Attracting Profit Shifting or Fostering Innovation? On Patent Boxes and RD Subsidies

Andreas Haufler (LMU Munich and CESifo)
Dirk Schindler (Erasmus University Rotterdam)

Discussion Paper No. 336

September 9, 2022

Collaborative Research Center Transregio 190 | www.rationality-and-competition.de
Ludwig-Maximilians-Universität München | Humboldt-Universität zu Berlin
Spokesperson: Prof. Georg Weizsäcker, Ph.D., Humboldt University Berlin, 10117 Berlin, Germany
info@rationality-and-competition.de

Attracting profit shifting or fostering innovation? On patent boxes and R&D subsidies*

Andreas Haufler† Dirk Schindler‡

May 25, 2022

Abstract

Many countries have introduced patent box regimes in recent years, offering a reduced tax rate to businesses for their IP-related income. In this paper, we analyze the effects of patent box regimes when countries can simultaneously use patent boxes and R&D subsidies to promote innovation. We show that when countries set their tax policies non-cooperatively, innovation is fostered, at the margin, only by the R&D subsidy, whereas the patent box tax rate is targeted at attracting international profit shifting. In equilibrium, patent box regimes emerge endogenously under policy competition, but never under policy coordination. We also compare the competition for mobile patents with the competition for mobile R&D units and show that enforcing a nexus principle is likely to reduce the aggressiveness of patent box regimes.

Keywords: corporate taxation; profit shifting; patent boxes; R&D tax credits; tax competition

JEL classification: H25, H87, F23

*Paper presented at the 2021 online conferences of the Canadian Economic Association, the International Institute of Public Finance, the CESifo Area Conference in Public Economics, and the Summer Symposium of the Centre for Business Taxation in Oxford as well as the THEMA seminar at CY Cergy Paris Université. We particularly thank Ron Davies, Irem Güceri, Anna Gumpert, Eckhard Janeba, Steffen Juranek, Etienne Lehmann, Max Löffler, Nadine Riedel, Max Todtenhaupt, and Martin Watzinger for helpful comments and suggestions. Andreas Haufler acknowledges financial support from the German Research Foundation through CRC TRR 190. This paper was started when Dirk Schindler visited CES at the University of Munich. He wishes to thank the members of CES for their hospitality.

†University of Munich, CESifo, and NoCeT; email: Andreas.Haufler@econ.lmu.de

‡Erasmus University Rotterdam, NoCeT, Tinbergen Institute, and CESifo; email: Schindler@ese.eur.nl

1 Introduction

The importance of innovation for economic development and growth has received major attention in the last 20 years, and providing public support for the underlying R&D investment has become an important policy objective. Out of 36 OECD countries, 83% offered R&D tax incentives in 2018, up from 53% in the year 2000 (Appelt et al., 2019, Figure 2). In the same period, the average implicit R&D subsidy rate for profit-making firms has increased from 4-5% in the year 2000 to 14-16% in 2018.[1] The economic reason for rising R&D subsidies are their impact on innovation, economic growth and market efficiency (see Bloom et al., 2019, for an overview). Moreover, increasing market integration strengthens both international R&D spillovers, and the case for R&D subsidies.[2]

At the same time, profit shifting by multinational corporations (henceforth MNCs) remains high on the agenda of both academics and policymakers. A large empirical literature has established convincing evidence that MNCs use various channels to transfer their profits from high-tax to low-tax countries.[3] Current attempts to quantify the overall extent of profit shifting estimate that close to 40% of all profits of MNCs are shifted to tax havens (Tørsløv et al., 2018). With the OECD's (2013) action plan against base erosion and profit shifting (BEPS), the topic has also taken center stage in policy debates.

A policy instrument that connects both policy issues are so-called 'patent boxes', which introduce reduced corporate tax rates for income derived from patents and other intellectual property. These have become a hotly debated issue after many countries, particularly in Europe, but also elsewhere, opted for them.[4] Table 1 shows that 15 European countries had introduced such patent boxes by the year 2020. In most countries, patent boxes were introduced with the stated aim of fostering domestic R&D. However, empirical research has established that placing patents in low-tax countries is one prominent channel by which MNCs engage in profit shifting (Karkinsky and Riedel, 2012; Baumann et al., 2020). Therefore, it is widely believed that attracting inward profit shifting from MNCs is a further main reason for introducing patent box regimes.

Given these twofold effects of patent box regimes, the policy debate surrounding them has been highly controversial. The current policy compromise (OECD, 2015) is to permit patent tax regimes, but to confine the preferential tax treatment to income from patents that have been developed to a substantial degree in the country granting the tax rebate

[1] See Appelt et al. (2019, Figure 7). This figure uses the OECD R&D tax incentives database to aggregate various policies to promote R&D to an implied R&D subsidy rate.

[2] See Haaland and Kind (2008) for a theoretical analysis of the effects of market integration on R&D subsidy choices, and Fracasso and Marzetti (2015) for empirical evidence that higher trade flows lead to disproportionate increases in international R&D spillovers.

[3] See Cristea and Nguyen (2016) and Davies et al. (2018) for recent examples of this literature, and for further references.

[4] In the United States, the 2017 tax reform includes a concessionary tax on foreign-derived intangible income (FDII). Though not officially labelled so, this provision operates like a patent box with a maximum tax rate of 13% (Mintz, 2018).

Table 1: Patent box regimes in Europe (2020)

country	year of introduction	qualifying assets: patents	software	other	patent box tax rate (%)	statutory CIT rate (%)
Belgium	2007	x	x		4.5	29.6
Cyprus	2012	x	x	x	2.5	12.5
France	2000	x	x		10	34.4
Hungary	2003	x	x		0, 4.5[a]	9
Ireland	1973/2015	x	x	x	6.25	12.5
Italy	2015				14	28
Lithuania	2018	x	x		5	15
Luxembourg	2008	x	x		5.2	26
Netherlands	2007	x	x	x	7	20
Poland	2019	x	x		5	19
Portugal	2014	x			10.5	21
Slovakia	2018		x		10.5	21
Spain	2008	x	x		10	25
Switzerland	2020	x			by canton[b]	by canton[b]
United Kingdom	2013	x			10	19

[a]: 0% for capital gains and 4.5% for royalty income
[b]: patent box rates and regular CIT rates differ by canton; patent box reductions are up to 90% of regular cantonal CIT rates

Sources: OECD Dataset Intellectual Property Regimes (2018), Tax Foundation Report: Patent Box Regimes in Europe (2019). Years of patent box introduction from Fabris (2019, 40-41).

(nexus requirement). This policy compromise follows empirical findings that the strategic (re-) location of patents within MNCs is most sensitive to patent box regimes that do not have a nexus requirement (Alstadsæter et al., 2018). However, even if tax concessions are confined to IP-related income that meets the nexus requirement, a harmful *race-to-the bottom* for the taxation of IP-related income that results in revenue losses for all countries involved is still a possible, and perhaps even a likely, outcome (Griffith et al., 2014).

In this paper, we analyse tax policy towards R&D incorporating the simultaneous goals of governments to foster innovation and to attract tax base. In particular, we argue that the analysis of patent box regimes must account for the fact that countries already have a set of policy instruments to promote innovation, such as R&D subsidies or tax credits, which they are increasingly using (see Appelt et al., 2019, referenced above). We show that if patent box regimes and R&D tax subsidies are introduced as separate policy instruments in an optimal tax framework, then a clear targeting result emerges: Direct R&D subsidies will be the marginal instrument to increase R&D, whereas patent box regimes are used to attract MNCs' profit shifting. Patent box regimes thus emerge from our analysis as a classical beggar-thy-neighbor policy, and this is revealed by incorporating countries' simultaneous choice of R&D subsidies.

To formally derive our results, we consider a region of n symmetric countries that is connected to the rest of the world through capital mobility. Within the region, each country is host to a parent company of an MNC, which has production affiliates in all countries in the region. The R&D unit in the parent country actively develops a patent that can be used in all its affiliates, thus receiving IP-related income from each of the subsidiaries. Each government has three tax instruments at its disposal: the standard corporate tax rate, the R&D subsidy rate, and a special tax rate that applies to the royalty (or patent) income of the parent firm.

In the benchmark case, countries in the region coordinate all their policy instruments. When there are no pure profits in the R&D sector, the optimal coordinated tax policy features an R&D subsidy, and it equates the tax rate on patent income to the standard corporate tax rate. With pure profits from R&D, the coordinated royalty tax rate is even higher than the statutory tax rate, in order to tax the rents generated in the R&D sector. Hence, a tax discount for patent income is never part of a coordinated set of tax policies. In contrast, when countries unilaterally choose their optimal policies, each country will set the tax rate on royalty income below the statutory corporate tax rate, in order to attract inward profit-shifting. Consequently, a patent box regime emerges endogenously under tax competition.

We also compare the outcome under unrestricted tax competition to a case of partial tax harmonization where governments commit not to introduce patent boxes, but compete over both statutory tax rates and R&D subsidies. While fully unambiguous results cannot be obtained for this case, our analytical and numerical arguments suggest that abolishing patent box regimes is welfare-increasing, at least when governments place some value on private income. The role of R&D subsidies is again crucial in this setting, as R&D subsidies will rise in equilibrium, following the abolition of the patent box. Therefore, by committing not to introduce a patent box, countries effectively switch to a different policy instrument to foster R&D, which cannot be used for profit shifting.

In an extension of our benchmark model, we allow firms' R&D units and patents to move across jurisdictions. In particular, we compare the setting of non-cooperative policies in the case where patents are bound in the country where R&D has occurred, but R&D units are internationally mobile, to the case where patents can be relocated across countries, but R&D units stay in the country of the MNC's headquarters. We argue that the first case is relevant for patent box regimes with a nexus requirement, whereas the second case applies to patent boxes without this requirement. We find that patent box regimes are likely to be more harmful in the second case where patents, rather than R&D units, are internationally mobile. This result implies that the nexus requirement is indeed a suitable coordination measure, which dampens the aggressiveness of patent box regimes.

Our paper contributes to the literatures on patent box regimes on the one hand, and on R&D subsidies on the other, which have so far been almost completely separated.

The empirical literature on patent boxes has come to different conclusions as to how effective patent boxes have been in fostering R&D and attracting profit shifting. Bradley et al. (2015) find some positive effect of patent box regimes on patenting activity, but no effect on profit shifting. Davies et al. (2020) estimate that patent box regimes increase the average success rate of patent applications, but the effect turns negative for frequent innovators. Gaessler et al. (2021) instead find no effect of patent boxes on innovation itself, but a (small) positive effect on trade in patents. Similarly, Bornemann et al. (2020) find for the Belgian IP box that innovative activity increases, but patent quality decreases and all real effects are driven by national firms. In contrast, MNCs largely enjoy reductions in their effective tax rates. Koethenbuerger et al. (2018) decompose the total effect of introducing patent box regimes on national tax bases using a double difference-in-difference analysis. They attribute most of the increase in the tax base to inward profit shifting, and only a smaller fraction to the induced increase in R&D.[5]

Some papers on patent boxes explicitly address the nexus requirement. Alstadsæter et al. (2018) show that unconditional patent boxes have strong effects in attracting patents from abroad, but these fiscal externalities are attenuated in the presence of a local R&D requirement. Schwab and Todtenhaupt (2021) empirically examine the cross-border effects of patent boxes on real R&D activity in neighboring countries and show that these effects depend critically on whether patent boxes are designed with or without a nexus requirement. Bradley et al. (2021) find that introducing a nexus requirement negatively affects M&A volumes and acquisition probabilities, arguing that the nexus approach interferes with beneficial firm restructuring.

A separate literature studies the effectiveness of R&D incentives by means of tax credits or direct subsidies. Bloom et al. (2019) provide a recent review of this literature and evaluate its policy implications. Several recent studies have used administrative data and quasi-experimental designs to evaluate the effectiveness of national R&D measures; see Rao (2016) for the United States, Guceri and Liu (2018) for the United Kingdom, and Chen et al. (2021) for China. Boesenberg and Egger (2017) are one of the few empirical studies of R&D incentives that also incorporate patent box regimes. Controlling for a broad range of simultaneous R&D incentives, they find that patent box regimes have a very low, and sometimes even negative effect on the filing of patents, and thus, on innovation activity. Finally, Knoll et al. (2021) study cross-border effects of input-related R&D tax incentives and show that MNCs redirect the R&D investment of their affiliates to subsidizing countries, with little change in the total R&D activity of the entire group. These empirical results point to the importance of simultaneously incorporating all policies to promote R&D, and to the relevance of international policy competition for mobile R&D units. Both features are incorporated in our analysis.

[5]Relatedly, Chen et al. (2019) look at real activity and find that those high-tax countries that introduce the most aggressive patent boxes experience less income shifting out of the country, more investment, and increased employment.

The theoretical literature on the effects of R&D incentives is very limited. In a closed economy, Akcigit et al. (2021) study the optimal mix of (non-linear) corporate taxes and R&D subsidies in a dynamic, heterogeneous firms model. Their model prominently features asymmetric information and technology spillovers between firms, but it does not incorporate international profit-shifting, or patent box regimes. Chen et al. (2021) study how R&D investment and the relabeling of non-R&D expenses respond to R&D tax incentives. In an international setting, Shehaj and Weichenrieder (2021) show that a corporate tax increase raises R&D in the presence of a patent box regime, and they provide empirical support for this effect. Sharma et al. (2021) theoretically analyze the location of patents when the R&D process is uncertain, focusing on the effect of asymmetric loss-offset rules on patent location. Neither of the last two papers uses an optimal tax framework, however, in which patent box regimes are derived endogenously.

Finally, we also contribute to the theoretical literature on optimal corporate tax policy with several tax instruments. This literature has developed from the question of whether the abolition of tax preferences for mobile tax bases raises or reduces tax revenues in the competing countries (Janeba and Peters, 1999; Keen, 2001; Janeba and Smart, 2003). More recently, these results have been applied to the taxation of MNCs that are able to shift profits across countries. Examples of this literature are Peralta et al. (2006), Hong and Smart (2010), Haufler et al. (2018), Choi et al. (2020), and Mongrain and van Ypersele (2020). The novel element in our paper is to add a R&D decision of the MNC, as well as policies to promote this activity.

We proceed as follows. Section 2 presents our model of the MNCs' R&D, production and profit-shifting decisions. Section 3 analyzes the optimal set of tax policies when countries coordinate all their tax instruments. Section 4 contrasts these results to the case where countries choose all policy instruments non-cooperatively. Section 5 studies the intermediate case where countries commit to not offering a patent box regime, but choose their remaining tax instruments non-cooperatively. Section 6 extends the analysis by comparing policy competition when either R&D units or patents are mobile internationally. Section 7 discusses further aspects of the choice between patent box regimes and R&D policies. Section 8 concludes.

2 The model

2.1 Basic framework

We model a region of $n \geq 2$ symmetric countries, whose tax policies affect the regional interest rate r. The region is partly integrated in the world capital market through international capital mobility, but the activities of the MNC are confined to the n countries in the region. Each country in the region is home to one MNC, which consists of a headquarters unit (henceforth HQ), an R&D unit, and production affiliates. In our benchmark model, the location decisions of all MNC entities are exogenously given and the R&D unit of an MNC is always located in the HQ country of the MNC.[6] Moreover, each MNC has a production affiliate in each of the n countries in the region.

Each country is equipped with a fixed stock of internationally mobile capital $\bar{k}$. The R&D unit of each MNC uses capital to conduct research and improve the MNC's production technology. This technology is then used by all production affiliates of the MNC and, together with capital, produces a homogeneous consumption good. In each country, the affiliates of all MNCs sell the final good y to local customers at a price that is normalized to unity. Finally, each country is home to one national firm that earns profits π_N. These profits are exogenous from the perspective of the national firm, but they are affected by spillovers from the MNC's R&D activity.

More specifically, consider a pair of countries i, j in the region, with $i \neq j$. The R&D unit of an MNC headquartered in country $h \in \{i, j\}$, produces an MNC-specific public good q^h that enhances, as technological quality, output production in all affiliates of the MNC.[7] The capital input k_R into R&D has a positive and non-increasing marginal productivity, leading to a production function for technological quality q^h of

$$q^h = q^h(k_R^h) \quad \text{with} \quad q_k^h > 0, \quad q_{kk}^h \leq 0, \tag{1}$$

where subscripts k denote partial derivatives.

The producing affiliates use capital inputs k_m^h for the production of the final output good, where the subscript $m \in \{i, j\}$ stands for the host country of the affiliate, and the superscript $h \in \{i, j\}$ stands for the HQ country of the MNC. Given the technological quality q^h from the R&D process, affiliate m of MNC h generates output y_m^h according to the production function

$$y_m^h = f(k_m^h, q^h) \quad \text{with} \quad f_k > 0,\ f_{kk} < 0,\ f_q > 0,\ f_{qq} < 0,\ f_{kq} > 0, \tag{2}$$

where subscripts k and q again denote partial derivatives. Hence, capital and technological quality both have positive, but decreasing marginal productivities. Furthermore, technological quality and capital inputs are complements, i.e., the marginal productivity of capital increases with technological quality q^h.

R&D investment in country h provides a positive externality on the domestic economy. For our purposes, it is immaterial whether the positive externality is driven by a direct technology spillover or, for example, by a better trained workforce that benefits from

[6]For U.S. MNCs, Bilir and Morales (2020) show that about 80% of R&D activity is concentrated in the headquarters location. In Section 6, we will, however, relax this assumption and make the R&D unit mobile internationally.

[7]Hence, our model assumes that the R&D process leads to deterministic outcomes. We discuss the implications of introducing uncertainty about the returns from R&D in Section 7.

learning-on-the-job spillovers. Therefore, we simply capture the positive externality by assuming that the profits of the national firm π_N^h depend positively on domestic R&D investment k_R^h, that is $\pi_N^h(k_R^h)$ with $\partial\pi_N^h/\partial k_R^h > 0$.[8]

In exchange for using the technological quality produced in the R&D unit, each production affiliate pays royalties to the R&D unit. The value of its specific technology is private information of an MNC, and cannot be observed by tax authorities. We assume, however, that tax authority m can observe the *average* effect of technology on output across all MNCs' affiliates in market m. Then, it sets the arm's-length price p_m equal to this marginal R&D productivity at the market level.[9] This gives

$$p_m = \frac{f_q(k_m^i, q^i) + (n-1)f_q(k_m^j, q^j)}{n} = f_q, \tag{3}$$

where the last equality follows from the symmetry of MNC i and the foreign MNCs $j \neq i$ (with a collective weight of $n-1$). This average R&D transfer price p_m (the 'blueprint price') is exogenous from the perspective of each MNC when the number of countries in the region n, and hence the number of MNCs operating in market m is sufficiently large.

