Royalty Taxation under Tax Competition and Profit Shifting*

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Abstract

The increasing use of intellectual property as a means to shift profits to low-tax jurisdictions or jurisdictions with so-called ‘patent boxes’ is a major challenge for the corporate tax base of medium- and high-tax countries. Extending a standard tax competition model for capital-enhancing technology, royalty payments, and profit shifting, this paper suggests a simple fix: It is always optimal to set a withholding tax on (intra-firm) royalty payments equal to the corporate tax rate and deny any deductibility of royalties. As the tax applies to the full payment, the problem of identifying the arm's-length component in a digital economy (OECD BEPS Action 1) does not apply. Most importantly, the denial of royalty deductions is the Pareto-efficient solution under coordination *and* the unilaterally optimal policy under competition for mobile capital. In the latter case, a weakened thin capitalization rule is a crucial part of the policy package in order to avoid negative investment effects. Our results question the ban of royalty taxes in double tax treaties and the EU Interest and Royalty Directive.

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1 Introduction

In recent years, profit shifting by multinationals, or international corporate tax avoidance in more general, has been perceived as a major challenge to public policy. The Organisation for Economic Co-operation and Development (OECD) states in its "Base Erosion and Profit Shifting" (BEPS) report that "at stake is the integrity of the corporate income tax" (OECD, 2013, p. 8). The report identifies transfer pricing and debt shifting as the major profit-shifting strategies. In particular, transfer pricing in intellectual properties related to the digital economy is considered as a severe issue, because it is unclear how the arm's-length principle can be implemented and enforced there, see Action 1 in the OECD Action Plan (OECD, 2015b). Indeed, empirical research already presents evidence that the location of patents in multinational firms responds to tax incentives (e.g., Dischinger and Riedel, 2011; Karkinsky and Riedel, 2012).

The challenge is amplified by the fact that many countries implemented so-called patent boxes that offer preferential tax rates for intellectual property revenues, see Table 1 for an overview. Many of these countries do not require a nexus between royalty income and substantial domestic economic activity that generates the underlying intellectual property. Thus, these patent boxes can be used as an instrument for tax competition to attract corporate income. Empirical evidence documents that such tax competition strategies have a significant effect on where multinational firms locate the ownership of their intellectual property, especially for high-quality patents.[1] The problem is likely to grow in the future. In its recent tax reform in December 2017, the U.S. also installed a patent box at a 12.5% tax rate without any nexus requirements.[2] Furthermore, there is some apprehension that the U.K., which already hosts a patent box with a 10% tax rate, may turn itself into a tax haven after Brexit (Economist, 2017).

[Insert Table 1 about here]

Thus, all medium- and high-tax countries face the challenge of how to deal with royalty payments on intellectual property and how to defend their domestic tax bases against intensified global tax competition.[3] In its joint BEPS Action Plan, the G20 countries and the OECD prominently argue in favor of controlled-foreign-company (CFC) rules (Action 3) and thin capitalization rules (Action 4) as measures to curb profit shifting

[1]See, e.g., Griffith et al. (2014) and Böhm et al. (2015). Most recently, Köthenbürger et al. (2017) quantify the effects for European patent boxes and document that the ones without a nexus clause rather are a tax-competition instrument than a means to promote local R&D investment.

[2]See H.R. 1, 115th Congress, "An Act to provide for reconciliation pursuant to titles II and V of the concurrent resolution on the budget for fiscal year 2018." (2017)

[3]Note that abusive royalty payments and its induced profit shifting do not have a positive intensive-margin investment effect in high-tax countries (Juranek et al., 2018), and in contrast to debt shifting, transfer pricing rather reduces welfare (Gresik et al., 2015). Hence, such profit shifting only comes with costs, but does not provide any compensating investment effects for high-tax countries.

(OECD, 2015a). There is, however, a twofold problem with thin capitalization rules. They primarily target debt shifting, i.e., the replacement of equity by (internal) debt, and only have an indirect, if any, effect on transfer pricing. In addition, they are an instrument for tax competition, and countries have incentives to set weak thin capitalization rules in order to attract FDI from multinational companies (Haufler and Runkel, 2012). Similarly, CFC rules only allow for mitigating profit shifting by multinationals, headquartered domestically, not by affiliates of foreign-based multinationals. In particular U.S. multinationals such as Apple and Google have proven to be tax aggressive, and it appears unlikely that the U.S. government will abolish the check-the-box regime and reintroduce bite to the U.S. CFC rules ('subpart F income'), see Blouin and Krull (2015) for an overview. Consequently, countries need an instrument that directly tackles abusive royalty payments made by domestic affiliates, and that can be sustained under tax competition.

The results in this paper suggest a simple fix to the problem of abusive royalty payments on intellectual property. We show that it is always optimal to set a withholding tax on (intra-firm) royalty payments equal to the corporate tax rate and deny any deductibility of royalty payments. As the optimal royalty tax also applies to arm's-length payments, the problem of measuring the fair payment and implementing a tractable concept of arm's-length pricing vanishes. Most importantly, the denial of royalty deductions is both the Pareto-efficient solution in a setting with multinational cooperation and the unilaterally optimal policy choice under tax competition. In the latter case, however, there are negative investment effects from taxes falling on arm's-length payments. Therefore, the optimal policy package requires that countries grant investment incentives by relaxing thin capitalization rules. In reality, many countries impose both thin capitalization rules and royalty taxes already (see Table 1). But, the latter very often fall short of their optimal level (see columns (1) and (3) of Table 1), and many double tax treaties and multinational agreements, e.g., the EU Interest and Royalty Directive, limit the scope of royalty taxes or even ban them completely.

