tag{A1}$$

Simplifying (since $\frac{d\tilde{\pi}^i}{ds} = \pi_s^i + \pi_q^i \frac{d\tilde{q}^i}{ds} + \pi_x^i \frac{d\tilde{x}^i}{ds}$, with $\pi_q^i = 0$ and $\pi_x^i = 0$ from the final stage and $\pi_s^i = x^i$), expression (A1) reduces to

$$(\beta - s) + \lambda^i \frac{d\tilde{q}^i}{ds} \bigg/ \frac{d\tilde{x}^i}{ds} = 0. \tag{A2}$$

Using (6) and (7) in (A2), we obtain the optimal subsidy, conditional on location i, with $\lambda^h > 0$ and $\lambda^f = 0$, implying

$$s^{h*}(\beta, \lambda^h) = \beta + \lambda^h/2 \tag{A3}$$

and

$$s^{f*}(\beta) = \beta. \tag{A4}$$

Given optimal tax setting, the firm will not offshore provided $s \leq \bar{s}$. Thus, (A3) applies for $\beta + \lambda^h/2 \leq \bar{s}$, or, in terms of β, for $\beta \leq \underline{\beta}^e = \bar{s} - \lambda^h/2 = \beta' - \lambda^h/2$.

(i) For $\beta < \underline{\beta}^e$, $s^{h*}(\beta, \lambda^h) = \beta + \lambda^h/2 < \bar{s}$ and thus $s^*(\beta, \lambda^h) = s^{h*}(\beta, \lambda^h)$. For any s, welfare is at least as high when taxes are paid in h rather than in f. Since, for $\beta < \underline{\beta}^e$, $s^*(\beta, \lambda^h) < \bar{s}$, we have $\tilde{\pi}^h(s^*) > \tilde{\pi}^f(s^*)$; the highest τ, conditional on the firm paying taxes in h is then

$$\tau^* = \bar{\tau}(s^*(\beta, \lambda^h)) = \frac{2F^f(2-\eta) - (\bar{c}^h - \bar{c}^f)(A^f + A^h + 2\eta(\beta + \lambda^h/2))}{(A^h)^2 + 2\eta(A^h + (\beta + \lambda^h/2))} > 0.$$

(ii) For $\beta = \underline{\beta}^e$, $s^{h*} = \underline{\beta}^e + \lambda^h/2 = \bar{s}$ and $W^{h*} = \tilde{\pi}^h + \lambda^h(\tilde{q}^h - (\tilde{x}^h/2))$. A marginal increase in the subsidy at $\bar{s}$ implies a discrete drop in welfare as it leads to offshoring and $\tilde{q}^h = 0$. Hence, for $\beta - \underline{\beta}^e > 0$ small enough, $W^h(\bar{s}, \beta) > W^{f*}(s^{f*}(\beta))$ and thus $s^* = \bar{s}$. The corresponding τ^* is

$$\bar{\tau}(\bar{s}) = \frac{2F^f(2-\eta) - (\bar{c}^h - \bar{c}^f)(A^f + A^h + 2\eta\bar{s})}{(A^h)^2 + 2\eta(A^h + \bar{s})},$$

with $\bar{\tau}(\bar{s}) = 0$ from the definition of $\bar{s}$. Since $W^{f*}(s^{f*}(\beta))$ rises faster in β than $W^h(\bar{s}, \beta)$ does, there exists a $\bar{\beta}^e > \underline{\beta}^e$, such that $W^h(\bar{\beta}^e, \bar{s}) = \tilde{\pi}^h(\bar{s}) + (\bar{\beta}^e - \bar{s})\tilde{x}^h(\bar{s}) + \lambda^h \tilde{q}^h(\bar{s})$ equals optimized welfare conditional on offshoring, $W^{f*}(\bar{\beta}^e) = \tilde{\pi}^f(s^{f*}(\bar{\beta}^e))$ and $W^h(\bar{s}, \bar{\beta}^e) = W^{f*}(s^{f*}(\bar{\beta}^e))$. Thus, $s^* = \bar{s}$ for $\underline{\beta}^e \leq \beta \leq \bar{\beta}^e$ and, the corresponding τ^* is $\bar{\tau}(\bar{s}) = 0$.

We can obtain an explicit expression for $\bar{\beta}^e$, using $\tilde{\pi}^h(\bar{s}) = \tilde{\pi}^f(\bar{s})$ (from the definition of $\bar{s}$) to replace $\tilde{\pi}^h(\bar{s})$; we have

$$W^{f*}(\bar{\beta}^e, s^f(\bar{\beta}^e)) - W^h(\bar{\beta}^e, \bar{s}) = \tilde{\pi}^f(s^{f*}(\bar{\beta}^e)) - \tilde{\pi}^f(\bar{s}) - (\bar{\beta}^e - \bar{s})\tilde{x}^h(\bar{s}) - \lambda^h \tilde{q}^h(\bar{s}) = 0.$$

From this and expressions (5)–(7) we obtain a quadratic in $\bar{\beta}^e$ with solution

$$\bar{\beta}^e(\bar{s}, \lambda^h) = \frac{1}{2}\left((A^h - A^f + 2\bar{s}) + \sqrt{(A^f - A^h)^2 + 4\lambda^h \frac{1}{\eta}(A^h + \eta\bar{s})}\right).$$

Using $\bar{s} = \beta'$, we obtain $\bar{\beta}^e = \beta' + \frac{1}{2}\left(\sqrt{(A^f - A^h)^2 + 4\lambda^h \frac{1}{\eta}(A^h + \eta\beta')} - (A^f - A^h)\right) > \beta'$ for $\lambda^h > 0$.

(iii) For $\beta > \bar{\beta}^e$, $W^f{}^*(s^f{}^*(\beta)) > W^h(\bar{s}, \beta)$. From (A4), $s^*(\beta) = s^f{}^*(\beta) = \beta$. Since here $s^*(\beta) > \bar{s}$, the firm offshores regardless of τ. To ensure taxes are paid in h, $\tau^* = 0$ for $\beta > \bar{\beta}^e$. □