Each MNC can, however, deviate from the average royalty payment $p_m q^h$ in a host country $m \in \{i, j\}$ by (falsely) claiming that its technological quality differs from the average quality. The deviation from the arm's length royalty payment is labelled a_m^h, with $a_m^h \gtrless 0$. The MNC-specific royalty payment is then $p_m q^h + a_m^h$, thus permitting the MNC to transfer an amount of profits a_m^h from the production affiliate in country m to its R&D unit in country h. Assuming that profit shifting is lump-sum, and hence does not affect the MNC's optimal quality choice q^h, is an analytical simplification. It corresponds, however, to the incentives under the *transactional net margin (TNM)* method, which is one of the standard methods used for transfer pricing in the OECD.[10]

The activity of shifting profits involves tax planning costs C, which can be interpreted as documentation or negotiation costs. Following the literature, we assume that the tax planning costs C are a convex and, for simplicity, quadratic function of the amount a_m^h

[8]The empirical literature provides strong evidence for such positive externalities of R&D on the local economy; see, e.g., Bloom et al. (2013). Note also that these externalities can be derived from a general estimation strategy without imposing specific spillover channels (Eberhardt et al., 2013).

[9]While imposing a 'correct' arm's length price is difficult in practice, assuming that tax authorities can observe (or estimate) the average productivity of R&D investment in their country seems to be a good first approximation. If tax authorities can only infer a lower bound for the productivity increase, more productive MNCs can shift some profits without incurring tax planning costs (Bauer and Langenmayr, 2013). This additional source of profit shifting should not change our qualitative results, however.

[10]Under this method, manipulating the transfer price dominates any distortive changes in real variables. This effectively leads MNCs to choose the tax-efficient amount of shifted profits in a lump-sum fashion. See Nielsen et al. (2022).

by which royalty payments are misdeclared:[11]

$$C = C(a_m^h) = \frac{\beta}{2}(a_m^h)^2. \tag{4}$$

The cost parameter β measures how difficult it is to justify deviations from the arm's-length payment and shift profits. It can therefore be interpreted as an inverse measure for the degree of goods and capital market integration in the world economy. The more integrated the MNC is (the lower is β), the easier it is to hide excessive royalty payments (i.e., profit shifting) in its global, intra-firm trade flows.[12]

The government of each country h has three tax instruments at its disposal. First, it taxes the profits of all production affiliates that are active in country h, using the statutory corporate tax rate t_h. Second, each government can set a special royalty tax rate τ_h that falls on the returns of the R&D unit residing in country h. If the royalty tax rate is lower than the corporate tax rate, $\tau_h < t_h$, we obtain a preferential treatment of royalty income that corresponds to a patent box (see Table 1 in the introduction).[13] Finally, the government can grant a direct R&D subsidy s_h, or equivalently a R&D tax credit, that reduces the rental costs per unit of capital in the R&D sector.[14]

For simplicity, we assume that all capital investment is financed by equity. Following most OECD countries' tax codes, the cost of equity is not deductible from the corporate tax base. We also adopt the ruling international standard by which the residence country of an MNC exempts foreign incomes from tax. Consequently, the profits of an affiliate are taxed in the affiliate's host country, and dividend payments to the HQ country (i.e., profit repatriations) do not cause additional tax payments in the country of the parent company.[15]

2.2 The multinationals' choices

The R&D unit of an MNC in country h earns revenues from invoicing royalty payments in all production affiliates of the MNC. These royalty payments consist of the 'true'

[11]In general, results in the profit shifting literature are sensitive to the exact specification of tax planning costs. However, Juranek et al. (2018) have shown that the analysis of transfer pricing in intangibles, such as royalties, is largely insensitive to the modelling of these costs.

[12]A good example of market integration is the EU Interest and Royalties Directive from 2003. It facilitated capital flows between member states of the European Economic Area (EEA) by abolishing withholding taxes on interest and royalty payments between EEA countries.

[13]For brevity, we use the term 'royalty tax rate' as being synonymous with 'patent box tax rate'.

[14]R&D tax credits lead to a dollar-for-dollar reduction in the firm's tax payments. Therefore, direct R&D subsidies and R&D tax credits have analogous effects as long as the net tax payment of the MNC in its HQ country remains positive. The symmetry of the model ensures that this condition is fulfilled throughout our analysis.

[15]The exemption method has traditionally been applied in countries of continental Europe. During the last decade, the United Kingdom, Japan and the United States (in its 2017 tax reform) also switched to the exemption method. Therefore, with few exceptions (Chile, Israel, Mexico, and South Korea), the exemption method is now the dominant scheme of taxing MNCs in OCED countries.

transfer price p_m applied to the MNC's technological quality q^h, plus the profit-shifting component a_m^h. The tax rate on the profits of the R&D unit is the royalty tax rate τ_h. The capital costs of the R&D unit are given by the regional interest rate r, less the R&D subsidy s_h per unit of capital investment k_R^h. The after-tax profits of the R&D unit in country h, resulting from royalty payments by the producing affiliate in country i and in $(n-1)$ symmetric affiliate countries j are thus given by

$$\pi_R^h = (1-\tau_h)\left\{[p_i + (n-1)p_j]q^h + a_i^h + (n-1)a_j^h\right\} - (r - s_h)k_R^h. \tag{5}$$

A production affiliate in country m earns after-tax revenues from selling output y_m^h, and it deducts royalty payments at the host country's corporate tax rate t_m. In addition, the affiliate carries non-deductible capital costs rk_m^h and the tax planning costs $C(a_m^h)$. For simplicity, and without affecting any of our qualitative results, we assume that tax planning costs are not tax-deductible.[16] The after-tax profits of a production affiliate of MNC h in country m are then

$$\pi_m^h = (1-t_m)[f(k_m^h, q^h) - p_m q^h - a_m^h] - rk_m^h - \frac{\beta}{2}(a_m^h)^2. \tag{6}$$

Total after-tax profits of an MNC headquartered in country h, Π_M^h, equal the sum of all affiliates' profits in (5) and (6). The MNC maximizes Π_M^h by choosing investment in the R&D unit (k_R^h), investment in all producing affiliates (k_m^h), and the levels of income shifting to the R&D unit (a_m^h). Using symmetry of the affiliates in countries j gives

$$\begin{aligned}
\max_{k_R^h, k_i^h, k_j^h, a_i^h, a_j^h} \quad \Pi_M^h &= \pi_R^h + \pi_i^h + (n-1)\pi_j^h \qquad (7)\\
&= (1-t_i)f(k_i^h, q^h) + (n-1)(1-t_j)f(k_j^h, q^h) + (t_i - \tau_h)(p_i q^h + a_i^h) - \frac{\beta}{2}(a_i^h)^2\\
&+ (n-1)[(t_j - \tau_h)(p_j q^h + a_j^h) - \frac{\beta}{2}(a_j^h)^2] - r[k_R^h + k_i^h + (n-1)k_j^h] + s_h k_R^h.
\end{aligned}$$

Capital investment k_m^h in an affiliate m follows from the first-order condition

$$\frac{\partial \Pi_M^h}{\partial k_m^h} = (1-t_m)f_k - r = 0. \tag{8a}$$

Each producing affiliate balances marginal after-tax returns against marginal capital costs. As revenues are taxed, whereas the costs of equity are non-deductible, the statutory tax rate t_m distorts each affiliate's production decision and reduces investment. This subjects countries to tax competition via the statutory tax rate t_m.

The first-order condition for the optimal R&D investment of an MNC in country h

[16] In reality, tax planning costs comprise deductible items such as the costs of tax consulting and legal advice, but also non-deductible components such as expected penalties in case of detected misconduct.

can be simplified using the definition of the arm's-length price [eq. (3)], the profits of the R&D unit in (5) and symmetry. This yields

$$\frac{\partial \Pi_M^h}{\partial k_R^h} = (1-\tau_h) n f_q q_k^h - (r - s_h) = 0. \tag{8b}$$

In our setting, R&D investment is an MNC-specific public good. Therefore, the first-order condition (8b) corresponds to a Samuelson condition stating that the aggregated marginal net returns from using the developed technology in the final-good production of all affiliates must equal the marginal net investment costs. In the same way as in (8a) above, the royalty tax rate τ_h reduces R&D investment, as revenues are taxed but capital inputs are not tax deductible. However, the R&D subsidy s_h counteracts this distortion.

Finally, the MNC determines its level of profit shifting via royalty payments from the affiliate in m to the R&D unit in h . There is no public-good character in profit shifting, and on the margin, there are no economies of scale in the tax planning costs.[17] The deviation from the arm's-length price is country-specific and needs to be justified and defended in each affiliate against the local tax authority. Hence, we obtain the standard transfer pricing formula

$$a_m^h = \frac{t_m - \tau_h}{\beta}. \tag{8c}$$

A positive tax rate differential $t_m - \tau_h$ between a production affiliate m and the R&D unit sets incentives to shift profits, and thus causes an excessive royalty payment a_m^h. Higher costs for tax planning, as measured by the parameter β, reduce the net gains from profit shifting and hence reduce a_m^h.

2.3 Capital market equilibrium

The regional interest rate r is endogenously determined in our symmetric n country model. Capital supply to the region is given by a capital endowment equal to $\bar{k}$ in each of the n countries. Moreover, the regional capital market is financially integrated with the rest of the world. Therefore, while MNCs operate only within the region, an increase in the regional interest rate r will lead to capital inflows from third (non-region) countries.[18] Capital market clearing in the region therefore implies

$$n[k_i^i + (n-1)k_i^j + k_R^i] = n\bar{k} + k^W(r), \tag{9}$$

[17] This does not preclude that tax planning causes some fixed costs in the HQ country besides the variable costs in each affiliate. Such fixed costs would not matter for our analysis, as long as the MNC is sufficiently large so that the tax savings from profit shifting overcompensate the fixed costs.

[18] Incorporating trade flows with the rest of the world ensures that a coordinated capital tax is not a lump-sum tax on capital owners in the region. Assuming that the region is an importer of capital is merely a convenient simplification.

where $k^W(r) > 0$ are the region's capital imports from the rest of the world, with the interest derivative $k_r^W > 0$. Together with the capital demand functions characterized by the first-order conditions (8a) and (8b), capital market clearing determines the regional interest rate r. Appendix A.1 derives the effects on the regional interest rate for each of our policy instruments. These are:

$$\frac{dr}{dt_m} < 0, \quad \frac{dr}{d\tau_h} < 0, \quad \text{and} \quad \frac{dr}{ds_h} > 0. \tag{10a}$$

The induced capital outflow from an increase in the corporate tax rate of country m increases the net capital supply to the other countries in the region and triggers a decrease in the regional interest rate to accommodate the FDI flow. The same applies for an increase in the tax rate on royalty payments τ_h in country h . In contrast, an increase in the R&D subsidy s_h raises capital demand in the region and leads to a higher regional interest rate.

For investments into R&D, we get (see Appendix A.1):

$$\frac{dk_R^h}{dt_h} > 0, \quad \frac{dk_R^h}{ds_h} > 0, \quad \text{and} \quad \frac{dk_R^h}{d\tau_h} = -nf_q q_k \frac{dk_R^h}{ds_h} < 0. \tag{10b}$$

An interesting result of our setup is that a higher statutory tax rate t_h increases R&D investment.[19] A higher tax t_h reduces investment in the production affiliate h, and thus reduces the world market interest rate from (10a). This lowers the costs of R&D investment, whereas the returns to R&D investment (i.e., royalty incomes) are unaffected by the change in t_h.[20] Similarly, higher R&D subsidies reduce the costs of investing into R&D and raise k_R^h. In contrast, an increase in the tax rate for royalty income, τ_h, lowers R&D investment. Note, finally, that the last two effects are linearly dependent on each other.

Capital investment in production affiliates reacts according to

$$\frac{dk_m^h}{dt_m} < 0, \quad \frac{dk_m^h}{ds_h} > 0, \quad \text{and} \quad \frac{dk_m^h}{d\tau_h} = -nf_q q_k \frac{dk_m^h}{ds_h} < 0, \tag{10c}$$

where we assume that the number of countries n is sufficiently large.[21] A higher statutory tax rate t_m in a *host country* m reduces the value of after-tax sales in the production affiliate of all MNCs $h \in \{i, j\}$, thus discouraging capital investment k_m^h. In contrast, a higher R&D subsidy s_h in a *parent country* h fosters technological quality and renders the

[19] Shehaj and Weichenrieder (2021) also derive this result theoretically and provide empirical evidence for it, using R&D data for U.S. majority-owned foreign affiliates operating in countries with a patent box regime.

[20] In the absence of a patent box, i.e., with $t_h = \tau_h$, the returns to R&D *are* affected by t_h, and R&D falls in response to a higher statutory tax rate.

[21] This ensures that the direct effects of policy instruments dominate the offsetting impact from the change in the interest rate. See Appendix A.1.

capital investment of MNC h in all countries $m \in \{i, j\}$ more productive. The opposite holds for the tax rate τ_h on royalty payments, which discourages investment in R&D in country h and makes all capital investments k_m^h less profitable. Once again, the effects of the R&D subsidy s_h and the tax rate on royalty income τ_h are linearly dependent.

Finally, there are two sets of externalities of policy changes in country i on the other countries $j \neq i$ in the region, which operate through changes in the regional interest rate. The first set of externalities is caused by the effects on country j's R&D investments:

$$\frac{dk_R^j}{dt_i} > 0, \quad \frac{dk_R^j}{ds_i} < 0, \quad \text{and} \quad \frac{dk_R^j}{d\tau_i} = -nf_q q_k \frac{dk_R^j}{ds_i} > 0. \tag{10d}$$

An increase in the corporate tax rate of country i reduces the regional interest rate, and thus, increases the profitability of R&D investments by MNCs j in the same way as it fosters R&D investment by MNC i [eq. (10b)]. In contrast, an increase in the R&D subsidy in country i increases the regional interest rate, and hence, makes R&D investment in all other countries $j \neq i$ less profitable. This is the standard capital-importing externality of a capital subsidy. The reverse applies to an increase in the royalty tax rate τ_i.

The second set of externalities falls on the capital investment in producing affiliates:

$$\frac{dk_j^j}{dt_i} > 0, \quad \frac{dk_j^j}{ds_i} < 0, \quad \text{and} \quad \frac{dk_j^j}{d\tau_i} = -nf_q q_k \frac{dk_j^j}{ds_i} > 0. \tag{10e}$$

Higher tax rates t_i and τ_i reduce the regional interest rate and increase capital investment k_j^j in all host countries $j \neq i$ and for all MNCs $j \neq i$. The opposite holds for an increase in R&D subsidies s_i.

3 Regional welfare maximization

In this section, we derive the optimal coordinated policies when the governments in the region collectively maximize regional welfare. This serves as a benchmark for comparison with the outcome under tax competition, which we analyze in the next section.

Welfare in each country, W_i, is defined as the weighted sum of tax revenue in country i and private capital income. The private capital income of a representative resident in country i equals the return to her capital endowment, $r\bar{k}$, and the after-tax profit of both the domestic firm, $(1 - t_i)\pi_N^i$, and of the MNC headquartered in country i, Π_M^i. Thus, we assume that each MNC is fully owned by the resident of its HQ country.

We normalize the welfare weight of tax revenue to unity, whereas the welfare weight of private capital income is $\gamma \leq 1$. Our model therefore incorporates two different cases. In the first case, the welfare weight of private income coincides with that of tax revenue, $\gamma = 1$. In this case the government simply maximizes national income. A frequent interpretation of this case is that the government has access to an 'outside' lump-sum tax, and therefore pure revenue collection is not an argument to employ the policy instruments studied here. In the second case, there is also an outside tax, but this is distortionary and causes a fixed excess burden of taxation. In this case, $\gamma < 1$ and tax revenue has a higher weight than private income, as each dollar of corporate tax revenue can be used to reduce the outside, distortive tax.[22]

Regional welfare $\tilde{W}_G$ is obtained by summing over the welfare levels of all countries, $\tilde{W}_G = nW_i$. Since all countries are symmetric and choose identical tax policies in the cooperative tax equilibrium, we can focus on the average welfare level per country, $W_G = \tilde{W}_G/n$. This gives

$$\begin{aligned} W_G &= t\left\{\pi_N^i(q^i) + f(k_i^i, q^i) - f_q(k_i^i, q^i)q^i - a_i^i + (n-1)\left[f(k_i^j, q^j) - f_q(k_i^j, q^j)q^j - a_i^j\right]\right\} \\ &+ \tau\left\{f_q(k_i^i, q^i)q^i + a_i^i + (n-1)[f_q(k_j^i, q^i)q^i + a_j^i]\right\} \\ &- s_i k_R^i + \gamma\left\{r\bar{k} + (1-t_i)\pi_N^i(q^i) + \Pi_M^i\right\}, \end{aligned} \tag{11}$$

where investment levels $k_m^i(t,\tau,s)$ and $k_R^i(t,\tau,s)$ and R&D output $q^i(t,\tau,s)$ depend on the coordinated tax instruments. Despite policy coordination, profit shifting $a_m^i(t,\tau)$ will arise whenever the statutory tax rate and the royalty tax rate diverge in the coordinated tax equilibrium. We assume $W_G(t,\tau,s)$ to be concave in each of the policy instruments, implying that the second-order conditions for optimality are met.

Regionally optimal statutory tax rate. Differentiating (11) with respect to the statutory tax rate t and using capital market clearing from (9) leads to

$$\begin{aligned} \frac{\partial W_G}{\partial t} &= (1-\gamma)\left[\pi_N^i + n\left(f(k_i^i, q^i) - p_i q^i - a_i\right)\right] + [t + \gamma(1-t)]\frac{\partial \bar{\pi}_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial t} \\ &+ nt\left(f_k\frac{\partial k_i^m}{\partial t} - q^i\left[f_{qk}\frac{\partial k_i^m}{\partial t} + f_{qq}q_k\frac{\partial k_R^m}{\partial t}\right] - \frac{\partial a_i^m}{\partial t}\right) - s\frac{\partial k_R^i}{\partial t} \\ &+ n\tau\left(q^i\left[f_{qk}\frac{\partial k_m^i}{\partial t} + f_{qq}q_k\frac{\partial k_R^i}{\partial t}\right] + f_q q_k\frac{\partial k_R^i}{\partial t} + \frac{\partial a_m^i}{\partial t}\right) - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial t} = 0. \end{aligned} \tag{12}$$

It is sufficient for our purposes to show that the coordinated statutory corporate tax rate is positive in the optimum, i.e., $t^* > 0$. In the following, we focus on the principal effects that cause the statutory tax rate to be positive, leaving out the interaction with other policy variables. Hence, we evaluate (12) in a situation in which governments set all tax instruments to zero, $t = \tau = s = 0$. This gives

$$\left.\frac{\partial W_G}{\partial t}\right|_{t=\tau=0} = n(1-\gamma)\left[\pi_N^i + n\left(f(k_i^i, q^i) - p_i q^i\right)\right] + n\gamma\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial t} - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial t} > 0. \tag{13}$$

[22] Treating the excess burden of 'outside' taxes as fixed can be justified by the fact that corporate tax revenue is only a small share of total tax revenue in OECD countries (typically 5-10%). See, e.g., Keen and Lahiri (1998) and Haufler et al. (2018) for further analyses using this assumption.