The main driving force behind our finding is that abusive royalty payments only have a mechanical investment effect on the extensive margin and this investment effect can be fully reproduced by allowing for more thin capitalization, even if the royalties are a variable payment based on sales or revenues.[4] Because firms balance marginal tax savings against marginal concealment costs, the decision on abusive profit shifting with royalties is fully independent from capital investment and has no behavioral effect on effective capital costs. Therefore, when setting withholding taxes on royalties, countries do not need to trade off reduced profit shifting against losses in investment, beyond the

[4] Empirical evidence shows that most royalty payments are made relative to sales revenue or units sold or as a combination of a fixed payment and payments relative to sales. See San Martín and Saracho (2010) for an overview.

mechanical effect. The latter effect works via average capital costs only and and can be compensated by weakening the thin capitalization rule, allowing for more internal debt shifting. Consequently, the combination of a weaker policy against debt shifting and a tough shut-down of tax deductibility of royalty payments avoids negative investment effects, but eliminates all incentives for transfer pricing and in particular prevents that economic profits can be shifted.

In order to derive our results, we build on the standard tax competition model with national and multinational firms and two large countries developed by Haufler and Runkel (2012). In line with their model, all firms can respond to tax policies through an adjustment of their level of external debt, and multinational firms can additionally use internal debt in order to reduce their capital costs further. We extend the basic model by an intellectual property that provides a capital-enhancing technology and renders mobile capital more productive (i.e., it increases the amount of effective capital available). Moreover, multinational firms are able to overcharge transfer prices for (intra-firm) royalties and shift profits, in addition to arm's-length payments, to a tax haven. We also extend the set of policy instruments simultaneously available in Haufler and Runkel (2012), i.e., statutory tax rates and thin capitalization rules, by withholding taxes on royalties. While thin capitalization rules are used to limit the tax deductibility of internal debt, withholding taxes on royalties specifically target profit shifting through abusive transfer prices for royalties.

Our analysis contributes in several ways to the literature. First, we challenge the dominant view that withholding taxes are always poor instruments. Generally, they violate the production efficiency theorem and hamper an efficient factor allocation in an integrated market. This view induced the European Union (EU) to ban royalty taxes in its EU Interest and Royalty Directive. Another standard result in public finance states that withholding taxes face a race to the bottom and are competed away under competition for FDI between countries (e.g., Bucovetsky, 1991, Bucovetsky and Wilson, 1991).[5] We point out that both arguments do not apply to the case of royalty payments. We find that, even under tax competition, countries set the royalty tax rate at its efficient level, which is equal to the corporate tax rate. Denying tax deductibility of royalty payments gives each country an instrument to curb transfer pricing effectively. All tax competition is relegated to thin capitalization rules that are relaxed in order to neutralize adverse investment effects. Hence, profit shifting can be eliminated without harming investment and efficiency.

Second, we extend Haufler and Runkel (2012) in their findings on thin capitalization rules. In a tax-competition setting where some capital is internationally mobile, these

[5] Alternatively, withholding taxes are set too high in case of foreign ownership of firms in order to extract rents and income from foreigners, see, e.g., Huizinga and Nielsen (1997). Note that our model does not embed such a feature. For a broad review of the comprehensive literature on international tax competition, see Keen and Konrad (2013).

authors find that it is optimal to grant some deductibility for internal debt in multinationals in order to lower their effective capital costs. Thus, lax thin capitalization rules are an instrument for tax competition.[6] We derive the optimal design of these rules in equilibrium and highlight the driving forces behind them. In particular, our findings show that the results in Haufler and Runkel (2012) carry over to a setting that also features shifting of paper profits, intellectual property, differences in productivity of immobile and mobile capital, and an extended tool set for the government. Actually, thin capitalization rules become an even more important instrument for tax competition and turn into a crucial complement to curb excessive profit shifting in intangibles. By weakening thin capitalization rules, multinationals can be compensated for the overshooting effect of royalty taxes that do not differentiate between arm's-length remuneration for intellectual property and abusive profit shifting. A laxer thin capitalization rule is a key element to ensure an efficient treatment of royalties under tax competition. From this follows that some internal debt shifting can be beneficial in a second-best optimum and thin capitalization regulation should not become too strict. It is more important to curb abusive royalty payments that do not contribute to domestic investment and production in the same manner as internal debt.

Third, in a political dimension, our results call into question many provisions in double tax treaties that waive royalty taxes on cross-border payments and the EU Interest and Royalty Directive that bans royalty taxation for all payments between member states in the European Economic Area. As a response to patent box competition within the EU and challenges by the development in the U.S. and the 'post-Brexit' U.K., it may be beneficial to impose strong royalty taxes. They provide a unilateral measure to protect a country's tax base against such tax competition. Because these taxes *optimally* fall on both arm's-length payments and abusive profit shifting, there is no need to differentiate between these payments and the problem of identifying the arm's-length component does not apply. As long as a country supplements such withholding taxes with weakened thin capitalization regulation, it does not suffer from any loss in physical capital investment either.[7] We show that such a package is the dominant, welfare-maximizing choice even under non-cooperative decision making and tax competition.

Finally, the literature with respect to royalty taxes is scant. Fuest et al. (2013,

[6]Looking at one country in an optimal-tax approach, Hong and Smart (2010) established that some debt shifting to implement discrimination between domestic and national firms is always optimal. Again, lax thin capitalization rules allow for positive investment effects and more targeted firm-specific tax rates. Gresik et al. (2015), however, show that adding transfer pricing to such a model questions this view. Transfer pricing is welfare-deteriorating, and larger FDI and thin capitalization allow for more transfer pricing.

[7]Problems can occur when domestic firms also need to wire royalty payments to foreign patent owners. One solution could be to implement a royalty stripping rule similar to earnings stripping rules for thin capitalization. Granting some deductibility and denying any royalty deductions above a certain threshold from the tax base, relative to some earnings measure, should allow to handle this problem. We will elaborate on this more in the concluding remarks.

section 5) propose withholding taxes on royalty payments that are creditable in the residence country as one policy option to reduce BEPS. In a brief statement, the authors verbally discuss the scope of such a measure.[8] For a small open economy without strategic interaction, Juranek et al. (2018) provide a comprehensive positive analysis of the effects of royalty taxation on firms' investment and profit shifting behavior, depending on various different OECD methods to regulate transfer pricing. One main finding is that under standard OECD methods, transfer pricing in intellectual property does not have any effect on the intensive investment margin. In all these papers, government policies are exogenous. Our results confirm that there is no behavioral ('intensive-margin') effect, but identify a mechanical investment effect on the extensive margin. But, this effect can be reproduced by other instruments so that royalty taxation remains an effective instrument to curb profit shifting in a package with several policy instruments. Most importantly, we extend the analysis in this strand of the literature by bringing it on a rigorous normative level. Royalty taxes are an efficient instrument to curb profit shifting and can be maintained under tax competition, as long as they are accompanied by (lax) thin capitalization rules.

The remainder of the paper is set up as follows. Section 2 develops the model. In Section 3, the Pareto-optimal solution where policy instruments are coordinately chosen is derived as a benchmark. Section 4 analyzes the non-cooperative symmetric equilibrium. In Subsections 4.1 and 4.2, we discuss the equilibrium for special cases of available policy instruments where either the withholding tax on royalties or internal debt (and the thin capitalization rule) are not available. In Subsection 4.3, we then derive the equilibrium for the full set of policy instruments. Section 5, finally, concludes.

2 The model

Our analysis rests on the standard model provided in Haufler and Runkel (2012). In order to capture the challenges of the digital economy, intellectual properties, and intensified tax competition for both physical capital and paper profits, we extend this model by capital-augmented technological progress, royalty payments for the underlying intellectual property, and differences in productivity of domestic (immobile) and international (mobile) capital. Furthermore, a royalty tax provides an additional instrument for the government.

There are two symmetric countries $i \in \{A, B\}$ engaging in competition for mobile capital. In each country, there are national and multinational firms (superscript n and m,

[8] Related to this, a Norwegian government committee on capital taxation in a small open economy discussed practical options for royalty taxation in 2014, but voiced mixed opinions (NOU, 2014, chapter 7.3). In contrast, Finke et al. (2014) estimate in an empirical analysis that most countries would benefit from a withholding tax on royalty payments, whereas the U.S. that receives the largest royalty income worldwide would lose a significant share of its revenue.

respectively). Each firm, independently whether it is national or multinational, uses one unit of capital as a unique input factor in the production process. We denote capital used in national firms (k_i^n) as immobile and capital used in multinational firms (k_i^m) as mobile. The net return for both types of capital differs for two reasons. First, multinational firms have access to an intellectual property that allows them to use their capital inputs more efficiently (i.e., they are more productive). Second, national and multinational firms are treated differently by the tax system, because investment by multinationals is internationally mobile.

In our analysis, we assume that all governments apply the tax-exemption method in case of foreign-earned income, i.e., territorial income tax systems apply.[9] We follow the main tax-competition literature in modelling a capital tax per unit of capital input instead of a (proportional) corporate tax rate on firms' taxable profits. This choice simplifies the analysis, but is known to not affect the qualitative results as long as there is no imperfect competition (see, e.g., Haufler and Runkel, 2012, p. 1090). Thus, both types of firms in our model face a statutory tax rate on effective capital input denoted by t_i.

All firms decide about how much of their investment to finance by external debt. Following most tax codes worldwide, (external) debt is tax deductible, while equity is not. Hence, firms can reduce their effective tax rate by choosing their external leverage $\alpha_i \in [0,1]$, i.e., the extent to which investment is financed by external debt. As is well known from the trade-off literature, external debt causes additional non-tax benefits and costs.[10] On the one hand, it is seen as useful in mitigating moral-hazard problems in incentivizing managers (e.g., lax management and empire-building strategies). On the other hand, a higher external leverage increases the risk of bankruptcy and may cause bankruptcy costs, or induce a debt-overhang situation, in which profitable investment is not undertaken. In line with the standard finance literature, we summarize costs of external debt by a U-shaped function $C(\alpha_i - \bar{\alpha})$, where $\bar{\alpha}$ denotes the optimal external leverage ratio in absence of taxation (i.e., the cost-minimizing level of external debt). Any deviation from $\bar{\alpha}$ causes marginal agency costs with $C(0) = 0$, $C'(\cdot) > 0$ if $\alpha_i > \bar{\alpha}$, $C'(\cdot) < 0$ if $\alpha_i < \bar{\alpha}$, and $C''(\cdot) > 0 \; \forall \; \alpha_i$.

In addition, multinational firms host an affiliate in a tax haven that, for simplicity, charges a zero tax rate on capital and corporate income.[11] Thus, our model captures both shifting profits to offshore tax havens and very aggressive patent boxes. By inves-

[9]Since the U.S. went from worldwide to territorial taxation in its tax reform in December 2017, more or less all major (OECD) countries operate a territorial tax system and the tax-exemption method. Remaining exceptions are, e.g., Chile, Israel, and Mexico.

[10]See, e.g., Hovakimian et al. (2004) and Aggarwal and Kyaw (2010) for some overviews and more detailed discussions of the full set of costs and benefits of external debt.

[11]This assumption corresponds, e.g., with Hong and Smart (2010), Haufler and Runkel (2012), and Gresik et al. (2015). A positive tax rate in the tax haven would not affect our results at all as long as tax payments on royalty income in the tax haven can be credited against potential royalty tax payments in the productive affiliates (see also the proposal in Fuest et al., 2013, section 5).

ting equity in the tax haven, the multinational can turn this affiliate into an internal bank that passes on the equity as internal debt to the productive affiliate in country i. Because internal debt is – per se – also tax deductible, the additional debt financing lowers the effective tax rate in country i further. Actually, multinational firms would like to replace the entire equity in their productive affiliates by internal debt, but face a thin capitalization rule λ_i that denotes the maximum internal leverage (i.e., the internal-debt-to-asset ratio) that is tax deductible.[12]

Finally, the multinational's affiliate in country i has access to intellectual property (e.g., a capital-enhancing technology) owned by the tax-haven affiliate. In order to capture the (technological) advantage of multinational firms over domestic entities, we assume that the intellectual property implies that one unit of mobile capital is more productive than a unit of immobile capital. Specifically, we assume that one unit of immobile capital equals $\kappa \leq 1$ units of mobile, or effective, capital units.[13] In other words, the multinationals' technology enhances any unit of raw capital, used in their affiliates, to $1/\kappa > 1$ units of effective capital. Both types of capital contribute to a country's aggregate production $f(k_i)$ where the aggregated production function is specified over total *effective* capital units k_i employed in country i and features the standard properties $f'(k_i) > 0$ and $f''(k_i) < 0$. The total amount of effective capital units is given by $k_i = \kappa k_i^n + k_i^m$. Capital supply is exogenous. The representative household in country i owns n units of national 'raw' capital k_i^n and one unit of mobile capital k_i^m. Hence, supply of effective capital units amounts to $\kappa n + 1$ in country i.