Equation (13) shows that the profits earned by the national firms generate a first-order incentive for the government to tax these profits when $\gamma < 1$, as the tax redistributes from private income to tax revenue. The second term in (13) is also positive, as a higher corporate tax rate raises R&D investment, and thus increases the positive spillover effect on the national firm's profits. Therefore, even if $\gamma = 1$, and the first effect is thus zero, the optimal coordinated statutory tax rate is always positive from the second term. Finally, the third term is also positive as a higher statutory tax rate lowers the interest rate that is to be paid for capital imports from the rest of the world. We assume that the sum of these effects dominates any potentially counteracting effects arising from non-zero levels of τ_i and s_i. Then, the optimal statutory tax rates will be unambiguously positive in our analysis.

Regionally optimal patent box tax rate. The first-order condition for the coordinated royalty tax τ is derived in Appendix A.2 and is given by

$$\begin{aligned} \frac{\partial W_G}{\partial \tau} &= n(1-\gamma)\left(f_q q^i + a_i\right) - n(t-\tau)\frac{\partial a_i}{\partial \tau} + [t+\gamma(1-t)]\frac{\partial \pi_N^i}{\partial q^i}\frac{\partial k_R^i}{\partial \tau} + ntf_k\frac{\partial k_i^i}{\partial \tau} \quad (14) \\ &- n(t-\tau)q^i\left[f_{qk}\frac{\partial k_i^i}{\partial \tau} + f_{qq}q_k\frac{\partial k_R^i}{\partial \tau}\right] + n\tau f_q q_k \frac{\partial k_R^i}{\partial \tau} - s\frac{\partial k_R^i}{\partial \tau} - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial \tau} = 0. \end{aligned}$$

An increase in the royalty tax rate increases welfare by the direct revenue effect of the tax, net of the reduction in private income. This is the first term in the first line of equation (14). The second term in the first line has the same sign as $(t-\tau)$, as $\partial a_i/\partial \tau < 0$. Starting from a patent box regime with a lower tax rate on royalty income ($t > \tau$), an increase in τ will therefore raise world welfare by this second effect. The third and fourth effects in the first line are instead negative. Via reduced R&D investment, an increase in the royalty tax lowers the spillover effect on the national firm, and this also reduces the revenue from taxing this firm's profits.

Furthermore, the change in τ_i has ambiguous effects on the marginal productivity of R&D, f_q, and hence on the arm's-length price of royalty payments. The total change is weighted by the tax differential $t_i - \tau_i$, as seen by the first term in the second line of (14). The lower R&D investment also reduces the quality of R&D and this lowers the tax base for the royalty tax. This is the second term in the second line. Moreover, the induced reduction in R&D investment reduces the payments on R&D subsidies, as shown in the last-but-one term of (14). Finally, a higher royalty tax reduces the interest rate and increases private net capital income, given that the region is an importer of capital.

Regionally optimal R&D subsidy. Following equivalent steps, the first-order condition for the globally optimal R&D subsidy is

$$\begin{aligned}\frac{\partial W_G}{\partial s} &= -(1-\gamma)k_R^i + [t+\gamma(1-t)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial s} + ntf_k\frac{\partial k_i^i}{\partial s} \\ &- n(t-\tau)q^i\left[f_{qk}\frac{\partial k_i^i}{\partial s} + f_{qq}q_k\frac{\partial k_R^i}{\partial s}\right] + n\tau f_q q_k\frac{\partial k_R^i}{\partial s} - s\frac{\partial k_R^i}{\partial s} - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial s} = 0.\end{aligned} \tag{15}$$

A higher R&D subsidy redistributes tax revenues from the government to the private sector. This leads to a negative direct effect on welfare if $\gamma < 1$, as shown by the first term in the first line of (15). Via increased R&D investment, however, an increase in the R&D subsidy boosts profits of national firms, due to a larger positive spillover effect, and this leads to higher corporate tax revenues, as captured by the second term. Similarly, the higher R&D subsidy fosters capital investment and increases corporate tax income by the last term in the first line. Like the royalty tax rate, the change in s_i has an ambiguous effect on the arm's-length price f_q, as given in the first term in the second line of (15). Moreover, the subsidy increases the R&D quality and boosts royalty payments, increasing revenue from the patent box; see the fifth term. Furthermore, the subsidy fosters R&D investment and leads to higher R&D subsidy expenditures for a given level of s_i, as shown by the negative last-but-one term in the second line of (15). Finally, once again, the last term captures the terms of trade effect of a change in the interest rate.

The three first-order conditions (12), (14) and (15) implicitly define a coordinated tax equilibrium in three interdependent instruments. We assume that the second-order conditions are fulfilled and the coordinated tax instruments define a welfare maximum. We can combine the first-order conditions (14) and (15), using the linear relationship in the comparative-static effects of the royalty tax and the R&D subsidy.[23] Appendix A.2 derives the simplified first-order condition for the coordinated royalty tax rate when the R&D subsidy is simultaneously chosen to maximize global welfare. This is

$$(2-\gamma)(t^* - \tau^*) + \beta(1-\gamma)f_q(q^i - q_k k_R^i) = 0. \tag{16}$$

If the government disposes of lump-sum taxes and $\gamma = 1$, the second term in (16) is zero. In this case, it follows immediately that there is no reason to differentiate the statutory and the royalty tax rates, and the optimal coordinated policy implies $t^* = \tau^*$. The reason for this is straightforward. The only effect of reducing τ below t is to permit MNCs to shift profits from their producing affiliates to a tax-privileged patent box. Since this process incurs costs, profit shifting increases private after-tax income by less than it

[23]The qualitative effects of changes in coordinated tax instruments on the capital market equilibrium can be inferred by substituting $n = 1$ in the results in Appendix A.1. This is because the effects of coordinated policy changes in a union of symmetric countries are analogous to policy changes in a closed economy.

reduces global tax revenue. This can never be optimal when the welfare weight of tax revenue is equal to that of private profit income. Finally, note that all terms in (15) are either zero or strictly positive in this case, except for the second-to-last term in the second line. From this we can infer that the R&D subsidy s^* is unambiguously positive when $\gamma = 1$ and $t^* = \tau^*$ holds.

If outside lump-sum taxes do not exist and $\gamma < 1$, the second term in (16) is instead positive. This implies that the royalty tax rate must *exceed* the statutory tax rate under global policy coordination. The combination of a tax on the returns to R&D and a subsidy on R&D inputs gives governments the possibility to tax the economic rents in the R&D sector without distorting the MNC's decision to invest in R&D. This will lead to $\tau^* > t^*$, as the statutory tax rate, but not the royalty tax, distorts the MNC's investment decision in the production of the final good.

Interestingly, under full policy coordination, the negative tax gap $t^* - \tau^* < 0$ incentivizes MNCs to *underinvoice* their intangibles so as to reduce their royalty income. Effectively, the profit shifting incentive is inverted and this constrains the extent to which the R&D profits can be confiscated by governments. This effect is captured by the term β in the second term of (16). Full economic integration ($\beta \to 0$) implies that MNCs can shift income between tax bases without costs. This makes it impossible to enforce a higher tax on royalty income and leads to $t^* = \tau^*$ in the coordinated optimum. Higher costs of profit shifting ($\beta > 0$) will constrain the possibilities of MNCs to work around the higher royalty tax and the coordinated tax differential $\tau^* - t^* > 0$ increases. If profit shifting becomes prohibitively expensive ($\beta \to \infty$), the royalty tax turns into a true lump-sum tax and the coordinated level of the royalty tax will be $\tau^* = 1$.

We summarize these results in:

Proposition 1 *When symmetric countries coordinate their tax policies (t, τ, s), the following holds:*

(i) If lump-sum taxes exist ($\gamma = 1$), the R&D subsidy is strictly positive, $s^* > 0$, and the optimal royalty tax rate is equal to the statutory corporate tax rate, $\tau^* = t^*$.

(ii) If $\gamma < 1$, the optimal royalty tax exceeds the statutory corporate tax rate, $\tau^* > t^*$. The tax gap $\tau^* - t^*$ falls when the costs of profit shifting fall (a fall in β).

It follows from Proposition 1 that a patent box with $t^* - \tau^* > 0$ is never part of a coordinated, Pareto-optimal tax policy. In the benchmark case where $\gamma = 1$, full policy coordination implies a positive investment subsidy, and equal profit tax rates on all incomes of the MNC, so as to prevent profit shifting into the patent box. In the following section, we will compare this benchmark result to the policy choices that emerge under tax competition.

4 Optimal policies under tax competition

We now assume that each government non-cooperatively chooses the policy vector (t_i, τ_i, s_i) to maximize its domestic welfare. Otherwise, the specification from the coordinated tax regime in the previous section is unchanged. Then each country's tax problem reads

$$\begin{aligned}
\max_{t_i,\tau_i,s_i} W_i &= t_i \left\{ \pi_N^i(k_R^i) + f(k_i^i, q^i) - f_q(k_i^i, q^i)q^i - a_i^i \right. \\
&+ \left. (n-1)\left[f(k_i^j, q^j) - f_q(k_i^j, q^j)q^j - a_i^j \right] \right\} \\
&+ \tau_i \left\{ f_q(k_i^i, q^i)q^i + (n-1)f_q(k_j^i, q^i)q^i + a_i^i + (n-1)a_j^i \right\} - s_i k_R^i \\
&+ \gamma \left\{ r\bar{k} + (1-t_i)\pi_N^i(k_R^i) + \Pi_M^i \right\}. \qquad (17)
\end{aligned}$$

In (17), the investment levels $k_i^i(t_i, \tau_i, s_i)$ and $k_R^i(t_i, \tau_i, s_i)$ depend on all policy parameters. Note also that under symmetry the arm's-length price in country i turns into $p_i = f_q[k_i^i(t_i, \tau_i, s_i), q^i(t_i, \tau_i, s_i)]$. It is endogenous from the perspective of each government, because the average marginal productivity of technology responds to changes in tax policy. On the other hand, the profit shifting terms $a_i^h(t_i, \tau_h)$ depend only on the difference between the statutory corporate tax rate and the tax rate on royalty income.

Each country i chooses its tax instruments (t_i, τ_i, s_i) to maximize (17), neglecting the impact of its policies on welfare in other countries.

4.1 Non-cooperative policy choices

Optimal statutory tax rate t_i. The first-order condition for the optimal statutory tax rate t_i in country i is

$$\begin{aligned}
\frac{\partial W_i}{\partial t_i} &= (1-\gamma)(\pi_N^i + B_1 - a_i^i) + (n-1)(B_2 - a_i^j) + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial t_i} \\
&+ n t_i f_k \frac{\partial k_i}{\partial t_i} - n t_i q^i \left[f_{qk}\frac{\partial k_i}{\partial t_i} + f_{qq} q_k \frac{\partial k_R^i}{\partial t_i} \right] - t_i \frac{\partial a_i^i}{\partial t_i} - (n-1) t_i \frac{\partial a_i^j}{\partial t_i} \qquad (18) \\
&+ n \tau_i q^i \left[f_{qk}\frac{\partial k_i}{\partial t_i} + f_{qq} q_k \frac{\partial k_R^i}{\partial t_i} \right] + n f_q \tau_i q_k^i \frac{\partial k_R^i}{\partial t_i} + \tau_i \frac{\partial a_i^i}{\partial t_i} - s_i \frac{\partial k_R^i}{\partial t_i} - \gamma \frac{k^W(r)}{n}\frac{\partial r}{\partial t_i} = 0,
\end{aligned}$$

where $B_1 = f(k_i^i, q^i) - p_i q^i$ and $B_2 = f(k_i^j, q^j) - p_i q^j$ are the tax bases before profit shifting in affiliates in country i, and we have used the capital-market clearing condition (9) to simplify the first-order condition.

To show that the optimal statutory tax rate is positive also under tax competition, we proceed as before and evaluate the first-order condition (18) for $t = \tau = s = 0$. Using symmetry, we further get $B_1 = B_2$ and $a_i^i = a_i^j = 0$. Eq. (18) then simplifies to:

$$\left.\frac{\partial W_i}{\partial t_i}\right|_{t_i=\tau_i=s_i=0} = (1-\gamma)\pi_N^i + \gamma \frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial t_i} + (n-\gamma)B_1 - \gamma \frac{k^W(r)}{n}\frac{\partial r}{\partial t_i} > 0, \qquad (19)$$

which is unambiguously positive. The first two terms in (19) correspond to the effects that also exist under policy coordination [eq. (13)]. The first term refers to the taxation of the domestic firm and leads to a welfare gain when $\gamma < 1$, as the tax redistributes from private income to tax revenue. The second term is positive because a higher corporate tax rate raises R&D investment, and thus increases the positive net spillover effect on the national firm's profits. Under tax competition, there is a third term which is also unambiguously positive (since $B_1 > 0$). This is because the corporate tax does not only fall on the domestic MNC, but also on the $(n-1)$ foreign-owned MNCs, whose reduction in private income does not enter country i's welfare function. Finally, the fourth term is positive for a capital importer. Assuming that these effects dominate any potentially counteracting effects arising from non-zero levels of τ_i and s_i, optimal corporate tax rates will always be positive under policy competition.

Optimal patent box tax rate. Next, we consider the optimal tax rate on royalty income τ_i. The first-order condition for this tax instrument is derived in Appendix A.3 and is given by

$$\begin{aligned} \frac{\partial W_i}{\partial \tau_i} &= (1-\gamma)n\left(f_q q^i + a^i\right) + (\tau_i n - t_i)\frac{\partial a^i}{\partial \tau_i} + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial \tau_i} + t_i f_k \frac{\partial k_i^i}{\partial \tau_i} \qquad (20) \\ &- (t_i - \tau_i)nq^i\left[f_{qk}\frac{\partial k_i^i}{\partial \tau_i} + f_{qq}q_k\frac{\partial k_R^i}{\partial \tau_i}\right] + \tau_i n f_q q_k \frac{\partial k_R^i}{\partial \tau_i} - s_i\frac{\partial k_R^i}{\partial \tau_i} - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial \tau_i} = 0. \end{aligned}$$

The terms in (20) correspond to the terms in (14) and are explained there. The critical difference lies in the second terms. With policy competition, a higher tax rate on royalty income reduces profit shifting via excessive royalty payments from all n producing affiliates to the R&D unit of the home-based MNC. Since $\partial a^i/\partial \tau_i < 0$, the second term in (20) will therefore be negative (unless τ_i is very far below t_i) and tend to reduce the R&D tax rate in each country. This reflects the incentive to set patent box tax rates below the ones maximizing regional welfare, in order to benefit from inward profit shifting.

Optimal R&D subsidies. Following equivalent steps, the first-order condition for R&D subsidies s_i results in

$$\begin{aligned} \frac{\partial W_i}{\partial s_i} &= -(1-\gamma)k_R^i + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial s_i} + t_i f_k \frac{\partial k_i^i}{\partial s_i} \qquad (21) \\ &- (t_i - \tau_i)nq^i\left[f_{qk}\frac{\partial k_i^i}{\partial s_i} + f_{qq}q_k\frac{\partial k_R^i}{\partial s_i}\right] + \tau_i n f_q q_k \frac{\partial k_R^i}{\partial s_i} - s_i\frac{\partial k_R^i}{\partial s_i} - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial s_i} = 0. \end{aligned}$$

Again these terms generally correspond to the effects under policy coordination [eq. (15)]. An important difference is, however, in the third term in the first line of (21). For a rise in s_i only, the positive corporate tax base effect in the home country will be incorporated in the government's R&D policy, but not the positive effects on corporate tax revenues accruing in the host countries of the MNC's other affiliates. Other things equal, the optimal R&D subsidy will therefore be lower under policy competition, as compared to the coordinated benchmark.

4.2 Tax policy mix in Nash equilibrium

We can now turn to the Nash equilibrium for the optimal tax policy mix. In our symmetric model, the first-order conditions in (18), (20) and (21) implicitly define an equilibrium where t_i^*, τ_i^* and s_i^* are simultaneously chosen. A symmetric Nash equilibrium exists in our model, if the welfare functions $W_i(t_i, \tau_i, s_i; t_j, \tau_j, s_j)\ \forall\ i, j\ (i \neq j)$ are continuous in the policies of both countries i and j, and strictly quasi-concave in the policies of country i. Continuity is guaranteed in our setting, because all components of W_i are continuous functions of the policy parameters in i and j. The first-order conditions in (18), (20) and (21) are too complex, however, to derive and prove the second-order conditions for the policy parameters t_i, τ_i and s_i. As is standard in the tax competition literature, we therefore have to assume that the sufficient second-order conditions for all tax policy choices are indeed met. Given the symmetry of our model, we can then infer that a symmetric Nash equilibrium must exist. While we cannot guarantee uniqueness of the Nash equilibrium, our focus in the following lies on the symmetric Nash equilibrium, even if further, asymmetric Nash equilibria should exist.