For the use of the intellectual property, the tax-haven affiliate charges a royalty payment per unit of capital $R_i = R_i^a + R_i^b$ that is tax deductible in the productive affiliate in country i. R_i^b captures the arm's-length payment that mirrors the actual value created per unit of capital. Because the royalty can both be lump-sum in nature and depend on capital investment in various ways (e.g., on production $f(k_i)$ or on sales revenue $pf(k_i)$ where p denotes the price), R_i^b depends on capital investment k_i and an exogenous vector $\boldsymbol{b} = (b_1, ..., b_N)^T$ that denotes the corresponding arm's-length rates.[14] In contrast, R_i^a

[12] Accordingly, we focus on the traditional safe harbor rules when it comes to regulation of thin capitalization. The new trend, fostered by Action 4 in the OECD BEPS Action Plan, is to implement earnings stripping rules which allow deductibility of (internal) interest expenses relative to some earnings measure. It is not trivial to implement such rules into a setting with tax competition, heterogeneous firms, differences in productivity, and profit shifting. This would require a very different model set up than the one to come, and a specification of firm-specific taxable-profit functions. Nevertheless, we believe that our results with respect to royalty taxes carry over to a world with earnings stripping rules as well. In what follows, the crucial role of thin capitalization rules will be to reduce effective capital costs for multinationals, and this can be done both via safe harbor rules and by earnings stripping rules.

[13] Since the statutory tax t_i is levied on effective capital units, domestic firms pay a lower effective tax per unit of 'raw' capital (their endowment is worth κn, $\kappa \leq 1$, effective capital units only). This effect corresponds to a corporate tax on firms' profits, where in absence of tax avoidance, domestic firms would have a lower total tax payment as they are less productive and have lower profits than multinational firms.

[14] As discussed in San Martín and Saracho (2010), most royalty payments are made relative to sales revenue or units sold or as a combination of a fixed payment and payments relative to sales.

measures the amount of profit shifting that is achieved by the tax-haven affiliate charging a surcharge above the arm's-length royalty payment. This surcharge depends on capital investment and an N-dimensional choice vector $\boldsymbol{a} = (a_1, ..., a_N)^T$ which elements allow for adjustment of the arm's-length rates. Hence, the abusive part of the royalty payment is given by $R_i^a(\boldsymbol{a}, k_i)$. Put together, the total royalty payment per unit of capital is given by $R_i(\boldsymbol{a}, k_i) = R_i^a(\boldsymbol{a}, k_i) + R_i^b(k_i)$. We assume that the aggregated arm's-length royalty payment $R_i^b(k_i)k_i$ is increasing and concave in k_i. The latter assumption implies that the respective royalty payment per unit of capital, $R_i^b(k_i)$, decreases in capital k_i, i.e., $\partial R_i^b / \partial k_i < 0$.[15]

To shift profits and deviate from the arm's-length payment R_i^b, i.e., in order to charge an abusive surcharge payment R_i^a, the multinational has to incur concealment costs. These costs can be interpreted as the use of lawyers and accountants to justify the chosen rates within a given leeway and disguise the abusive part of the royalty payment, or as non-tax deductible fines related to abusive pricing.[16] The costs depend on the level of mispricing, and the more profits are shifted, the higher these costs become. Juranek et al. (2018) show that the OECD standard transfer pricing methods imply a functional form of royalty-related concealment costs which defines its argument over the deviation from the arm's-length payment, i.e., over $R_i - R_i^b = R_i^a$.[17] Therefore, assuming the OECD standard methods to apply, we define concealment costs as $c = c(R_i^a)$ with $c(0) = 0$, $c'(R_i^a)R_i^a > 0$, and $c''(R_i^a) > 0$.

The government has three tax instruments at its disposal. It charges a statutory capital tax rate t_i per unit of capital k_i that is invested in country i. The thin capitalization rule sets the internal leverage λ_i that is tax deductible. Finally, a withholding tax $\tau_i \in [0, t_i]$ on royalty payments can be charged in order to reduce profit shifting that is undertaken through mispricing of royalties. The maximum of the withholding tax is given by the capital tax rate t_i. Total tax revenue is used to finance a public consumption good g_i. While all three instruments can be used for tax competition, thin capitalization rules and withholding taxes additionally allow for discrimination between national and multinational firms in order to attract mobile capital. As we are going to show later, these two policy instruments are, however, differently affected by the competition for mobile resources.

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[15] The aggregate arm's-length payment may, for example, be determined proportional to output $f(k_i)$ so that $R_i^b(k_i) = bf(k_i)/k_i$ with $b > 0$. As the production function is concave, the royalty payment also is concave.

[16] See, e.g., Kant (1988) and Haufler and Schjelderup (2000). Whether concealment costs are tax deductible does not matter for the qualitative results to come.

[17] To the standard methods listed by the OECD (2015c, 2017a) belong the Controlled Unrelated Price Method, Transactional Net Margin Method, and Cost Plus Method. For profit-allocation methods such as the Transactional Profit Split Method, however, the specification does not work well. See Juranek et al. (2018) for details.