To study the properties of the symmetric Nash equilibrium, we combine the first-order conditions (20) and (21), using the fact that the patent box tax rate τ_i and the R&D subsidy have linearly dependent effects on the investment levels of both the R&D units and the producing affiliates [cf. eqs. (10b)-(10e)]. As shown in Appendix A.3, this leads to a simplified first-order condition for the royalty tax rate τ_i when the R&D subsidy is simultaneously optimized:

$$\frac{[(1-\gamma)+\frac{1}{n}]t_i - [(1-\gamma)+1]\tau_i}{\beta} + (1-\gamma) f_q (q^i - q_k k_R^i) = 0. \tag{22}$$

Eq. (22) has a straightforward interpretation. The optimal royalty tax τ_i, and hence the optimal design of the patent box, depends only on profit shifting considerations (the first term on the left-hand side), and on the existence of supernormal profits from R&D investment (the second term). The optimal royalty tax does not, however, depend on any real effects that τ_i has on R&D investment, or on the spillover on the host country's national firm. All the real effects on R&D and its externality on the domestic economy are instead captured by the optimal R&D subsidy s_i implicitly defined in (21). The optimal R&D subsidy trades off the direct revenue cost of R&D subsidies against the revenue increases that follow from the induced changes in R&D investment and total output production. In general, the sign of the optimal R&D subsidy is ambiguous. However, if the spillover effect on π_N^i [the second term in (21)] is sufficiently large, the optimal subsidy will be positive, $s_i^* > 0$.[24]

In the following, we discuss the central equation (22) for two different cases, depending on whether governments have access to an outside lump-sum tax ($\gamma = 1$), or only to distortive taxes ($\gamma < 1$).

Lump-sum taxes available. With $\gamma = 1$, the second term on the left-hand side of (22) vanishes.[25] The first term also simplifies and the optimal tax pattern (t_i, τ_i) reduces to

$$\frac{t_i^*}{\tau_i^*} = n > 1. \tag{23}$$

Eq. (23) shows that the royalty tax rate τ_i is unambiguously *below* the statutory corporate tax rate t_i in the national tax optimum. Consequently, a patent box regime with a reduced rate on royalty income emerges under tax competition. The reason is that, by reducing τ_i, country i gives an incentive to *all* foreign affiliates of its home-based MNC to make excessive royalty payments to the R&D unit in country i. Hence, a marginal reduction in τ_i leads to an inframarginal inflow of additional tax base from abroad. Evaluated at $t_i = \tau_i$ there is, however, no first-order loss in tax revenue when the domestic affiliate of the home-based MNC also shifts some of its profits into the patent box. Therefore, in the tax optimum, $\tau_i^* < t_i^*$ must hold.

It is also straightforward to see from equation (23) that the tax discount on royalty income becomes larger when the number of foreign affiliates of the domestic MNC grows (i.e., when n rises). The more foreign affiliates a domestic MNC has, the more tax base can be gained from other countries by reducing the royalty tax rate τ_i, whereas the domestic tax revenue cost of lowering τ_i is unaffected by the parameter n. In this sense, the continued integration of MNCs in the global economy (i.e., an increasing number of affiliates n) increases the incentives for the domestic government to grant generous patent box regimes with low royalty tax rates τ_i.

No lump-sum taxes. We now turn to the general case where outside taxes are distortionary and $\gamma < 1$. When the R&D production function is concave ($q_{kk} < 0$), R&D investment generates supernormal profits and $q^i - q_k k_R^i > 0$ in the second term of (22). Consequently, there is now an incentive to tax royalty income at a *higher* rate, all else equal.

[24]Empirical studies suggest that the spillover effects are indeed large. Bloom et al. (2013, pp. 1383ff), for example, estimate the marginal social return on R&D to be on average twice as high as the marginal private return (58% to 20.8%).

[25]The second term would also vanish, if the production technology for innovation $q^i(k_R^i)$ is linear. In this case, $q^i = q_k k_R^i$ and there are no profits in the R&D sector.

This can be seen in the special case where profit shifting is prohibitively expensive for the MNC ($\beta \to \infty$). In this case, the first term in (22) is zero and the second term of this equation is always positive. In combination with (21), we get

$$\left(\frac{1}{n f_q q_k} \frac{\partial W_i}{\partial \tau_i} + \frac{\partial W_i}{\partial s_i} \right) \Big|_{\beta \to \infty} = \frac{(1-\gamma)(q^i - q_k k_R^i)}{q_k} > 0. \tag{24}$$

The combination of a special tax rate τ_i on royalty income and a R&D subsidy s_i then jointly implements a tax system that taxes the economic rent from R&D without creating distortions on the intensive R&D investment margin. The subsidy ensures that the marginal return to k_R in (8b) remains undistorted, while the royalty tax confiscates all rents. The optimal royalty tax is then equal to one, and it must exceed the statutory tax rate t_i, which distorts the investment decisions of producing affiliates.

In the general case, the profit shifting effect [the first term in (22)] is present, however. As discussed above, this isolated effect works towards a lower tax on royalty income, as compared to the statutory tax rate t_i.[26] Therefore, with positive profits from R&D and profit shifting, the tax gap $t_i - \tau_i$ cannot be signed unambiguously. The easier is profit shifting (the lower is β), the more likely is it that the profit shifting motive dominates the motive to tax the pure profits in the R&D sector. In the extreme case of costless profit shifting ($\beta \to 0$), the second term in (22) becomes negligible, only profit shifting matters, and the corporate tax rate must exceed the tax rate on royalties.

We summarize our results for the non-cooperative setting of tax policies in:

Proposition 2 *When countries compete in the set of tax policies* (t_i, τ_i, s_i)*, the following holds:*

(i) The R&D subsidy s_i *is the marginal instrument used to increase technological quality, and to internalize the spillover effects from R&D.*

(ii) At the margin, the royalty tax rate τ_i *is determined only by profit shifting considerations, and by the level of pure profits in the R&D sector.*

(iii) When governments have access to lump-sum taxes ($\gamma = 1$)*, the optimal royalty tax rate is strictly below the statutory corporate tax rate,* $\tau_i^* < t_i^*$*.*

(iv) If $\gamma = 1$*, the tax gap* $(t_i^* - \tau_i^*)$ *increases in the number of MNC affiliates* n*.*

Parts (*i*) and (*ii*) of Proposition 2 correspond to the fundamental *principle of targeting*. Both the R&D subsidy s_i and the royalty tax rate τ_i are able to increase real R&D activity, but the royalty tax rate has the additional affect of attracting inward profit shifting through excessive royalty payments. Therefore, when all policy instruments are

[26] Note from the first term in (22) that $t_i^* > \tau_i^*$ also holds in the case of $\gamma < 1$.

simultaneously optimized, the R&D subsidy is directed exclusively at the R&D investment margin, whereas the royalty tax rate is focused on the MNC's profit shifting margin. This pattern suggests that the rising trend in R&D subsidies (see Appelt et al., 2019) is to be explained by a higher valuation of the technological improvements and their spillover effects that are induced by higher R&D subsidies, or by the reduced costs of providing such subsidies (for example, because of low interest rates on government debt).

On the other hand, the proliferation of patent box regimes shown in Table 1 can be explained by increased levels of MNCs' profit shifting (see Zucman, 2014, Figures 2 and 3). The feature of patent boxes to tax royalty payments at a rate below the statutory corporate tax rate emerges endogenously in our model, and it is isolated in the case where $\gamma = 1$ [see Proposition 2(*iii*)]. Finally, as the number of MNC affiliates n rises, the opportunities for profit shifting into a patent box increase. Indeed, the few available time series on MNCs and their affiliates, based on UNCTAD data, report that the number of MNCs almost tripled between 1995 and 2010 (from 38,500 to 104,000), and the total number of affiliates increased by a factor 3.5 from 251,500 to 892,000. The average number of affiliates per MNC hit a maximum of about 10 just before the financial crisis in 2007/08, see Jaworek and Kuzel (2015, p. 57 and Table 1). Part (*iv*) of Proposition 2 shows that these trends make patent box regimes more aggressive, in the sense of causing a larger tax gap between the statutory and the royalty tax rates.

5 Partial tax coordination

So far our analysis has compared the cases of full policy coordination and fully decentralized policies. An intermediate case arises when countries cooperate only partially. The most relevant scenario is when countries collectively commit not to use patent boxes. In our setting this implies that the policy restriction $t_i = \tau_i$ applies to all countries. However, countries continue to compete over both the statutory tax rate t_i and the R&D subsidy s_i. This case of partial tax coordination has also been labelled *non-discriminatory tax competition* and it links our analysis to the literature on preferential tax regimes (Janeba and Peters, 1999; Keen, 2001; Janeba and Smart, 2003; Hong and Smart, 2010).

The optimality condition for the corporate tax rate t_i, given the constraint $t_i = \tau_i$, effectively combines the FOCs (18) and (20), whereas the optimality condition for s_i has the same terms as the FOC in the fully decentralized case [eq. (21)], but evaluates these terms at a common tax rate $t_i = \tau_i$.[27]

In the following, we start from an initial equilibrium with partial coordination $t = \tau$ and consider the welfare effects of a small change in τ_i, which implies a discriminatory taxation of R&D profits in country i. This change has to account for the simultaneous

[27] The first-order conditions for the remaining two policy instruments t_i and s_i in the case of $t_i = \tau_i$ are provided together with some additional analysis in a separate appendix that is available upon request.

adjustments in the coordinating countries' remaining tax instruments. Hence, the full analysis of a small movement towards discriminatory tax policies $\tau \neq t$ has to evaluate:

$$\frac{dW_j}{d\tau_i} = \frac{\partial W_j}{\partial \tau_i} + \frac{\partial W_j}{\partial t_i}\,\frac{dt_i}{d\tau_i} + \frac{\partial W_j}{\partial s_i}\,\frac{ds_i}{d\tau_i}\,. \tag{25}$$

Differentiating (17) for country j with respect to τ_i gives the direct effect of this reform:

$$\begin{aligned}\frac{\partial W_j}{\partial \tau_i} &= -(n-1)t_j\,\frac{\partial a_j^i}{\partial \tau_i} + [t_j + \gamma(1-t_j)]\frac{\partial \pi_N^j}{\partial k_R^j}\frac{\partial k_R^j}{\partial \tau_i} + nt_j f_k \frac{\partial k_j^h}{\partial \tau_i} \\ &+ (\tau_j n f_q q_k - s_j)\frac{\partial k_R^j}{\partial \tau_i} + \gamma(\bar{k} - k_R^j - nk_j^j)\frac{dr}{d\tau_i}.\end{aligned} \tag{26}$$

The externalities in (26) derive from two effects. The first term in the first line is positive from (8c). When τ_i rises, there is a reduced incentive for MNCs from all countries $j \neq j$ to shift their profits into the patent box of country i. This effect increases the corporate tax base in country j. All remaining effects arise from the fall in the world interest rate that is caused by the higher patent box tax rate τ_i, which reduces capital demand for R&D purposes in country i. The fall in the world interest rate stimulates R&D investments in country j, as well as productive investments f_i^j made by country j's MNC in all countries in the region [cf. eqs. (10a)–(10e)]. If n is sufficiently large so that $\tau_j n f_q q_k - s_j > 0$ and when country j is a capital importer ($\bar{k} - k_R^j - nk_j^j < 0$), then all these effects will be positive, and the entire derivative in (26) is positive. This implies that a small *reduction* in τ_i, starting from an initially coordinated level $\tau_i = t_i$ will *harm* all neighboring countries j in the region by the direct effect.

Our theoretical analysis is, however, limited in two respects. First, it considers only small deviations from partially coordinated tax polices $t_i = \tau_i$ and second it ignores the simultaneous adjustments in t_i and s_i. The full general equilibrium analysis of even a small tax reform $d\tau_i > 0$ is too complex in our three-instrument model to be derived analytically. We therefore turn to numerical results for specific cases. Table 2 reports optimal policy choices and equilibrium welfare levels for the fully non-cooperative and the partially coordinated equilibria for different values of the welfare weight of private income γ, and for the elasticity of capital supply from third countries, κ.

The results for the low capital supply elasticity $\kappa = 1$ in panel A show that under unrestricted tax competition, $t_i > \tau_i$ holds for any level of γ. Moreover, as γ increases, the tax differential $t_i - \tau_i$ also increases, in accordance with our theoretical result in eq. (22). Intuitively, a higher welfare weight of private income γ causes tax rates to fall while the R&D subsidy increases. Under partial tax coordination the common tax rate $t_i = \tau_i$ lies in between the two tax rates under discriminatory tax competition, for each level of γ. Moreover, the R&D subsidy is always larger under partial tax discrimination. This is a core difference to existing models of discriminatory tax competition: a higher tax

Table 2: Unrestricted tax competition vs. partial policy coordination

	unrestricted tax competition				partial tax coordination		
	t_i	τ_i	s_i	W_i	$t_i = \tau_i$	s_i	W_i
A. low capital supply elasticity $\kappa = 1$							
$\gamma = 0$	0.248	0.236	-0.294	1.973	0.243	-0.271	1.971
$\gamma = 0.5$	0.220	0.168	0.100	2.759	0.208	0.163	2.782
$\gamma = 1$	0.158	0.040	0.355	3.455	0.156	0.448	3.542
B. high capital supply elasticity $\kappa = 10$							
$\gamma = 0$	0.331	0.327	-0.027	3.600	0.330	-0.021	3.604
$\gamma = 0.5$	0.294	0.234	0.159	4.574	0.284	0.216	4.645
$\gamma = 1$	0.222	0.055	0.300	5.542	0.219	0.404	5.725

Parameters held constant: $\bar{k} = 2$, $\beta = 0.25$, $n = 4$, $q = k_R^{0.5}$, $f(k, q) = k^{0.5} * q^{0.5}$, $\pi_N = k_R^{0.5}$.

τ_i on the more mobile tax base can be counteracted in our model by adjusting a third policy instrument, the granting of higher R&D subsidies. As a result, and for all levels of γ, the statutory corporate tax rate falls only little in the equilibrium with partial tax coordination, relative to the benchmark of unrestricted tax competition.

The welfare comparison in panel A shows that unrestricted tax competition dominates when $\gamma = 0$, but partial tax coordination yields higher welfare for $\gamma \geq 0.5$. Intuitively, the tax gap $t_i - \tau_i$ is rising in γ under unrestricted tax competition [eq. (22)]. This implies high levels of profit shifting with accompanying deadweight losses from concealment activities, and these losses are eliminated when preferential patent box regimes are abolished.

Results for the high elasticity of capital supply $\kappa = 10$ are shown in panel B. These are generally very similar to the results in panel A. However, partial tax coordination now welfare-dominates unrestricted tax competition for *all* levels of γ. Intuitively capital inflows to the region from the rest of the world are a falling function of the statutory tax rate, and this tax rate is lower under partial tax coordination. Therefore, the inflow of capital to the region is higher under partial tax coordination as compared to unrestricted tax competition, and this effect is stronger, the higher is κ. The result that a larger elasticity of the *aggregate* capital tax base tends to favour partial tax coordination is also known from the existing literature on preferential tax regimes (e.g., Janeba and Smart, 2003, Propositions 2 and 3).

In sum, we can conclude that the abolition of patent boxes in a regional union like the EU reduces profit shifting between the union countries, but it simultaneously aggravates tax competition via statutory tax rates. Different from existing models of discriminatory tax competition, however, our analysis incorporates three endogenous policy instruments, and the reduction in statutory tax rates is cushioned by the simultaneous increase in R&D subsidies. Consequently, policy competition shifts to an instrument that cannot be used to attract profit shifting, and this will increase welfare in the competing, symmetric countries for a wide range of parameter values.

6 Mobile R&D units vs. mobile patents

In our benchmark model of the previous sections, we have assumed that the location of R&D units, and the location of patents from which royalty incomes are derived, are fixed in the HQ country of the respective MNC. In this section, we relax these assumptions. In doing so, we analyze the implications of imposing a 'nexus requirement' on the use of patent box regimes, as introduced by the OECD (2015). A nexus requirement stipulates that a reduced tax rate on royalty income is permissible only if the patent has been developed in the country that applies the preferential rate. However, the nexus requirement implies that countries have an incentive to compete for *mobile R&D units*, to attract inward profit shifting. Therefore, to analyze the effects of a nexus requirement, the location of R&D units must be endogenized. This scenario is covered in Section 6.1. In the absence of a nexus requirement, it will be possible to relocate patents after the R&D process has been completed. This scenario of *patent mobility* is analyzed in Section 6.2.[28]

6.1 International relocation of R&D units

With an endogenous location choice of R&D units, the game analyzed in this section has three stages. In the third stage, MNCs choose their investment levels in the production affiliates and in the R&D unit, as well as the transfer price, conditional on government policies *and* the location of the R&D unit. All these decisions remain structurally unchanged from the benchmark model in the previous section. In the second stage, each MNC decides in which country its R&D unit shall reside, depending on the policy vector of governments. In the first stage, countries therefore compete not only over FDI in production affiliates and the shifting of profits, but also over the location of the internationally mobile R&D unit. The game is solved by backward induction.

For simplicity, we assume in this section that there are only $n = 2$ countries. There are, however, a large number of MNCs in each of the two countries. If an MNC headquartered in country i decides to set up its R&D unit in the foreign country $j \neq i$, it incurs an agency cost which is captured by the general cost parameter θ.[29] How severe the agency conflict becomes when the R&D unit is separated from the HQ depends on the type α of the MNC, which is uniformly distributed with support $\alpha \in [\underline{\alpha}, \overline{\alpha}]$. High-$\alpha$ types face higher agency costs than low-α types. The total MNC-specific agency costs of separating the MNC's R&D unit from its HQ are given by the product $\alpha\theta$.[30]

[28] The empirical analysis of Schwab and Todtenhaupt (2021) introduces a similar distinction and shows that patent box regimes with a nexus requirement have very different effects from those without nexus.

[29] Dischinger et al. (2014) provide empirical evidence that HQ units of MNCs are substantially more profitable than foreign subsidiaries. This indicates that MNCs have non-tax reasons to locate profitable units, such as R&D units, in their HQ country.

[30] An alternative interpretation of the costs $\alpha\theta$ is that FDI and the setting up of a foreign affiliate require MNC-specific market entry costs (Arkolakis, 2010). These costs are heterogeneous and only low-cost types will become an MNC and set up a foreign affiliate (here: a foreign R&D unit).

We extend the notation from our benchmark model by introducing an additional subscript $v \in \{i, j\}$ for the country in which the R&D unit is hosted. Hence, the global profits Π^i_{Mv} (before agency costs) of an optimally invested MNC with HQ in country i and the R&D unit in country v can be written as

$$\begin{aligned}
&\max_{k^i_{iv}, k^i_{jv}, k^i_{Rv}, a^i_{iv}, a^i_{jv}} \Pi^i_{Mv} = \pi^i_{Rv} + \pi^i_{iv} + \pi^i_{jv} \\
= \;& (1-t_i) f(k^i_{iv}, q^i_v) + (1-t_j) f(k^i_{jv}, q^i_v) + (t_i - \tau_v)(p_i q^i_v + a^i_{iv}) - \frac{\beta}{2}(a^i_{iv})^2 \\
+ \;& (t_j - \tau_v)(p_j q^i_v + a^i_{jv}) - \frac{\beta}{2}(a^i_{jv})^2 - r[k^i_{iv} + k^i_{jv} + k^i_{Rv}] + s_v k^i_{Rv}, \qquad (27)
\end{aligned}$$

where π^i_{jv} and π^i_{Rv} denote the profits of the production affiliate in country j and the R&D unit, respectively, of an MNC residing in country i and hosting its R&D unit in country $v \in \{i, j\}$. The tax rate τ_v is the patent box tax rate applicable in the R&D unit's host country v.