2.1 Firm behavior

Given the described tax system, the net return on immobile capital in country i, per effective-capital unit, is

$$r_i^n = f'(k_i) - t_i(1 - \alpha_i^n) - C(\alpha_i^n - \bar{\alpha}), \tag{1}$$

which translates into a net return of κr_i^n per unit of national 'raw' capital. The optimal external leverage of national firms, i.e., α_i^{n*}, solves

$$t_i = C'(\alpha_i^n - \bar{\alpha}). \tag{2}$$

The net return on mobile capital in country i is

$$r_i^m = f'(k_i) - t_i(1 - \lambda_i - \alpha_i^m) - C(\alpha_i^m - \bar{\alpha}) + \mu_i R_i(\boldsymbol{a}, k_i) - c(R_i^a(\boldsymbol{a}, k_i)), \tag{3}$$

where we define $\mu_i \equiv t_i - \tau_i$. We interpret μ_i as the net deductibility rate for royalties.

The net return on mobile capital is higher than the net return on immobile capital for three reasons. First, mobile capital is more productive due to the use of the intellectual property. Second, multinationals can reroute equity via the internal bank and declare some capital as internal debt (denoted by λ_i). This reduces their effective tax rate and, therefore, their user costs of capital. Third, multinationals can lower their effective tax rate via the deduction of royalty payments (captured by $\mu_i R_i(\boldsymbol{a}, k_i)$). In order to do so, the multinational has to incur concealment costs $c(R_i^a)$ for the part of royalties that are abusive. But in the optimum, these concealment costs do not overcompensate the tax deduction.

The optimal external leverage chosen by multinational firms α_i^{m*} is given by the solution of

$$t_i = C'(\alpha_i^{m*} - \bar{\alpha}). \tag{4}$$

It corresponds to the choice of external leverage in national firms, i.e., $\alpha_i^* \equiv \alpha_i^{n*} = \alpha_i^{m*}$, because the decision for external debt is independent of internal debt and royalty payments.

Equation (4) allows us to analyze the effect of the capital tax rate, the thin capitalization rule, and the deductibility rate for royalties. We find that the optimal level of external debt increases in the capital tax rate t_i, but is not affected by changes in the thin capitalization rule λ_i or the deductibility rate for royalties μ_i, i.e.,

$$\frac{d\alpha_i^*}{dt_i} = \frac{1}{C''(\alpha_i^* - \bar{\alpha})} > 0 \quad \text{and} \quad \frac{d\alpha_i^*}{d\lambda_i} = \frac{d\alpha_i^*}{d\mu_i} = 0. \tag{5}$$

The multinationals' first-order condition with respect to the royalty structure follows as

$$\frac{\partial r_i^m}{\partial a_s} = \mu_i \tfrac{\partial R_i^{a*}(\boldsymbol{a},k_i)}{\partial a_s} - c'(R_i^{a*}(\boldsymbol{a},k_i))\tfrac{\partial R_i^{a*}(\boldsymbol{a},k_i)}{\partial a_s} = 0 \quad \forall s = 1, ..., N \quad \Rightarrow \quad \mu_i = c'(R_i^{a*}). \tag{6}$$

The first-order condition shows that the vector $\boldsymbol{a}$ is indeterminate because the first-order condition is the same for each element $s = 1, ..., N$. Hence, it suffices for the multinational to choose one surcharge element a_s. However, the shape of the optimal abusive-surcharge function $R_i^{a*}(\boldsymbol{a}, k_i)$ is unambiguously determined by the inverse of the marginal concealment cost function. Note further, that the optimal royalty payment per unit of capital, R_i^{a*}, is independent of capital investment k_i. The reason is that any effect that comes from changes in optimal capital investment can be neutralized by an adjustment of the surcharge vector $\boldsymbol{a}$ in order to maintain the total profit shifting via royalties on its optimal level (see also Juranek et al., 2018).

In the following, we hold the deductibility rate μ_i constant whenever we analyze the effects of a change in the capital tax t_i, that is, we assume that the royalty tax rate τ_i adjusts implicitly to hold $\mu_i = t_i - \tau_i$ unchanged. Then, abusive royalties per unit of capital are neither affected by the capital tax t_i nor by the thin capitalization rule λ_i; however, they increase in the deductibility rate for royalties μ_i, that is,

$$\frac{dR_i^{a*}}{dt_i} = \frac{dR_i^{a*}}{d\lambda_i} = 0 \quad \text{and} \quad \frac{dR_i^{a*}}{d\mu_i} = \frac{1}{c''(R_i^{a*}(\boldsymbol{a}, k_i))} > 0. \tag{7}$$

Optimal demand for effective capital units k_i in country i is determined by the equilibrium on the world capital market, i.e.,

$$k_i + k_j = 2(1 + \kappa n). \tag{8}$$

As we have assumed both countries to be symmetric, the representative households in both countries own half of the total capital supply. Moreover, the net return on mobile capital must be equal in both countries, that is, there is no possibility for arbitrage. Capital demand in country i is, therefore, determined by

$$\begin{aligned} & f'(k_i) - t_i(1 - \lambda_i - \alpha_i^*) - C(\alpha_i^* - \bar{\alpha}) + \mu_i[R_i^{a*} + R_i^b(k_i)] - c(R_i^{a*}) \\ = \; & f'(k_j) - t_j(1 - \lambda_j - \alpha_j^*) - C(\alpha_j^* - \bar{\alpha}) + \mu_j[R_j^{a*} + R_j^b(k_j)] - c(R_j^{a*}), \end{aligned} \tag{9}$$

where we have used the optimal solutions for external debt and abusive royalties, i.e., (2) and (6). Using equation (8) in order to substitute for k_j in equation (9) and then differentiating the arbitrage condition with respect to k_i and t_i yields

$$\left[f''(k_i) + \mu_i \frac{\partial R_i^b}{\partial k_i}\right] dk_i - [1 - \lambda_i - \alpha_i^*]\, dt_i = -\left[f''(k_j) + \mu_j \frac{\partial R_j^b}{\partial k_j}\right] dk_i. \tag{10}$$

Applying symmetry, i.e., $\alpha_j^* = \alpha_i^*$, $k_j = k_i$, $t_j = t_i$, and $\mu_j = \mu_i$, we can rewrite that to

$$\frac{dk_i}{dt_i} = -\frac{dk_j}{dt_i} = \frac{1 - \lambda_i - \alpha_i^*}{2\left[f''(k_i) + \mu_i \frac{\partial R_i^b}{\partial k_i}\right]} < 0. \tag{11}$$

Because both the production function and the aggregated arm's-length royalty payment function are concave, it always holds $2\left[f''(k_i) + \mu_i \frac{\partial R_i^b}{\partial k_i}\right] < 0$. Hence, an increase in the statutory capital tax decreases capital demand in the respective country and leads to an increase in capital demand in the other country. The result illustrates the standard tax base externality arising from tax competition for mobile resources.