For the decision of where to locate the R&D unit, an MNC headquartered in country i compares its global after-tax profits with the R&D unit also in country i to the profits, including agency costs, of placing the R&D unit in country j (where $j \neq i$); that is, it compares Π^i_{Mi} to $\Pi^i_{Mj} - \alpha^i \theta$. The pivotal MNC that is indifferent between locating its R&D unit in either country i or j is then defined by the cutoff value

$$\hat{\alpha}^i = \frac{\Pi^i_{Mj} - \Pi^i_{Mi}}{\theta}. \qquad (28)$$

MNCs of type $\alpha^i > \hat{\alpha}^i$ are too vulnerable to agency conflicts when locating their R&D unit away from the HQ, and will decide to host their R&D unit in the HQ country.

For a uniform distribution of types α, the number of R&D units in country i is given by $x^i = 1 - \hat{\alpha}^i + \hat{\alpha}^j$, where $\hat{\alpha}^i$ captures the share of MNCs headquartered in country i that locates their R&D unit in country j, and $\hat{\alpha}^j$ is the share of MNCs based in country j that place their R&D unit in country i. Appendix A.4 derives the effects of changes in country i's policy parameters on the pivotal type $\hat{\alpha}^i$. With symmetry, we get:

$$\frac{d\hat{\alpha}^i}{dt_i} = 0, \qquad \frac{d\hat{\alpha}^i}{d\tau_i} > 0, \qquad \frac{d\hat{\alpha}^i}{ds_i} < 0. \qquad (29)$$

An increase in the corporate tax rate in country i has no effect on $\hat{\alpha}^i$, because the tax does not directly affect the profits of the R&D unit, and the induced interest rate changes are the same for R&D investments in countries i and j. A higher royalty tax rate τ_i reduces the return on R&D investment in country i. This induces more MNCs to locate their R&D unit in the other country j, increasing $\hat{\alpha}^i$. In contrast, a higher R&D subsidy in country i reduces the costs of R&D investment and makes country i more attractive for R&D units, reducing $\hat{\alpha}^i$. The effects of changes in the policy parameters of country j are qualitatively equivalent, and of opposite sign.

Appendix A.4 derives the optimal royalty tax rate τ_i, and optimal R&D subsidy s_i for this extended model.[31] We assume again that the second-order conditions are fulfilled, and the optimal tax choices define a symmetric Nash equilibrium. Combining the first-order conditions for τ_i and s_i leads to:

$$\frac{t_i^*}{\tau_i^*} = \frac{4-2\gamma-4B/\theta}{3-2\gamma-4B/\theta} - \beta\,\frac{f_q[q-q_k k_R]}{\tau_i}\frac{[2(1-\gamma)-4B/\theta]}{(3-2\gamma-4B/\theta)}\ , \tag{30}$$

where

$$B = \tau_i \pi_{Ri}^i - s_i k_R^i + 2k_R^i[t_i + \gamma(1-t_i)]\frac{\partial \pi_N}{\partial k_R^i}$$

is the total net benefit of attracting an additional R&D unit. This net benefit equals the additional tax revenue from the profits of the R&D unit, net of payments for the R&D investment subsidy, and augmented by the effects of the positive externality that increased local R&D has on the profits of the national firm.

It is straightforward to compare eq. (30) to (22) in our benchmark model. For prohibitively high agency costs ($\theta \to \infty$), the first term in (30) corresponds to the first term in (22) when $n = 2$. Therefore, the basic motivation for taxing R&D profits at a rate below the corporate income tax remains unchanged in this extended setup. For finite values of θ the gap between t and τ is enlarged, however, due to the mobility of R&D units.[32] This is intuitive, because the profits of the R&D unit are taxed at the royalty tax rate τ. Therefore, international competition for R&D units will reduce the royalty tax rate τ in equilibrium, relative to the statutory corporate tax rate t.

The interpretation of the second term in (30) differs from that in our benchmark model. If $\gamma = 1$, this term becomes positive, and thus, *increases* the tax gap $t_i^* - \tau_i^*$. Intuitively, if $\gamma = 1$, taxing pure profits in the R&D unit of the *domestic* MNC does not increase welfare, but there is still an incentive to tax pure profits in R&D units of *foreign* MNCs. In order to earn such tax revenue, however, the foreign R&D units first need to be attracted, and this is done by reducing the patent box tax rate. If instead $\gamma < 1$, the government also wants to tax economic profits in the R&D unit of the domestic MNC, calling for $\tau_i^* > t_i^*$, just as in our benchmark model. Then, the second term in (30) may turn negative, and therefore tend to raise τ_i^*. Finally, note from (30) that there is no effect on R&D investment at the margin. Consequently, with respect to the intensive investment margin, the targeting property for the patent box tax rate and the R&D subsidy, as identified in parts (*i*) and (*ii*) of Proposition 2, remains in place.

[31] The optimality condition for the statutory tax rate is extended from the benchmark model, as it includes the effects of t_i on the relocation of R&D units. However, this does not change our result that the corporate tax rate t_i will always be positive in the government's optimum. Therefore, we omit the first-order condition for the statutory tax rate from this extension.

[32] The parameter range for θ must be restricted to ensure that the denominator in both terms of (30) remains positive.

We emphasize that the competition for R&D units (i.e., the extensive margin) in this setting occurs through both the patent box rate (as discussed above) and the R&D subsidy. The optimality condition for the R&D subsidy is (cf. Appendix A.4)

$$\begin{aligned}\frac{\partial W_i}{\partial s_i} &= -(1-\gamma)k_{Ri} + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial RD^i}\left(\frac{\partial k_{Ri}}{\partial s_i} - 2k_{Ri}\frac{\partial \hat{\alpha}^i}{\partial s_i}\right) + 2t_i f_k \frac{\partial k_i}{\partial s_i} + 2\tau_i f_q q_k^i \frac{\partial k_{Ri}}{\partial s_i} \\ &+ 2(\tau_i - t_i)q^i\left[f_{qk}\frac{\partial k_i}{\partial s_i} + f_{qq}q_k^i\frac{\partial k_R^i}{\partial s_i}\right] - s_i\frac{\partial k_{Ri}}{\partial s_i} - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial s_i} - 2[\tau_i\pi_R^i - s_i k_{Ri}]\frac{\partial \hat{\alpha}^i}{\partial s_i} \\ &= 0. \end{aligned} \tag{31}$$

The main difference to the benchmark case [eq. (21)] lies in the positive last term of eq. (31), which tends to raise the optimal R&D subsidy s_i^*. Therefore, the optimal R&D subsidy incorporates a strategic effect under this extension that is absent in the benchmark model. This strategic use of R&D subsidies to attract internationally mobile R&D units is consistent with recent findings in the empirical literature that MNCs relocate their R&D units to countries where they receive the highest subsidy (Knoll et al., 2021).[33]

6.2 International relocation of patents

In this section, we consider the alternative case where patents, after having been 'produced' in the R&D unit in the MNC's HQ country, can be relocated to another country, benefitting there from a reduced patent box tax rate. This corresponds to a setting where no internationally binding nexus requirements are introduced. In this analysis, we assume, however, that the location of the R&D unit is fixed in the MNC's HQ country.

From an analytical perspective, this case has many parallels to the case where R&D units are internationally mobile, but there are also important differences. We restrict our analysis again to $n = 2$ countries. Hosting the patent in another country than the country where the development has occurred causes additional costs, which we capture with a general cost parameter θ_P. One important cost that may arise from the relocation of patents are 'exit taxes' that many countries levy when a patent that has been developed domestically is leaving the country. Our cost specification captures either the exit tax that has to be paid, or the extra administrative and legal efforts needed to bypass these exit taxes. Once again, we assume that MNCs are affected in different ways by these costs, for example because exit taxes are easier to quantify and to enforce in some sectors than in others. Therefore, we retain the individual cost parameter α, which is uniformly distributed with support $\alpha \in [\underline{\alpha}, \overline{\alpha}]$. Effective relocation costs of separating the patent from the R&D unit are then given by the MNC-specific costs $\alpha\theta_P$.

Once again, we have a three-stage game. In the third stage, all results on firms' choices

[33] Our result also corresponds to the finding of strategic business-stealing competition in R&D subsidies; see, for example, Haaland and Kind (2008).

remain unchanged, conditioned upon government policy *and* the location of the patent. In the second stage, the MNC decides in which country to place the patent, depending on the policy choices of governments. Hence, there is now international policy competition over the location of patents, in addition to the competition for FDI and for profit shifting.

The global profits Π^i_{Mv} of an MNC now carry a subscript v to specify the location of the patent in $v \in \{i, j\}$. With analogous notation for other variables, the MNC's maximization problem is

$$\begin{aligned}
\max_{k^i_{iv}, k^i_{jv}, k^i_{Rv}, a^i_{iv}, a^i_{jv}} \quad \Pi^i_{Mv} &= \pi^i_{Rv} + \pi^i_{iv} + \pi^i_{jv} \\
&= (1 - t_i) f(k^i_{iv}, q^i_j) + (1 - t_j) f(k^i_{jv}, q^i_v) + (t_i - \tau_v)(p_i q^i_v + a^i_{iv}) - \frac{\beta}{2}(a^i_{iv})^2 \\
&+ (t_j - \tau_v)(p_j q^i_v + a^i_{jv}) - \frac{\beta}{2}(a^i_{jv})^2 - r[k^i_{iv} + k^i_{jv} + k^i_{Rv}] - s_i k^i_{Rv}, \qquad (32)
\end{aligned}$$

where π^i_{jv} denotes profits in the production affiliate in country j of an MNC residing in country i and hosting its patent in country v. A critical difference to the case of mobile R&D units is that the R&D subsidy s_i in the last term is decided in the country where the R&D activity is located (i.e., in the HQ country of the MNC). Hence, the R&D subsidy may now be granted by a different country than the country in which the patent is eventually placed and to which royalty income flows.

For the decision of where to locate the patent, an MNC headquartered in country i compares global after-tax profits with the patent located in its home country i to the ones, including relocation costs, of placing the patent in country j. In equilibrium, the cutoff value $\hat{\alpha}^i_P$ for an MNC headquartered in country i that is just indifferent between having its patent in country i or in country j is

$$\hat{\alpha}^i_P = \frac{\Pi^i_{Mj} - \Pi^i_{Mi}}{\theta_P}. \qquad (33)$$

Formally, the analysis is fully analogous to that in the previous section. Using these analogies, Appendix A.5 derives the effects of all tax parameters on the MNC with the critical cost level $\hat{\alpha}^i_P$. Imposing symmetry yields:

$$\frac{d\hat{\alpha}^i_P}{dt_i} = 0, \qquad \frac{d\hat{\alpha}^i_P}{d\tau_i} > 0, \qquad \frac{d\hat{\alpha}^i_P}{ds_i} = 0. \qquad (34)$$

The main difference to the case of mobile R&D units [eq. (29)] is that the R&D subsidy s_i has no effect on the pivotal MNC with patent relocation costs $\hat{\alpha}^i_P$. This is because the decision of where to locate the patent is made only *after* the MNC has collected R&D subsidies in its parent country.

Appendix A.5 derives the optimal royalty tax rate τ_i and the optimal R&D subsidy s_i

for this problem. Combining these two first-order conditions leads to

$$\frac{t_i^*}{\tau_i^*} = \frac{4 - 2\gamma - 4B_P/\theta_P}{3 - 2\gamma - 4B_P/\theta_P} - \frac{\beta f_q \, [q^i - q_k k_R^i][2(1-\gamma) - 4B_P/\theta_P]}{\tau_i(3 - 2\gamma - 4B_P/\theta_P)} + \frac{4\beta f_q \, q_k k_R^i B_P/\theta_P}{\tau_i(3 - 2\gamma - 4B_P/\theta_P)}, \tag{35}$$

where $B_P = \tau_i \pi_R^i$ are the benefits of attracting an additional patent. These are given by the revenues derived from taxing the profits of the R&D unit, which all accrue in the country where the patent is located.

It is then straightforward to compare the optimal patent box regime under the international mobility of R&D units in (30) with the patent box regime that results under patent mobility in (35). The first terms in both equations are identical in structure and will always imply a tax discount for R&D profits in the national optimum. However, these terms will generally differ quantitatively in the two regimes. They depend on the comparison of the net benefits of attracting an additional R&D unit vs. attracting an additional patent (the terms B vs. B_P), and on the relative mobility of these two tax bases (the terms θ vs. θ_P).

The net benefits B and B_P differ by two components. On the one hand, the costs of R&D subsidies $s_i k_R^i$ must be subtracted from the net benefit of attracting an additional R&D unit in (30), but there is no corresponding cost in the term B_P in (35). As discussed above, this is because patents are attracted *after* the R&D process is completed, and subsidies from the host country of the R&D unit have been collected. On the other hand, a positive spillover from R&D investment on the local economy will only result when the R&D unit is attracted, whereas no corresponding gain accrues from attracting an additional patent. This is because positive spillovers are associated with the R&D *process*, not with the possession of a patent. In general, the comparison of the terms B vs. B_P in (30) and (35) is therefore ambiguous. Note, however, that for $\tau = t$, only the R&D subsidy s is used to internalize the spillover externality *and* to mitigate investment distortions from the corporate tax. Consequently, at least in this benchmark case, the subsidy will likely exceed the marginal externality such that $B_P > B$.

At the same time, the relative mobility of the two internationally mobile tax bases, as measured by θ vs. θ_P, also matters. Arguably, the costs of relocating an R&D unit are higher for an MNC as compared to the costs of relocating a patent. This holds in particular when exit taxes for relocating patents to other countries are low, or cannot be properly enforced. This expectation is confirmed by the empirical results of Schwab and Todtenhaupt (2021). Consistent with our setup, they find that some R&D units move, if there is a nexus requirement in place. Instead, if the nexus is not enforced, R&D is conducted in the home affiliate and only the patent relocates. The authors also show that the externalities caused by mobile R&D units are far smaller than those caused by mobile patents. The main reason for these results seems to be that there are large agglomeration benefits from real R&D activity that is clustered in certain hubs, making R&D activity rather unresponsive to international tax differentials (high θ). Overall, therefore, it is very likely that B/θ in (30) is smaller than B_P/θ_P in (35). By this effect, the tax wedge $t^* - \tau^*$ will then be larger under international patent mobility as compared to the international mobility of R&D units.

The second term in (35) is fully analogous to the second term in (30), and the discussion there applies. These terms include several endogenous variables, however, making a quantitative comparison difficult. Finally, there is a positive third term in (35), which is not present in (30). As we have discussed in our benchmark model, the instrument to foster R&D is the R&D subsidy, whereas the patent box regime is primarily used to attract profit shifting. The lower tax rate on R&D profits, which corresponds to an implicit output subsidy, will be counteracted in the government's optimum by a less generous direct subsidy for R&D [cf. our discussion of eq. (21)]. This limits the effectiveness of a generous patent box regime when R&D units are mobile. The interaction between τ_i and s_i is also present when patents are internationally mobile, but in this case the reduced R&D subsidy that accompanies a lower patent box tax rate does not affect the mobility of the patent. In this sense, patent box regimes are more powerful under patent mobility than under the mobility of R&D units.

The positive third term in (35) reinforces the result that the tax gap $t^* - \tau^*$ is larger under patent mobility than under the mobility of R&D units. We thus get unambiguous results when we compare (35) and (30) for the special case where the production function for technological quality is linear, and hence the second terms in (35) and (30) disappear. We summarize our results in this section in:

Proposition 3 *Comparing optimal policies under internationally mobile R&D units [eq.* (30)*] and under international patent mobility [eq.* (35)*] the following holds:*

(i) The patent box tax rate is strategically used for competition for R&D units and patents on the extensive margin, but it does not affect marginal investment per R&D unit. Thus, the targeting properties for the intensive margin [Proposition 1(i) and (ii)] carry over to mobile R&D units and mobile patents.

(ii) If the condition $B/\theta < B_P/\theta_P$ holds, and if the production function for technological quality $q^h(k_R^h)$ is linear, then the tax gap $t^* - \tau^*$ will be larger, and patent box regimes are more aggressive, when patents are internationally mobile, as compared to internationally mobile R&D units.

Applying our results to the nexus debate is then straightforward. In Proposition 3(*ii*), we have summarized that patent mobility will lead to more aggressive reductions in the profit tax rate on R&D units, as compared to the international mobility of R&D units. Moreover, we know from Proposition 1 that any preferential tax treatment for royalty income is inefficient from a global welfare perspective. Therefore, our results for the structure of patent box regimes support international arrangements that stipulate such a nexus requirement, as this policy will likely curb a mutually destructive *race to the bottom* in the setting of patent box tax rates.

Recall, however, from our discussion of (31) above, that R&D subsidies will tend to be inefficiently high when a nexus requirement is introduced and each country is trying to attract internationally mobile R&D units. From a positive perspective, we would therefore expect that the OECD's policy decision in favor of the nexus approach leads to a continued rise in the R&D subsidies offered by competing countries.

7 Discussion

In this section, we briefly discuss some further differences between patent box regimes and direct R&D subsidies in promoting innovative activities.

R&D as a dynamic and stochastic process. Our analysis has treated investments in the R&D sector as a static activity with deterministic results. In reality, R&D activities are long-run decisions with stochastic outcomes.[34] This leads to additional differences between R&D subsidies and reduced royalty tax rates, which have not been covered so far. First R&D subsidies are paid irrespective of whether the R&D activity leads to a successful outcome, whereas a reduced royalty tax rate benefits the investor only if the R&D activity is successful in generating patents, for which royalty income is earned. Risk-inverse investors will therefore prefer a R&D subsidy that is equal in expected value to a reduced tax on royalty income.

Second, R&D subsidies are a *front-end measure* that immediately reduces the costs of R&D investments. In contrast, reduced taxes on royalty income are a *back-end measure* that becomes effective only when the R&D investment has been transformed into output. This difference in the timing of government support is critical when investors are liquidity-constrained. They will then prefer an R&D tax credit of equal discounted value, even if they are risk-neutral. This more detailed treatment of the R&D process will, however, not affect the profit shifting incentives that we identified earlier.

Bad patents and relabeling of non-R&D expenses. Our analysis has assumed that patented activities are always associated with technological improvements and increased economic activity. These beneficial effects of patents are in line with some of the empirical evidence (Bradley et al., 2015; Koethenbuerger et al., 2018). There is, however, also evidence that patent quality decreases (Bornemann et al., 2020), or that patents are simply relocated in response to patent boxes (Gaessler et al., 2021). More generally, there

[34]Davies et al. (2020), for example, document that only about 50% of R&D activities are 'successful', in the sense that their patent application is granted.

is a lively debate on 'bad patents', which do not lead to real innovations, but merely serve to establish property rights (e.g. Bessen and Meurer, 2008). Indeed, as it is the granting of a patent that triggers preferential tax treatment under most existing patent box schemes (see Table 1), firms have an incentive to submit patent applications, even if they do not represent technological improvements. Hence, patent box regimes can be expected to contribute to the practice of patenting 'marginal innovations'.

On the other hand, it is also well known that R&D tax credits can be abused, and non-R&D expenses can be labeled as R&D expenses, in order to qualify for tax credits (Hall and Van Reenen, 2000). In a recent study of tax incentives for R&D in China, Chen et al. (2021) estimate that more than 24% of all reported R&D was due to the false labeling of non-R&D expenses. Effectively, both patent box regimes and R&D subsidies therefore have to account for the fact that some of the R&D activity incentivized by tax concessions is 'unproductive', in the sense of not expanding the knowledge base.

If such unproductive patenting is introduced in our model, the impact of patents on production and its spillover effects are reduced or even disappear. This weakens the economic case to employ either of these instruments, other things being equal. The incentives to attract paper profits from other countries via patent boxes remain, however. Therefore, absent clear evidence that patent-box regimes dominate R&D tax credits from the perspective of minimizing deadweight effects, the case for using R&D tax credits as the primary policy instrument to promote R&D is maintained.

8 Conclusions

Patent box regimes offer a reduced tax rate to business on their IP-related income. In this paper, we have analyzed the effects of such special tax regimes when governments can simultaneously choose optimal R&D subsidies. In this setting, the different policy instruments take on specialized roles. The R&D subsidy operates as the marginal policy instrument to promote real R&D activity, whereas the special tax rate on royalty income is used to attract profit shifting by MNCs. We have shown that patent box regimes with a preferential tax rate on royalty income emerge endogenously when countries that host large, well-integrated MNCs non-cooperatively choose their tax policies. In contrast, patent box regimes are never optimal under fully coordinated policy setting. Finally, we have compared the case of unrestricted tax competition with a partial coordination approach where countries commit not to use patent box regimes, but compete in the remaining tax instruments. Our analytical and numerical results suggest that abolishing patent box regimes is welfare-increasing in most cases. The reason is that, by committing not to introduce a patent box, countries instead increase R&D tax credits, which cannot be used for profit shifting.

From a policy perspective, these results indicate that patent boxes can indeed be seen as a measure of "harmful form of tax competition", and that they should be replaced by "well-designed research and development tax credits" (Bloom et al., 2019, p. 171). Moreover, our analysis provides a theoretical rationale for the nexus approach agreed upon by OECD countries, as the nexus requirement prevents designs of patent box regimes that aim most aggressively at attracting foreign profit tax bases. This is true even though the nexus approach gives MNCs an incentive to relocate their R&D unit in low-tax countries. As the relocation of R&D units is likely to have higher costs than the relocation of patents, tax competition can be expected to be less aggressive under the nexus approach.

Our results have implications for empirical studies on patent box regimes and related policies that reduce the tax rate on IP-related business income. In order to evaluate whether these measures do indeed foster innovation, it is essential to control for simultaneous policies that directly subsidize R&D. Since R&D subsidies have increased substantially in recent years, neglecting these policies may falsely attribute increased innovative activity to the rise of patent box regimes. The results of Boesenberg and Egger (2017) suggest that patent box regimes may cease to have any stimulating effects on patenting activity when comprehensive measures of direct R&D subsidies are incorporated in the regression analysis. Our analysis offers a theoretical rationale for their findings. Finally, some additional testable hypotheses emerge from our analysis. In particular, the generosity of the patent box regime in a particular country is expected to increase in the connectedness (i.e., the number of affiliates) of this country's MNCs, and in the ease (the inverse of costs) with which profit shifting to the patent box occurs.

A Appendix

A.1 Comparative static results

The market clearing condition (9) can be restated as

$$\sum_h \sum_m k_m^h + \sum_h k_R^h = n\bar{k} + k^W(r) = k^s, \tag{A.1}$$

where the superscript h indicates the MNC to which the affiliates belong, the subscript m indicates the country in which a production affiliate is located, and $k^W(r)$ represents endogenous capital supply from the rest of world with $k_r^W > 0$.

The first-order conditions for capital inputs k_m^h and k_R^h in (8a) and (8b) are equal to

$$(1-t_m) f_k(k_m^h, q^h) - r = 0, \tag{A.2}$$

$$(1-\tau_h) \sum_m f_q(k_m^h, q^h) q_k^h - (r - s_h) = 0. \tag{A.3}$$

Totally differentiating the first-order conditions, using symmetry, and consolidation gives

$$dk_m^h = -\frac{f_{kq} q_k}{f_{kk}}\, dk_R^h + \frac{f_k}{(1-t_m) f_{kk}}\, dt_m + \frac{dr}{(1-t_m) f_{kk}}. \tag{A.4}$$

$$dk_R^h = -\frac{(1-\tau) f_k \ (f_{kq} q_k)}{(1-t) A f_{kk}} \sum dt_m + \frac{n f_q q_k}{A} d\tau_h - \frac{ds_h}{A} + \frac{(1-t) f_{kk} - (1-\tau) n (f_{kq} q_k)}{(1-t) A f_{kk}} dr, \tag{A.5}$$

where

$$A = \frac{(1-\tau) n}{f_{kk}} \left[f_{kk} \left(f_{qq} q_k^2 + f_q q_{kk} \right) - (f_{kq} q_k)^2 \right] < 0 \tag{A.6}$$

because $f_{kk}\left(f_{qq} q_k^2 + f_q q_{kk}\right) - (f_{kq} q_k)^2 > 0$ is implied by the second-order conditions for optimal MNC behavior.

Substituting (A.5) into (A.4), we can derive changes in capital inputs in production affiliates in response to changes in tax-policy variables and the interest rate. Collecting terms results in

$$\begin{aligned} dk_m^h \; = \; & \frac{(1-\tau) f_k (f_{kq} q_k)^2}{(1-t) A f_{kk}^2} \sum_m dt_m + \frac{f_k A f_{kk}}{(1-t) A f_{kk}^2} dt_m - \frac{(1-t) f_{kk} n f_q f_{kq} q_k^2}{(1-t) A f_{kk}^2} d\tau_h \\ & + \frac{(1-t) f_{kk} f_{kq} q_k}{(1-t) A f_{kk}^2} ds_h - \frac{(1-t) f_{kk} (f_{kq} q_k) - (1-\tau) n (f_{kq} q_k)^2 - A f_{kk}}{(1-t) A f_{kk}^2} dr. \end{aligned} \tag{A.7}$$

From (A.5) and (A.7) it follows that the direct effects of changes in royalty tax rate τ_h and R&D subsidy s_h are linearly dependent for a given interest rate ($dr = 0$). Hence,

$$\left.\frac{dk_R^h}{d\tau_h}\right|_{dr=0} = -n f_q q_k \left.\frac{dk_R^h}{ds_h}\right|_{dr=0} \quad \text{and} \quad \left.\frac{dk_m^h}{d\tau_h}\right|_{dr=0} = -n f_q q_k \left.\frac{dk_m^h}{ds_h}\right|_{dr=0}. \tag{A.8}$$

Totally differentiating the market clearing condition (A.1) implies

$$ndk_m^h + dk_R^h = k_r^W dr,$$

and inserting the expressions from (A.5) and (A.7) yields

$$\begin{aligned} dr &= -\frac{\{(1-\tau)nf_k(f_{kq}q_k)^2 + f_k A f_{kk} - (1-\tau)f_k f_{kk}(f_{kq}q_k)\}}{n\Delta}\sum_m dt_m \\ &+ \frac{(1-t)f_{kk}[f_{kq}q_k - f_{kk}]}{n\Delta}\left\{nf_q q_k \sum d\tau_h - \sum ds_h\right\}, \end{aligned} \tag{A.9}$$

where $\Delta \equiv (1-\tau)n(f_{kq}q_k)^2 + Af_{kk} - (1-\tau)f_{kk}(f_{kq}q_k) + \frac{1-t}{n}f_{kk}^2 - (1-t)f_{kk}(f_{kq}q_k) - \frac{1-t}{n}Af_{kk}^2 k_r^W > 0$.

Since $A < 0$, it holds that $\frac{dr}{dt_m} < 0$, $\frac{dr}{d\tau_h} < 0$, and $\frac{dr}{ds_h} > 0$. It also follows that the induced changes in the interest rate caused by changes in either τ_i or s_i are linearly dependent. In conjunction with (A.8), we can thus conclude that

$$\frac{dk_R^h}{d\tau_h} = -nf_q q_k \frac{dk_R^h}{ds_h} \quad \text{and} \quad \frac{dk_m^h}{d\tau_h} = -nf_q q_k \frac{dk_m^h}{ds_h}. \tag{A.10}$$

Inserting the interest rate effects (A.9) in (A.5) and collecting terms gives the following comparative-static effects on capital investment in R&D:

$$\begin{aligned} \frac{dk_R^h}{ds_h} &= -\frac{(n-1)\left\{n(1-\tau)(f_{kq}q_k)^2 + \frac{n}{n-1}Af_{kk} - (1-t)f_{kk}(f_{kq}q_k)\right\}}{nA\Delta} \\ &+ \frac{(1-t)f_{kk}^2}{n\Delta}\, k_r^W > 0, \end{aligned} \tag{A.11}$$

where $\Delta > 0$ is given in (A.9). From (A.10) then follows $dk_R^h/d\tau_h < 0$. Additionally, we have

$$\begin{aligned} \frac{dk_R^h}{dt_m} &= -\frac{f_k f_{kk}}{n\Delta} + \frac{(1-\tau)f_k(f_{kq}q_k)f_{kk}}{n\Delta}\, k_r^W > 0, && \text{(A.12)} \\ &= -\frac{f_k f_{kk} k^s}{n\Delta k_m^h}\left[\frac{k_m^h}{k^s} - \varepsilon_{qk}^f \frac{\varepsilon_{kr}^s}{n}\right] > 0, && \text{(A.13)} \end{aligned}$$

if either the share of capital in final good production, $\frac{k_m^h}{k^s}$, or the number of countries/affiliates n is sufficiently high, or the capital-supply elasticity ε_{kr}^s is sufficiently low. To reach the second line, we used $(1-\tau)q_k = \frac{r-s_h}{nf_q}$ from the FOC (A.3) and $f_{kq} = f_{qk}$. In addition, we defined the capital elasticity of the marginal intermediate productivity as $\varepsilon_{qk}^f = f_{qk}\frac{k_m^h}{f_q}$ and the capital-supply elasticity as $\varepsilon_{kr}^s = k_r^W \frac{r-s_h}{k^s}$.

Inserting the interest rate effects (A.9) into (A.7), the comparative-static effect of

R&D subsidies on capital investment in final-good production reads

$$\frac{dk_m^h}{ds_h} = \frac{n-1}{n}\frac{(1-\tau)n(f_{kq}q_k)^3 + Af_{kk}(f_{kq}q_k) - (1-\tau)f_{kk}(f_{kq}q_k)^2 - (1-t)f_{kk}(f_{kq}q_k)}{Af_{kk}\Delta}$$
$$+ \quad \frac{f_{kk}}{n\Delta} - \frac{(1-t)f_{kk}(f_{kq}q_k)}{n\Delta}\, k_r^W > 0, \tag{A.14}$$

as long as the number of countries/affiliates n is sufficiently large to overcompensate the first term in the second line. From (A.10) then follows $dk_m^h/d\tau_h < 0$.

An increase in the corporate tax rate of another country $i \neq j$ fosters capital investment in production affiliates in country m from

$$\frac{dk_m^h}{dt_v} = -\frac{f_k}{(1-t)f_{kk}}\frac{n(1-\tau)(f_{kq}q_k)^2 - (1-t)f_{kk} + Af_{kk} - (1-\tau)f_{kk}(f_{kq}q_k)}{n\Delta}$$
$$- \quad \frac{f_k}{n\Delta}\,(1-\tau)(f_{kq}q_k)k_r^W > 0, \tag{A.15}$$

as long as either the number of countries/affiliates n is sufficiently high or the capital-supply elasticity ε_{kr}^s is sufficiently low. Finally, an increase in t_m has a negative effect on capital in production affiliates in country m,

$$\frac{dk_m^h}{dt_m} = \frac{(n-1)f_k}{n(1-t)f_{kk}\Delta}\left[n(1-\tau)(f_{kq}q_k)^2 + Af_{kk} - n(1-t)f_{kk}(f_{kq}q_k) - \frac{n}{n-1}(1-\tau)f_{kk}(f_{kq}q_k)\right]$$
$$- \quad \frac{f_k}{f_{kk}}\frac{(1-t)f_{kk}^2 - (1-\tau)f_{kk}(f_{kq}q_k) + (1-t)\left(Af_{kk}^2 + (1-\tau)f_{kk}(f_{kq}q_k)\right)k_r^W}{n(1-t)\Delta} < 0, \tag{A.16}$$

as long as the number of countries/affiliates n is sufficiently large.

A.2 Optimal R&D taxes under regional coordination

Differentiating regional welfare W_G in (11) for the simultaneous choice of the tax rate τ in all countries i leads to the first-order condition

$$\frac{\partial W_G}{\partial \tau} = (1-\gamma)n[f_q q^i + a_i] + [t + \gamma(1-t)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial \tau} + nt\left(f_k\frac{\partial k_i^i}{\partial \tau} + f_q q_k\frac{\partial k_R^i}{\partial \tau}\right)$$
$$- \quad nt\left[f_{qk}\frac{\partial k_i^i}{\partial \tau}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial \tau}q^i + f_q q_k\frac{\partial k_R^i}{\partial \tau} + \frac{\partial a_i}{\partial \tau}\right]$$
$$+ \quad n\tau\left[f_{qk}\frac{\partial k_i^i}{\partial \tau}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial \tau}q^i + f_q q_k\frac{\partial k_R^i}{\partial \tau} + \frac{\partial a_i}{\partial \tau}\right] - s\frac{\partial k_R^i}{\partial \tau} - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial \tau} = 0,$$

where capital market clearing [eq. (9)] has been used. Collecting terms leads to eq. (14) in the main text.

Applying (A.10), condition (14) transforms into

$$\begin{aligned}\frac{\partial W_G}{\partial \tau} &= n(1-\gamma)\left(f_q q^i + a_i\right) - n(t-\tau)\frac{\partial a_i}{\partial \tau} - n f_q q_k \left\{ [t+\gamma(1-t)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial s} \right. \qquad \text{(A.17)}\\ &+ \left. n t f_k \frac{\partial k_i^i}{\partial s} - n(t-\tau)q^i\left[f_{qk}\frac{\partial k_i^i}{\partial s} + f_{qq}q_k\frac{\partial k_R^i}{\partial s}\right] + n\tau f_q q_k \frac{\partial k_R^i}{\partial s} - s\frac{\partial k_R^i}{\partial s} - \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial s}\right\} = 0.\end{aligned}$$

Differentiating global welfare W_G in (11) with respect to the R&D subsidy s gives

$$\begin{aligned}\frac{\partial W_G}{\partial s} &= -(1-\gamma)k_R^i + nt\left(f_k\frac{\partial k_i^i}{\partial s} + f_q q_k\frac{\partial k_R^i}{\partial s} - \left[f_{qk}\frac{\partial k_i^i}{\partial s}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial s}q^i + f_q q_k\frac{\partial k_R^i}{\partial s}\right]\right)\\ &+ n\tau\left[f_{qk}\frac{\partial k_i^i}{\partial s}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial s}q^i + f_q q_k\frac{\partial k_R^i}{\partial s}\right] - s\frac{\partial k_R^i}{\partial s} + [t+\gamma(1-t)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial s}\\ &- \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial s} = 0, \qquad \text{(A.18)}\end{aligned}$$

where capital market clearing [eq. (9)] has been used. Collecting terms then leads to (15) in the main text.

Finally, inserting (15) into the rearranged FOC for τ_i in (A.17) results in

$$\left.\frac{\partial W_G}{\partial \tau}\right|_{s=s^*} = n\left\{(1-\gamma)f_q[q^i - q_k k_R^i] + (2-\gamma)a_i\right\} = 0, \qquad \text{(A.19)}$$

where we made use of $-(t-\tau)(\partial a_i/\partial \tau) = a_i$ from (8c). Solving this expression for a_i and using $a_i = (t-\tau)/\beta$ gives eq. (16) of the main text.

A.3 Optimal R&D taxes under policy competition

Optimal royalty tax rate. Differentiating national welfare W_i in (17) with respect to τ_i leads to the first-order condition

$$\begin{aligned}\frac{\partial W_i}{\partial \tau_i} &= (1-\gamma)[f_q^i q^i + (n-1)f_q^j q^i + a_i^i + (n-1)a_j^i] - t_i\frac{\partial a_i^i}{\partial \tau_i} + \tau_i\left[\frac{\partial a_i^i}{\partial \tau_i} + (n-1)\frac{\partial a_j^i}{\partial \tau_i}\right] + t_i f_k\frac{\partial k_i^i}{\partial \tau_i}\\ &+ t_i\left(f_q q_k\frac{\partial k_R^i}{\partial \tau_i} - \left[f_{qk}\frac{\partial k_i^i}{\partial \tau_i}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial \tau_i}q^i + f_q q_k\frac{\partial k_R^i}{\partial \tau_i}\right] - (n-1)\left[f_{qk}\frac{\partial k_i^i}{\partial \tau_i}q^j + f_{qq}q_k\frac{\partial k_R^i}{\partial \tau_i}q^j\right]\right)\\ &+ \tau_i\left(\left[f_{qk}\frac{\partial k_i^i}{\partial \tau_i}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial \tau_i}q^i + f_q^i q_k\frac{\partial k_R^i}{\partial \tau_i}\right] + (n-1)\left[f_{qk}\frac{\partial k_j^i}{\partial \tau_i}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial \tau_i}q^i + f_q^j q_k\frac{\partial k_R^i}{\partial \tau_i}\right]\right)\\ &+ \gamma\left[\bar{k} - \left(k_i^i + (n-1)k_j^i + k_R^i\right)\right]\frac{\partial r}{\partial \tau_i} + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial \tau_i} - s_i\frac{\partial k_R^i}{\partial \tau_i} = 0. \qquad \text{(A.20)}\end{aligned}$$

The first term in squared brackets in the last line equals $k^W(r)/n$ from the capital market clearing condition (9). Imposing symmetry and collecting terms then gives (20) in the main text.