Analogously, we differentiate (9) with respect to k_i and λ_i to obtain the effect of a change in the thin capitalization rule on capital demand. It is

$$\frac{dk_i}{d\lambda_i} = -\frac{dk_j}{d\lambda_i} = -\frac{t_i}{2\left[f''(k_i) + \mu_i \frac{\partial R_i^b}{\partial k_i}\right]} > 0. \tag{12}$$

Relaxing the thin capitalization rule, that is, increasing λ_i, leads to an increase in capital demand in the respective country and reduces the capital demand in the other country.

Finally, differentiating (9) with respect to k_i and μ_i yields

$$\frac{dk_i}{d\mu_i} = -\frac{dk_j}{d\mu_i} = -\frac{R_i^{a*} + R_i^b}{2\left[f''(k_i) + \mu_i \frac{\partial R_i^b}{\partial k_i}\right]} > 0. \tag{13}$$

The deductibility rate for royalties only has a mechanical effect on capital demand that can be interpreted as an extensive-margin effect. A higher deductibility of the royalty payment R_i reduces the effective tax rate, increases the after-tax return on capital, and makes investment more attractive, all else equal. Therefore, demand for capital in country i will be larger, and because each firm uses one unit of capital, this implies further settlements and relocation of multinationals. Consequently, an increase in the deductibility rate for royalties increases capital demand in the respective country and decreases capital demand in the other country. There is, however, no behavioral effect via profit shifting. It does not pay-off to increase capital beyond the mechanical effect in order to improve the profit-shifting position, because (aggregate) capital investment does not affect the trade-off between abusive royalty payments and concealment costs. On the margin, the behavioral effects cancel out. This is, with necessary modifications, equivalent to the absence of an intensive-margin effect in a setting where firms can adjust the level of their capital investment, see Juranek et al. (2018, Proposition 1).[18]

[18] Juranek et al. (2018) focus on a model with an intensive margin for capital investment and royalty payments that are defined per firm, not per unit of capital. In such a setting, profit shifting via royalty payments does not affect investment at all. In our setting with an aggregate production function, a

Importantly, the mechanical effect of the deductibility rate is proportional to the effect of the thin capitalization rule, and thus, can be fully offset by adjusting the thin capitalization regulation, as $\frac{dk_i}{d\mu_i} = \frac{R_i^{a*}+R_i^b}{t_i}\frac{dk_i}{d\lambda_i}$. Hence, the extensive margin can be fully controlled by the available government instruments.

2.2 Tax system

Per capita utility in country i is denoted by $u(x_i, g_i)$ where x_i and g_i are private and public consumption, respectively. Before we analyze the optimal tax policy with coordination and under competition, we derive the effects of the three policy instruments on private and public consumption. Based on the supply of n units of national 'raw' capital and one unit of mobile capital as well as returns measured per unit of effective capital, private consumption equals

$$x_i \quad = \quad \kappa n r_i^n + r_i^m + f(k_i) - f'(k_i)k_i, \tag{14}$$

where the returns on capital are given in (1) and (3), respectively. Private consumption is determined by the aggregate return of mobile and immobile capital. Moreover, inelastically supplied labor and the intellectual property give rise to decreasing returns to scale in production and generate supernormal profits. These profits provide the representative household with residual income that is captured by the last part of equation (14), i.e., by $f(k_i) - f'(k_i)k_i$.

Analogously, the provision of public goods is determined by tax revenue and reads

$$g_i \quad = \quad t_i(1-\alpha_i^*)\kappa n + \left[t_i(1-\lambda_i-\alpha_i^*) - \mu_i R_i^*\right](k_i - \kappa n), \tag{15}$$

where $k_i - \kappa n$ denotes mobile capital used in country i and $R_i^* \equiv R_i^{a*} + R_i^b(k_i)$. Considering the optimal solutions for internal debt and royalties, i.e., (2) and (6), the partial derivatives of private consumption with respect to the three policy instruments in a symmetric situation are[19]

$$\frac{\partial x_i}{\partial t_i} \quad = \quad -\kappa n(1-\alpha_i^*) - (1-\lambda_i-\alpha_i^*) + \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}, \tag{16a}$$

$$\frac{\partial x_i}{\partial \lambda_i} \quad = \quad t_i + \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}, \tag{16b}$$

$$\frac{\partial x_i}{\partial \mu_i} \quad = \quad R_i^* + \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}. \tag{16c}$$

unit of capital can be seen as establishing an additional firm (or affiliate). An increased deductibility of royalty payments then reduces the effective tax rate that is relevant for such an extensive-margin decision.

[19]Note that in the symmetric equilibrium, capital demand in country i is equal to $k_i = 1 + \kappa n$. We use this condition to derive equations (16a) to (16c)

Taking into account the effects of the policy instruments on capital demand, i.e., (11), (12), and (13), as well as $\frac{\partial R_i^b}{\partial k_i} < 0$, all three effects are generally ambiguous. Based on the standard direct effects, a higher statutory capital tax and a higher withholding tax reduce private consumption, while a laxer thin capitalization rule increases private consumption. But, a decrease in capital demand increases the arm's-length royalty payment per unit of invested capital so that income of the investors in country i increases, all else equal. Equivalently, an increase in capital demand reduces the arm's-length payment per invested capital so that the owners of these capital units experience a reduction in income, all else equal.