Using equation (A.10) in (20), the FOC for τ_i can be rewritten as

$$\begin{aligned}\frac{\partial W_i}{\partial \tau_i} &= (1-\gamma)n(f_q q^i + a_i^i) - t_i\frac{\partial a_i^i}{\partial \tau_i} + n\tau_i\frac{\partial a_i^i}{\partial \tau_i} - nf_q q_k[t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial s_i} \qquad \text{(A.21)}\\ &- nf_q q_k\left\{t_i f_k\frac{\partial k_i^i}{\partial s_i} - (t_i - \tau_i)nq^i\left[f_{qk}\frac{\partial k_i^i}{\partial s_i} + f_{qq}q_k\frac{\partial k_R^i}{\partial s_i}\right] + \tau_i n f_q q_k\frac{\partial k_R^i}{\partial s_i} - s_i\frac{\partial k_R^i}{\partial s_i}\right.\\ &- \left.\gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial s_i}\right\} = 0.\end{aligned}$$

Optimal R&D subsidy. Differentiating W_i in (17) with respect to s_i gives

$$\begin{aligned}\frac{\partial W_i}{\partial s_i} &= -(1-\gamma)k_R^i + t_i f_k\frac{\partial k_i^i}{\partial s_i} \qquad \text{(A.22)}\\ &+ t_i\left(f_q q_k\frac{\partial k_R^i}{\partial s_i} - \left[f_{qk}\frac{\partial k_i^i}{\partial s_i}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial s_i}q^i + f_q q_k\frac{\partial k_R^i}{\partial s_i}\right] - (n-1)\left[f_{qk}\frac{\partial k_i^i}{\partial s_i}q^j + f_{qq}q_k\frac{\partial k_R^i}{\partial s_i}q^j\right]\right)\\ &+ \tau_i\left(\left[f_{qk}\frac{\partial k_i^i}{\partial s_i}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial s_i}q^i + f_q^i q_k\frac{\partial k_R^i}{\partial s_i}\right] + (n-1)\left[f_{qk}\frac{\partial k_j^i}{\partial s_i}q^i + f_{qq}q_k\frac{\partial k_R^i}{\partial s_i}q^i + f_q^j q_k\frac{\partial k_R^i}{\partial s_i}\right]\right)\\ &+ \gamma\left[\bar{k} - \left(k_i^i + (n-1)k_j^i + k_R^i\right)\right]\frac{\partial r}{\partial s_i} + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial k_R^i}\frac{\partial k_R^i}{\partial s_i} - s_i\frac{\partial k_R^i}{\partial s_i} = 0.\end{aligned}$$

Using capital market clearing from (9), applying symmetry and collecting terms gives the first-order condition (21) in the main text.

Inserting (21) into the rearranged first-order condition for τ_i in (A.21) results in

$$\left.\frac{\partial W_i}{\partial \tau_i}\right|_{s=s^*} = (1-\gamma)n(f_q[q^i - q_k k_R^i] + a_i^i) - t_i\frac{\partial a_i^i}{\partial \tau_i} + n\tau_i\frac{\partial a_i^i}{\partial \tau_i} = 0. \qquad \text{(A.23)}$$

Using $\partial a_i^i/\partial t_i = -\partial a_i^i/\partial \tau_i = 1/\beta$ from the optimal profit shifting function (8c) leads to the optimality condition in equation (22) of the main text.

A.4 Location decision of the R&D unit

Applying the Envelope theorem to eq. (27) gives

$$\begin{aligned}
\frac{\partial \Pi^i_{Mi}}{\partial t_i} &= -f(k^i_{ii}, q^i_i) + p_i q^i_i + a^i_{ii} - [k^i_{ii} + k^i_{ji} + k^i_{Ri}]\frac{\partial r}{\partial t_i}, \\
\frac{\partial \Pi^i_{Mj}}{\partial t_i} &= -f(k^i_{ij}, q^i_j) + p_i q^i_j + a^i_{ij} - [k^i_{ij} + k^i_{jj} + k^i_{Rj}]\frac{\partial r}{\partial t_i}, \\
\frac{\partial \Pi^i_{Mi}}{\partial \tau_i} &= -[p_i q^i_i + p_j q^i_i] - [a^i_{ii} + a^i_{ji}] - [k^i_{ii} + k^i_{ji} + k^i_{Ri}]\frac{\partial r}{\partial \tau_i}, \\
\frac{\partial \Pi^i_{Mj}}{\partial \tau_i} &= -[k^i_{ij} + k^i_{jj} + k^i_{Rj}]\frac{\partial r}{\partial \tau_i}, \\
\frac{\partial \Pi^i_{Mi}}{\partial s_i} &= k^i_{Ri} - [k^i_{ii} + k^i_{ji} + k^i_{Ri}]\frac{\partial r}{\partial s_i}, \\
\frac{\partial \Pi^i_{Mj}}{\partial s_i} &= -[k^i_{ij} + k^i_{jj} + k^i_{Rj}]\frac{\partial r}{\partial s_i}.
\end{aligned}$$

The comparative-static effects of policy changes in country i on the location decision of R&D units can then be obtained by differentiating (28). This yields

$$\begin{aligned}
\frac{d\hat{\alpha}^i}{dt_i} &= -\frac{[f(k^i_{ij}, q^i_j) - p_i q^i_j] - [f(k^i_{ii}, q^i_i) - p_i q^i_i] - [a^i_{ij} - a^i_{ii}]}{\theta} - \frac{\Omega}{\theta}\frac{\partial r}{\partial t_i} \gtreqless 0, \\
\frac{d\hat{\alpha}^i}{d\tau_i} &= \frac{p_i q^i_i + p_j q^i_i + a^i_{ii} + a^i_{ji}}{\theta} - \frac{\Omega}{\theta}\frac{\partial r}{\partial \tau_i} > 0, \\
\frac{d\hat{\alpha}^i}{ds_i} &= -\frac{k^i_{Ri}}{\theta} - \frac{\Omega}{\theta}\frac{\partial r}{\partial s_i} < 0.
\end{aligned} \tag{A.24}$$

where $\Omega \equiv (k^i_{Rj} - k^i_{Ri}) + (k^i_{ij} - k^i_{ii}) + (k^i_{jj} - k^i_{ji})$.

Importantly, all effects working via a change in the interest rate disappear under symmetry. Moreover, the first term in the first line of (A.24) is also zero under symmetry. In addition, under symmetry, the effects of changes in the same policy variable are identical in absolute terms, and particularly $d\hat{\alpha}^i/d\tau_i = -d\hat{\alpha}^i/d\tau_j$ and $d\hat{\alpha}^i/ds_i = -d\hat{\alpha}^i/ds_j$.

Under symmetry, we also know from comparative statics and equation (A.10) that $dk^i_{Ri}/d\tau_i = -2f_q q_k(dk^i_{Ri}/ds_i)$, since $n = 2$ holds in this extension. Hence,

$$\frac{d\hat{\alpha}^i}{ds_i}\frac{dk^i_{Ri}/d\tau_i}{dk^i_{Ri}/ds_i} = -\frac{2f_q q_s k^i_R}{\theta} \quad \Leftrightarrow \quad \frac{d\hat{\alpha}^i}{d\tau_i} - \frac{d\hat{\alpha}^i}{ds_i}\frac{dk^i_{Ri}/d\tau_i}{dk^i_{Ri}/ds_i} = \frac{2f_q\,(q^i_i - q_k k^i_R) + 2a^i}{\theta} > 0, \tag{A.25}$$

which will be used below.

With $n = 2$ countries, internationally mobile R&D units, and a continuum of heterogenous MNCs that are uniformly distributed on $\alpha \in [\underline{\alpha}, \overline{\alpha}]$, the optimized social welfare function (17) from the main model of non-cooperative decision making can be restated as

$$\begin{aligned}
\max_{t_i,\tau_i,s_i} W_i &= t_i \left\{\pi_N^i(RD^i) + (1-\hat{\alpha}^i+\hat{\alpha}^j)[f(k_{ii}^i,q_i^i) - f_q(k_{ii}^i,q_i^i)q_i^i - a_{ii}^i]\right.\\
&+ \left.(1-\hat{\alpha}^j+\hat{\alpha}^i)[f(k_{ij}^j,q_j^j) - f_q(k_{ij}^j,q_j^j)q_j^j - a_{ij}^j]\right\}\\
&+ \tau_i(1-\hat{\alpha}^i+\hat{\alpha}^j)\left\{f_q(k_{ii}^i,q_i^i)q_i^i + f_q(k_{ji}^i,q_i^i)q_i^i + a_{ii}^i + a_{ji}^i\right\} - (1-\hat{\alpha}^i+\hat{\alpha}^j)s_i k_{Ri}^i\\
&+ \gamma\left\{r\bar{k} + (1-t_i)\pi_N^i + (1-\hat{\alpha}^i)\Pi_{Mi}^i + \hat{\alpha}^i\Pi_{Mj}^i - \frac{\theta}{2}\hat{\alpha}^{i2}\right\}, \qquad \text{(A.26)}
\end{aligned}$$

where we have used $k_{Ri}^i = k_{Ri}^j$, $k_{mi}^i = k_{mi}^j$, and $a_{mi}^i = a_{mi}^j$. Furthermore, $(\theta/2)\hat{\alpha}^{i2} = \int_0^{\hat{\alpha}^i}\alpha_i\theta d\alpha^i$ gives total agency costs from placing the R&D unit abroad, summed over all MNCs headquartered in country i. Finally, $RD^i = (1-\hat{\alpha}^i+\hat{\alpha}^j)k_{Ri}^i$ captures total R&D spending in country i as driver for the spillover effect on national firms.

Optimal patent box tax rate. Differentiating national welfare W_i in (A.26) with respect to the corporate tax rate τ_i gives

$$\begin{aligned}
\frac{\partial W}{\partial \tau_i} &= [(1-\gamma)(1-\hat{\alpha}^i)+\hat{\alpha}^j][(p_i q_i^i + a_{ii}^i) + (p_j q_i^i + a_{ji}^i)]\\
&+ [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial RD^i}\left\{\frac{\partial RD^i}{\partial \tau_i} - k_{Ri}^i\left(\frac{\partial\hat{\alpha}^i}{\partial\tau_i} - \frac{\partial\hat{\alpha}^j}{\partial\tau_i}\right)\right\}\\
&+ t_i(1-\hat{\alpha}^i+\hat{\alpha}^j)\left\{f_k\frac{\partial k_{ii}^i}{\partial\tau_i} - q_i^i\left[f_{qk}\frac{\partial k_{ii}^i}{\partial\tau_i} + f_{qq}q_k^i\frac{\partial k_{Ri}^i}{\partial\tau_i}\right] - \frac{\partial a_{ii}^i}{\partial\tau_i}\right\}\\
&+ t_i(1-\hat{\alpha}^j+\hat{\alpha}^i)\left\{f_k\frac{\partial k_{ij}^j}{\partial\tau_i} - q_j^i\left[f_{qk}\frac{\partial k_{ij}^j}{\partial\tau_i} + f_{qq}q_k^i\frac{\partial k_{Rj}^j}{\partial\tau_i}\right]\right\}\\
&+ \tau_i(1-\hat{\alpha}^i+\hat{\alpha}^j)\left\{q_i^i\left[f_{qk}\frac{\partial k_{ii}^i}{\partial\tau_i} + f_{qq}q_k^i\frac{\partial k_{Ri}^i}{\partial\tau_i}\right] + f_q q_k^i\frac{\partial k_{Ri}^i}{\partial\tau_i} + \frac{\partial a_{ii}^i}{\partial\tau_i}\right.\\
&+ \left. q_i^j\left[f_{qk}\frac{\partial k_{ji}^i}{\partial\tau_i} + f_{qq}q_k^j\frac{\partial k_{Ri}^i}{\partial\tau_i}\right] + f_q q_k^j\frac{\partial k_{Ri}^i}{\partial\tau_i} + \frac{\partial a_{ji}^i}{\partial\tau_i}\right\} - (1-\hat{\alpha}^i+\hat{\alpha}^j)s_i\frac{\partial k_{Ri}^i}{\partial\tau_i}\\
&+ \gamma\left\{\bar{k} - (k_i^i + k_j^i + k_{Ri}^i)\right\}\frac{\partial r}{\partial\tau_i} + \gamma\left[\Pi_{Mj}^i - \Pi_{Mi}^i - \hat{\alpha}^i\theta\right]\frac{\partial\hat{\alpha}^i}{\partial\tau_i}\\
&- \left\{t_i\left(\pi_{ii}^i - \pi_{ij}^i\right) + \tau_i\pi_R^i - s_i k_{Ri}^i\right\}\left(\frac{\partial\hat{\alpha}^i}{\partial\tau_i} - \frac{\partial\hat{\alpha}^j}{\partial\tau_i}\right) = 0. \qquad \text{(A.27)}
\end{aligned}$$

Using (9) and (29) and imposing symmetry, the first-order condition simplifies to

$$\begin{aligned}
\frac{\partial W}{\partial \tau_i} &= 2(1-\gamma)(f_q q^i + a_i) + [t_i+\gamma(1-t_i)]\frac{\partial\pi_N^i}{\partial RD^i}\left(\frac{\partial k_{Ri}}{\partial\tau_i} - 2k_{Ri}\frac{\partial\hat{\alpha}^i}{\partial\tau_i}\right) + (2\tau_i - t_i)\frac{\partial a_i}{\partial\tau_i}\\
&+ 2t_i f_k\frac{\partial k_i}{\partial\tau_i} + 2\tau_i f_q q_k^i\frac{\partial k_{Ri}}{\partial\tau_i} - s_i\frac{\partial k_{Ri}}{\partial\tau_i} + 2(\tau_i - t_i)q^i\left[f_{qk}\frac{\partial k_i}{\partial\tau_i} + f_{qq}q_k^i\frac{\partial k_{Ri}}{\partial\tau_i}\right]\\
&- \gamma\frac{k^W(r)}{n}\frac{\partial r}{\partial\tau_i} - 2[\tau_i\pi_R^i - s_i k_{Ri}]\frac{\partial\hat{\alpha}^i}{\partial\tau_i} = 0. \qquad \text{(A.28)}
\end{aligned}$$

Inserting the linear dependence of the royalty tax and the R&D subsidy from (A.10), the optimality condition turns into

$$\begin{aligned}\frac{\partial W}{\partial \tau_i} &= 2(1-\gamma)(f_q q^i + a_i) + (2\tau_i - t_i)\frac{\partial a_i}{\partial \tau_i} - 2f_q q_k^i[t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial RD^i}\frac{\partial k_{Ri}}{\partial s_i} \\ &- 2f_q q_k^i \left\{2t_i f_k \frac{\partial k_i}{\partial s_i} + 2\tau_i f_q q_k^i \frac{\partial k_{Ri}}{\partial s_i} - s_i \frac{\partial k_{Ri}}{\partial s_i} + 2(\tau_i - t_i) q^i \left[f_{qk}\frac{\partial k_i}{\partial s_i} + f_{qq} q_k^i \frac{\partial k_{Ri}}{\partial s_i}\right]\right\} \\ &+ 2f_q q_k^i \gamma \frac{k^W(r)}{n}\frac{\partial r}{\partial s_i} - 2[\tau_i \pi_R^i - s_i k_{Ri} - [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial RD^i} 2k_{Ri}]\frac{\partial \hat{\alpha}^i}{\partial \tau_i} = 0. \quad \text{(A.29)}\end{aligned}$$

Optimal R&D subsidy. The first-order condition for the optimal R&D subsidy is

$$\begin{aligned}\frac{\partial W}{\partial s_i} &= -[(1-\gamma)(1-\hat{\alpha}^i) + \hat{\alpha}^j]k_{Ri}^i + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial RD^i}\left\{\frac{\partial RD^i}{\partial s_i} - k_{Ri}^i\left(\frac{\partial \hat{\alpha}^i}{\partial s_i} - \frac{\partial \hat{\alpha}^j}{\partial s_i}\right)\right\} \\ &+ t_i(1-\hat{\alpha}^i + \hat{\alpha}^j)\left\{f_k \frac{\partial k_{ii}^i}{\partial d_i} - q_i^i \left[f_{qk}\frac{\partial k_{ii}^i}{\partial d_i} + f_{qq} q_k^i \frac{\partial k_{Ri}^i}{\partial s_i}\right]\right\} \\ &+ t_i(1-\hat{\alpha}^j + \hat{\alpha}^i)\left\{f_k \frac{\partial k_{ij}^j}{\partial s_i} - q_j^i \left[f_{qk}\frac{\partial k_{ij}^j}{\partial s_i} + f_{qq} q_k^i \frac{\partial k_{Rj}^j}{\partial s_i}\right]\right\} \\ &+ \tau_i(1-\hat{\alpha}^i + \hat{\alpha}^j)\left\{q_i^i \left[f_{qk}\frac{\partial k_{ii}^i}{\partial s_i} + f_{qq} q_k^i \frac{\partial k_{Ri}^i}{\partial s_i}\right] + f_q q_k^i \frac{\partial k_{Ri}^i}{\partial s_i}\right. \\ &\quad \left. + q_i^j \left[f_{qk}\frac{\partial k_{ji}^i}{\partial s_i} + f_{qq} q_k^j \frac{\partial k_{Ri}^i}{\partial s_i}\right] + f_q q_k^j \frac{\partial k_{Ri}^i}{\partial s_i}\right\} \\ &- (1-\hat{\alpha}^i + \hat{\alpha}^j)s_i \frac{\partial k_{Ri}^i}{\partial s_i} + \gamma\left\{\bar{k} - (k_i^i + k_j^i + k_{Ri}^i)\right\}\frac{\partial r}{\partial s_i} + \gamma\left[\Pi_{Mj}^i - \Pi_{Mi}^i - \hat{\alpha}^i \theta\right]\frac{\partial \hat{\alpha}^i}{\partial s_i} \\ &- \left\{t_i\left(\pi_{ii}^i - \pi_{ij}^i\right) + \tau_i \pi_R^i - s_i k_{Ri}^i\right\}\left(\frac{\partial \hat{\alpha}^i}{\partial s_i} - \frac{\partial \hat{\alpha}^j}{\partial s_i}\right) = 0, \qquad \text{(A.30)}\end{aligned}$$

which simplifies by the usual steps under symmetry to eq.(31) in the main text.