The effects of the three policy instruments on the private consumption in the other country are

$$\frac{\partial x_j}{\partial t_i} = \mu_j \frac{\partial R_j^b}{\partial k_j}\frac{\partial k_j}{\partial t_i} = -\mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i} < 0, \tag{17a}$$

$$\frac{\partial x_j}{\partial \lambda_i} = \mu_j \frac{\partial R_j^b}{\partial k_j}\frac{\partial k_j}{\partial \lambda_i} = -\mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i} > 0, \tag{17b}$$

$$\frac{\partial x_j}{\partial \mu_i} = \mu_j \frac{\partial R_j^b}{\partial k_j}\frac{\partial k_j}{\partial \mu_i} = -\mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i} > 0. \tag{17c}$$

In a standard tax-competition model without royalty payments, private consumption in country j is not affected by policy changes in country i and all externalities work via public consumption only (see, e.g., Haufler and Runkel, 2012, equations (9) and (13)). The facts that owners of mobile capital earn an arm's-length royalty payment on their capital unit invested in country j and that this payment shrinks when capital investment in country j expands, trigger a negative private-consumption externality of capital taxation in country i, but positive externalities from thin capitalization rules and deductibility rates in country i.

For public consumption, we obtain in a symmetric equilibrium

$$\frac{\partial g_i}{\partial t_i} = \kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - (1+\kappa n)t_i \frac{\partial \alpha_i^*}{\partial t_i} - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i} + \Delta_k \frac{\partial k_i}{\partial t_i}, \tag{18a}$$

$$\frac{\partial g_i}{\partial \lambda_i} = -t_i - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i} + \Delta_k \frac{\partial k_i}{\partial \lambda_i}, \tag{18b}$$

$$\frac{\partial g_i}{\partial \mu_i} = -R_i^* - \mu_i \frac{\partial R_i^{a*}}{\partial \mu_i} - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i} + \Delta_k \frac{\partial k_i}{\partial \mu_i}. \tag{18c}$$

with

$$\Delta_k \equiv t_i(1-\lambda_i-\alpha_i^*) - \mu_i R_i^* \geq 0 \tag{19}$$

denoting the tax wedge of capital investment. The tax wedge is positive whenever the deductibility of royalty payments μ_i is not too large.[20]

[20]In an equilibrium with optimal government strategies, $\Delta_k \geq 0$ will always hold. Otherwise, the

In general, the effects of the policy instruments on the public good in the same country are ambiguous in sign. In its optimum, however, the government will never choose a tax rate on the decreasing side of the Laffer curve so that $\frac{\partial g_i}{\partial t_i} \geq 0$. An increase in the capital tax rate has three effects on public consumption. First, there is a direct, positive effect through an increase in tax revenue (first two terms of (18a)). Second, there is a negative effect, because external debt increases due to an increase in the capital tax rate so that tax revenue is reduced. Third, there is a negative revenue effect as the deductible arm's-length royalty payment per capital unit increases when capital demand decreases. In addition, the decrease in capital demand also has a direct negative revenue effect whenever the capital tax wedge is positive. A laxer thin capitalization rule has two effects on public consumption. On the one hand, there is a direct reduction in tax revenue. On the other hand, the induced increase in capital demand fosters the capital tax base and reduces deductibility of arm's-length royalties per unit of capital. The effects of an increase in the deductibility rate for royalties on public consumption are threefold: There is a negative, direct effect on tax revenue. Furthermore, an increase in the deductibility rate of royalties increases the royalty through an increase in the abusive part. This response reduces tax revenue. Finally, there is a positive effect via capital demand, analogous to the capital-demand effect of the thin capitalization rule.

The effects of the policy instruments chosen by country i on the provision of public goods in country j arise due to changes in capital demand and are unambiguous for positive tax wedges:

$$\frac{\partial g_j}{\partial t_i} = -\mu_j \frac{\partial R_j^b}{\partial k_j}\frac{\partial k_j}{\partial t_i} + \Delta_k \frac{\partial k_j}{\partial t_i} = \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i} - \Delta_k \frac{\partial k_i}{\partial t_i} > 0, \tag{20a}$$

$$\frac{\partial g_j}{\partial \lambda_i} = -\mu_j \frac{\partial R_j^b}{\partial k_j}\frac{\partial k_j}{\partial \lambda_i} + \Delta_k \frac{\partial k_j}{\partial \lambda_i} = \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i} - \Delta_k \frac{\partial k_i}{\partial \lambda_i} < 0, \tag{20b}$$

$$\frac{\partial g_j}{\partial \mu_i} = -\mu_j \frac{\partial R_j^b}{\partial k_j}\frac{\partial k_j}{\partial \mu_i} + \Delta_k \frac{\partial k_j}{\partial \mu_i} = \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i} - \Delta_k \frac{\partial k_i}{\partial \mu_i} < 0. \tag{20c}$$

Both an increase in the statutory capital tax, a stricter thin capitalization rule (i.e., a lower λ_i), and a reduced deductibility rate of royalty payments (i.e., a lower μ_i) have positive external effects on the other country because such policies foster capital demand in the other country. In a world with royalty payments, the standard tax base effects (i.e., the terms via Δ_k) are fostered by the reduction of arm's-length royalty payments per unit of capital (cf. the effect on private consumption in country j). These effects via royalty payments are the direct counterparts to the externalities on private consumption in country j, that is, they have the same magnitude, but the opposite sign. Consequently,

government would have incentives to push capital out of the country in order to increase tax revenue and public consumption. But, this implies that it would reduce the deductibility rate μ_i (i.e., increase the withholding tax τ_i) until $\Delta_k = 0$.

under tax competition with royalty payments, the standard fiscal externalities are extended by additional consumption externalities. An export of capital does not only foster the other's country tax base, it also reduces the royalty payments per unit of capital in this country. Hence, private consumption decreases, but tax revenue and public consumption increase. The latter effect is welfare-enhancing whenever there is underprovision of public goods.