Combining (A.29) and (31) and using (A.25) gives

$$f_q\ [q^i - q_k^i k_R^i]\left(1 - \gamma - 2\frac{B}{\theta}\right) + a_i\left(1 - \gamma - 2\frac{B}{\theta}\right) + \frac{2\tau_i - t_i}{2}\frac{\partial a_i}{\partial \tau_i} = 0, \qquad \text{(A.31)}$$

where $B = \tau_i \pi_R^i - s_i k_R^i + 2k_R^i[t_i + \gamma(1-t_i)](\partial \pi_N^i / \partial k_R^i)$. Rearranging and using optimal profit shifting behavior $a_i^* = (t_i - \tau_i)/\beta$ gives (30) in the main text.

A.5 Location decision of the patent

Applying the Envelope theorem to (32) gives

$$\begin{aligned}
\frac{\partial \Pi^i_{Mi}}{\partial t_i} &= -f(k^i_{ii}, q^i_i) + p_i q^i_i + a^i_{ii} - [k^i_{ii} + k^i_{ji} + k^i_{Ri}]\frac{\partial r}{\partial t_i}, \\
\frac{\partial \Pi^i_{Mj}}{\partial t_i} &= -f(k^i_{ij}, q^i_j) + p_i q^i_j + a^i_{ij} - [k^i_{ij} + k^i_{jj} + k^i_{Rj}]\frac{\partial r}{\partial t_i}, \\
\frac{\partial \Pi^i_{Mi}}{\partial \tau_i} &= -[p_i q^i_i + p_j q^i_i] - [a^i_{ii} + a^i_{ji}] - [k^i_{ii} + k^i_{ji} + k^i_{Ri}]\frac{\partial r}{\partial \tau_i}, \\
\frac{\partial \Pi^i_{Mj}}{\partial \tau_i} &= -[k^i_{ij} + k^i_{jj} + k^i_{R_i}]\frac{\partial r}{\partial \tau_i}, \\
\frac{\partial \Pi^i_{Mi}}{\partial s_i} &= k^i_{Ri} - [k^i_{ii} + k^i_{ji} + k^i_{Ri}]\frac{\partial r}{\partial s_i}, \\
\frac{\partial \Pi^i_{Mj}}{\partial s_i} &= k^i_{Rj} - [k^i_{ij} + k^i_{jj} + k^i_{Rj}]\frac{\partial r}{\partial s_i}.
\end{aligned}$$

The comparative-static effects of policy changes in country i on the optimal location of a patent are then obtained from differentiating eq. (33). This yields

$$\begin{aligned}
\frac{d\hat{\alpha}^i_P}{dt_i} &= -\frac{[f(k^i_{ij}, q^i_j) - p_i q^i_j] - [f(k^i_{ii}, q^i_i) - p_i q^i_i] - [a^i_{ij} - a^i_{ii}]}{\theta_P} - \frac{\Omega}{\theta_P}\frac{\partial r}{\partial t_i}, \\
\frac{d\hat{\alpha}^i_P}{d\tau_i} &= \frac{p_i q^i_i + p_j q^i_i + a^i_{ii} + a^i_{ji}}{\theta_P} - \frac{\Omega}{\theta_P}\frac{\partial r}{\partial \tau_i} > 0, \\
\frac{d\hat{\alpha}^i_P}{ds_i} &= \frac{k^i_{Rj} - k^i_{Ri}}{\theta_P} - \frac{\Omega}{\theta_P}\frac{\partial r}{\partial s_i},
\end{aligned}$$

where Ω is the same as in (A.24). Imposing symmetry yields (34) in the main text.

The government's maximization problem under patent relocation is

$$\begin{aligned}
\max_{t_i,\tau_i,s_i} W_i &= t_i \left\{\pi^i_N(RD^i) + (1-\hat{\alpha}^i_P)[f(k^i_{ii}, q^i_i) - f_q(k^i_{ii}, q^i_i)q^i_i - a^i_{ii}] + \hat{\alpha}^j_P[f(k^j_{ii}, q^j_i) - f_q(k^j_{ii}, q^j_i)q^j_i - a^j_{ii}]\right. \\
&+ \left.(1-\hat{\alpha}^j_P)[f(k^j_{ij}, q^j_j) - f_q(k^j_{ij}, q^j_j)q^j_j - a^j_{ij}] + \hat{\alpha}^i[f(k^i_{ij}, q^i_j) - f_q(k^i_{ij}, q^i_j)q^i_j - a^i_{ij}]\right\} \\
&+ \tau_i \left\{(1-\hat{\alpha}^i_P)\left[f_q(k^i_{ii}, q^i_i)q^i_i + f_q(k^i_{ji}, q^i_i)q^i_i + a^i_{ii} + a^i_{ji}\right]\right. \\
&+ \left.\hat{\alpha}^j_P\left[f_q(k^j_{ii}, q^j_i)q^j_i + f_q(k^j_{ji}, q^j_i)q^j_i + a^j_{ii} + a^j_{ji}\right]\right\} - (1-\hat{\alpha}^i_P)s_i k^i_{Ri} + \hat{\alpha}^i_P s_i k^i_{Rj} \\
&+ \gamma\left\{r\bar{k} + (1-t_i)\pi^i_N(RD^i) + (1-\hat{\alpha}^i_P)\Pi^i_{Mi} + \hat{\alpha}^i_P\Pi^i_{Mj} - \frac{\theta}{2}\hat{\alpha}^{i2}_P\right\}, \qquad \text{(A.32)}
\end{aligned}$$

where now $RD^i = (1-\hat{\alpha}^i_P)k^i_{Ri} + \hat{\alpha}^i_P k^i_{Rj}$.

Differentiating (A.32) with respect to the tax rate τ_i, using the market equilbria (9) and (34) and imposing symmetry, gives the first-order condition

$$\begin{aligned} \frac{\partial W}{\partial \tau_i} &= 2(1-\gamma)(f_q q^i + a_i) + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial RD^i}\frac{\partial k_R^i}{\partial \tau_i} + (2\tau_i - t_i)\frac{\partial a_i}{\partial \tau_i} \\ &+ 2t_i f_k \frac{\partial k_i}{\partial \tau_i} + 2\tau_i f_q q_k^i \frac{\partial k_{Ri}}{\partial \tau_i} - s_i \frac{\partial k_{Ri}}{\partial \tau_i} + 2(\tau_i - t_i)q^i \left[f_{qk}\frac{\partial k_i}{\partial \tau_i} + f_{qq} q_k^i \frac{\partial k_R^i}{\partial \tau_i}\right] \\ &- \gamma \frac{k^W(r)}{n}\frac{\partial r}{\partial \tau_i} - 2\tau_i \pi_R^i \frac{\partial \hat{\alpha}_P^i}{\partial \tau_i} = 0. \end{aligned} \tag{A.33}$$

Inserting the linear dependence relations in (A.10), the optimality condition turns into

$$\begin{aligned} \frac{\partial W}{\partial \tau_i} &= 2(1-\gamma)(f_q q^i + a_i) + (2\tau_i - t_i)\frac{\partial a_i}{\partial \tau_i} - 2 f_q q_k^i [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial RD^i}\frac{\partial k_R^i}{\partial s_i} \\ &- 2 f_q q_k^i \left\{ 2t_i f_k \frac{\partial k_i}{\partial s_i} + 2\tau_i f_q q_k^i \frac{\partial k_R^i}{\partial s_i} - s_i \frac{\partial k_R^i}{\partial s_i} + 2(\tau_i - t_i) q^i \left[f_{qk}\frac{\partial k_i}{\partial s_i} + f_{qq} q_k^i \frac{\partial k_R^i}{\partial s_i}\right]\right\} \\ &+ 2 f_q q_k^i \gamma \frac{k^W(r)}{n}\frac{\partial r}{\partial s_i} - 2\tau_i \pi_R^i \frac{\partial \hat{\alpha}_P^i}{\partial \tau_i} = 0. \end{aligned} \tag{A.34}$$

The first-order condition for the optimal R&D subsidy s_i is derived analogously and leads to

$$\begin{aligned} \frac{\partial W}{\partial s_i} &= -(1-\gamma)k_R^i + [t_i + \gamma(1-t_i)]\frac{\partial \pi_N^i}{\partial RD^i}\frac{\partial k_R^i}{\partial s_i} + 2(\tau_i - t_i) q^i \left[f_{qk}\frac{\partial k_i}{\partial s_i} + f_{qq} q_k^i \frac{\partial k_R^i}{\partial s_i}\right] \\ &+ 2t_i f_k \frac{\partial k_i}{\partial s_i} + 2\tau_i f_q q_k^i \frac{\partial k_R^i}{\partial s_i} - s_i \frac{\partial k_R^i}{\partial s_i} - \gamma \frac{k^W(r)}{n}\frac{\partial r}{\partial s_i} = 0. \end{aligned} \tag{A.35}$$

Combining (A.34) with (A.35) and using (A.32) gives

$$(1-\gamma) f_q \, [q^i - q_k^i k_R^i] + (1-\gamma) a_i + \frac{2\tau_i - t_i}{2}\frac{\partial a_i}{\partial \tau_i} - 2\frac{B_P}{\theta_P}[f_q q^i + a_i] = 0, \tag{A.36}$$

where $B_P = \tau_i \pi_R^i$. Using $a_i^* = (t_i - \tau_i)/\beta$ from optimal profit shifting behavior gives

$$\frac{t_i}{\tau_i} = \frac{4 - 2\gamma - 4B_P/\theta_P}{3 - 2\gamma - 4B_P/\theta_P} - \frac{\beta f_q}{\tau_i}\frac{(2 - 2\gamma - 4B_P/\theta_P)q^i - (2-2\gamma) q_k k_R^i}{(3 - 2\gamma - 4B_P/\theta_P)} \tag{A.37}$$

Decomposing the second term in (A.37) gives eq. (35) in the main text.

References

Akcigit, U., Hanley, D., and Stantcheva, S. (2021). Optimal taxation and R&D policies. NBER Working Paper No. 22908. Cambridge, MA. Revised, November 2021.

Alstadsæter, A., Barrios, S., Nicodème, G., Skonieczna, A.M., and Vezzani, A. (2018). Patent boxes design, patents location and local R&D. *Economic Policy 33 (93)*, 131–177.

Appelt, S., Galindo-Rueda, F., and Gonzalez Cabral, A.C. (2019). Measuring R&D tax support: Findings from the new OECD R&D tax incentives database. OECD Science, Technology and Industry Working Paper 2019/06. Paris.

Arkolakis, C. (2010). Market penetration costs and the new consumers margin in international trade. *Journal of Political Economy 118*, 1151–1199.

Bauer, C., and Langenmayr, D. (2013). Sorting into outsourcing: Are profits taxed at a gorilla's arm's length? *Journal of International Economics 90*, 326–336.

Baumann, M., Böhm, T., Knoll, B., and Riedel, N. (2020). Corporate taxes, patent shifting and anti-avoidance rules: Empirical evidence. *Public Finance Review 48*, 467–504.

Bessen, J., and M. Meurer (2008). Patent failure. Princeton University Press.

Bilir, K., and Morales, E. (2020). Innovation in the global firm. *Journal of Political Economy 128*, 1566–1625.

Bloom, N., Schankerman, S., and van Reenen, J. (2013). Identifying technology spillovers and product market rivalry. *Econometrica 81*, 1347–1393.

Bloom, N., Van Reenen, J., and Williams, H. (2019). A toolkit of policies to promote innovation. *Journal of Economic Perspectives 33(3)*, 163–184.

Boesenberg, S., and Egger, P. (2017). R&D tax incentives and the emergence and trade of ideas. *Economic Policy 32 (89)*, 39–80.

Bornemann, T., Laplante, S.K., and Osswald, B. (2020). The effect of intellectual property boxes on innovative activity and effective tax rates. https://ssrn.com/abstract=3115977.

Bradley, S., Dauchy, E., and Robinson, L. (2015). Cross-country evidence on the preliminary effects of patent box regimes on patent activity and ownership. *National Tax Journal 68*, 1047–1072.

Bradley, S., Robinson, L., and Ruf, M. (2021). The impact of IP box regimes on the M&A market. *Journal of Accounting and Economics 72(2-3)*, 101448.

Chen, S., De Simone, L., Hanlon, M., and Lester, R. (2019). The effect of innovation box regimes on investment and employment activity. https://papers.ssrn.com/abstract_id=3864574.

Chen, Z., Liu, Z., Suárez Serrato, J.C., and Xu, D.Y. (2021). Notching R&D investment with corporate income tax cuts in China. *American Economic Review 111*, 2065–2100.

Choi, J.P., Furusawa, T., and Ishikawa, J. (2020). Transfer pricing regulation and tax competition. *Journal of International Economics 127*, 103367.

Cristea, A., and Nguyen, D. (2016). Transfer pricing by multinational firms: New evidence from foreign firm ownership. *American Economic Journal: Economic Policy 8*, 170–202.

Davies, R.B., Martin, J., Parenti, M., and Toubal, F. (2018). Knocking on tax haven's door: Multinational firms and transfer pricing. *Review of Economics and Statistics 100*, 120–134.

Davies, R.B., Kogler, D., and Hynes, R. (2020). Patent boxes and the success rate of applications. CESifo Working Paper No. 8375. Munich.

Dischinger, M., Knoll, B., and Riedel, N. (2014). There's no place like home: The profitability gap between headquarters and their foreign subsidiaries. *Journal of Economics and Management Strategy 23*, 369–395.

Eberhardt, M., Helmers, C., and Strauss, H. (2013). Do spillovers matter when estimating private returns to R&D? *Review of Economics and Statistics 95*, 436–448.

Fracasso, A., and Marzetti, G.V. (2015). International trade and R&D spillovers. *Journal of International Economics 96*, 138–149.

Gaessler, F., Hall, B.H., and Harhoff, D. (2021). Should there be lower taxes on patent income? *Research Policy-50*, 104129.

Griffith, R., Miller, H., and O'Connell, M. (2014). Ownership of intellectual property and corporate taxation. *Journal of Public Economics 112*, 12–23.

Guceri, I., and Liu, L. (2019). Effectiveness of fiscal incentives for R&D: Quasi-experimental evidence. *American Economic Journal: Economic Policy 11*, 266–91.

Haaland, J.I., and Kind, H.J. (2008). R&D policies, trade and process innovation. *Journal of International Economics 96*, 170–187.

Hall, B., and Van Reenen, J. (2000). How effective are fiscal incentives for R&D? A review of the evidence. *Research Policy 29*, 449–469.

Haufler, A., Mardan, M., and Schindler, D. (2018). Double tax discrimination to attract FDI and fight profit shifting: The role of CFC rules. *Journal of International Economics 114*, 25–43.

Hong, Q., and Smart, M. (2010). In praise of tax havens: International tax planning and foreign direct investment. *European Economic Review 54*, 82–95.

Jaworek M., and Kuzel M. (2015). Transnational corporations in the world economy: Formation, development and present position. *Copernican Journal of Finance & Accounting 4*, 55–70. http:// dx.doi.org/10.12775/CJFA.2015.004.

Janeba, E., and Peters, W. (1999). Tax evasion, tax competition and the gains from nondiscrimination: The case of interest taxation in Europe. *The Economic Journal 109*, 93–101.

Janeba, E., and Smart, M. (2003). Is targeted tax competition less harmful than its remedies? *International Tax and Public Finance 10*, 259–280.

Juranek, S., Schindler, D., and Schjelderup, G. (2018). Transfer pricing regulation and taxation of royalty payments. *Journal of Public Economic Theory 20*, 67–84.

Karkinsky, T., and Riedel, N. (2012). Corporate taxation and the choice of patent location within multinational firms. *Journal of International Economics 88*, 176–185.

Keen, M. (2001). Preferential regimes can make tax competition less harmful. *National Tax Journal 54*, 757–762.

Keen, M., and Lahiri, S. (1998). The comparison between destination and origin principles under imperfect competition. *Journal of International Economics 45*, 323–350.

Knoll, B., Riedel, N., Schwab, T., Todtenhaupt, M., and Voget, J. (2021). Cross-border effects of R&D tax incentives. *Research Policy 50*, 104326.

Koethenbuerger, M., Liberini, F., and Stimmelmayr, M. (2018). Is it just luring reported profit? The case of European patent boxes. CESifo Working Paper No. 7061. Munich.

Mintz, J. (2018). Global implications of U.S. tax reform. EconPol Working Paper No. 08/18. Munich.

Mongrain, S., and van Ypersele, T. (2020). Tax competition in presence of profit shifting. http://dx.doi.org/10.2139/ssrn.3630425.

Nielsen, S.B., Schindler, D., and Schjelderup, G. (2022). Transfer pricing and investment – How OECD transfer pricing rules affect investment decisions. Erasmus School of Economics and Norwegian School of Economics, mimeo.

OECD (2013). Action plan on base erosion and profit shifting. OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264202719-en

OECD (2015). Action 5: Agreement on Modified Nexus Approach for IP Regimes. OECD Publishing, Paris. https://www.oecd.org/ctp/beps-action-5-agreement-on-modified-nexus-approach-for-ip-regimes.pdf

Peralta, S., X. Wauthy, and van Ypersele, T. (2006). Should countries control international profit shifting? *Journal of International Economics 68*, 24–37.

Rao, N. (2016). Do tax credits stimulate R&D spending? The effect of the R&D tax credit in its first decade. *Journal of Public Economics 140*, 1–12.

Schwab, T., and Todtenhaupt, M. (2021). Thinking outside the box: The cross-border effect of tax cuts on R&D. *Journal of Public Economics 204*, 104536.

Sharma, R.R., Slemrod, J., and Stimmelmayr, M. (2021). Tax losses and ex-ante offshore transfer of intellectual property. CESifo Working Paper No. 9262. Munich.

Shehaj, P., and Weichenrieder, A. (2021). Corporate income tax, IP boxes and the location of R&D. CESifo Working Paper No. 9397. Munich.

Tørsløv, T., Wier, L., and Zucman, G. (2018). The missing profits of nations. NBER Working Paper No. 24701. Cambridge, Mass.

Zucman, G. (2014). Taxing across borders: Tracking personal wealth and corporate profits. *Journal of Economic Perspectives 28*, 121–148.