3 The Pareto-optimal solution

As a benchmark, we derive the optimal tax policy with coordination of policies in both countries. A country's welfare is determined by the utility of its representative household. Under coordination, the countries maximize aggregate welfare $W^c = u(x_i, g_i) + u(x_j, g_j)$ (where superscript c refers to coordinated tax policies). In this situation, the tax base externalities are taken into account so that the Pareto-optimal levels of the policy instruments are determined. Nevertheless, the deductibility of external debt, which is guaranteed by the tax systems, acts as a constraint on the Pareto-optimal solution. The optimization problem can be stated as

$$\max_{t_i,\lambda_i,\mu_i,t_j,\lambda_j,\mu_j} W^c = u(x_i, g_i) + u(x_j, g_j) \quad \text{s.t.} \quad (8), (14), \text{ and } (15). \tag{21}$$

Proposition 1 summarizes the result where $\varepsilon_{\alpha t}$ denotes the elasticity of external leverage with respect to the capital tax.

Proposition 1 *With symmetric countries, the Pareto-optimal tax policy is characterized by underprovision of the public good, i.e.,*

$$\frac{u_g}{u_x} = \frac{1}{1 - \varepsilon_{\alpha t}} > 1 \tag{22}$$

with $\varepsilon_{\alpha t} \equiv \frac{\partial \alpha_i^*}{\partial t_i} \frac{t_i}{1-\lambda_i-\alpha_i^*} > 0$*, a zero thin capitalization rule* $\lambda_i^c = 0$*, and a maximum withholding tax* $\tau_i^c = t_i^c$ *(i.e.,* $\mu_i^c = 0$*).*

Proof: See Appendix A.1.

Even for a Pareto-efficient tax policy, the marginal rate of substitution between public and private consumption is smaller than one, that is, smaller than the marginal rate of transformation. Consequently, there is underprovision of public goods compared to a fully undistorted decision. This result is driven by the deductibility of external debt that allows firms to avoid the capital tax by strategically distorting the firm's capital structure. Hence, the increasing external leverage constraints the level of the capital tax, and the elasticity of external leverage becomes a measure for the underprovision with public consumption. The faster agency costs increase with external leverage (i.e., the more convex the agency cost function), the less tax-responsive leverage will be and the higher the Pareto-optimal tax rate gets.[21]

Furthermore, internal debt is not tax deductible, because a positive thin capitalization rule would further foster the excessive leverage, and therefore, would lower the tax base even more. Both results are analogous to Proposition 1 in Haufler and Runkel (2012).

In addition, non-deductibility of royalty payments, i.e., a withholding tax on royalties at its maximum, avoids any tax distortion from transfer pricing. Consequently, in an Pareto-efficient equilibrium, abusive royalties are fully prevented and all profit shifting is eliminated.

4 Tax competition

We now turn to the optimal tax system under competition where each country maximizes utility of the domestic representative household $u = u(x_i, g_i)$ only. As we have assumed identical countries, we focus on the symmetric equilibrium. Thus, choosing all instruments simultaneously, the non-cooperative optimization problem to maximize national welfare W_i is

$$\max_{t_i,\lambda_i,\mu_i} W_i = u(x_i, g_i) \quad \text{s.t.} \quad (8), (9), (14), \text{ and } (15). \tag{23}$$

The first-order condition for the statutory capital tax reads

$$\frac{\partial u(x_i, g_i)}{\partial t_i} = u_x \frac{\partial x_i}{\partial t_i} + u_g \frac{\partial g_i}{\partial t_i} = 0. \tag{24}$$

Using (16a) and (18a), we can rewrite the condition as

$$\frac{u_g}{u_x} = \frac{\kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}}{\kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i} - (1+\kappa n)t_i \frac{\partial \alpha_i^*}{\partial t_i} + \Delta_k \frac{\partial k_i}{\partial t_i}} > 1, \tag{25}$$

with the tax wedge Δ_k as defined in (19).

The term $-(1+\kappa n)t_i \frac{\partial \alpha_i^*}{\partial t_i} + \Delta_k \frac{\partial k_i}{\partial t_i} < 0$ implies that $u_g > u_x$. Consequently, in each country, there is always underprovision of public goods and the optimal capital tax rate t_i^* is inefficiently lax. This inefficiency is driven by two effects: First, an increase in the capital tax fosters the distortion in firms' capital structure. The resulting increase in external leverage triggers a decrease in tax revenue, all else equal. This effect also appears with policy coordination as shown in the proof of Proposition 1. Second, there is an additional

[21] As usual in public finance, the 'optimal-tax expression' does not represent an explicit solution for the optimal tax rate (or in the following section, the other instruments). Generally, the elasticity in equation (22), for example, is not constant and will depend on the chosen tax rate. But, the optimal-tax expressions allow for highlighting relevant trade-offs and discussing their impacts on an optimal solution.

negative effect on tax revenue caused by a decrease in capital demand. This effect is not present in an equilibrium with coordination, but emerges from unilateral competition for mobile capital. Country i neglects the positive externality on welfare in country j that is created by shifting capital from country i to j. In sum, the underprovision is stronger than under cooperation and can be measured as

$$\frac{u_g - u_x}{u_g} = \frac{(1+\kappa n)t_i \frac{\partial \alpha_i^*}{\partial t_i} - \Delta_k \frac{\partial k_i}{\partial t_i}}{\kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}} > 0, \tag{26}$$

where $k_i = 1 + \kappa n$.

In contrast to the statutory tax rate, both the thin capitalization rule and the withholding tax on royalties are targeted instruments to compete for mobile capital. They only affect multinationals and their mobile investment. The respective first-order conditions are

$$\frac{\partial u(x_i,g_i)}{\partial \lambda_i} = u_x \frac{\partial x_i}{\partial \lambda_i} + u_g \frac{\partial g_i}{\partial \lambda_i} = (u_x - u_g)\left(t_i + \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right) + u_g \Delta_k \frac{\partial k_i}{\partial \lambda_i} \leq 0, \tag{27}$$

$$\frac{\partial u(x_i,g_i)}{\partial \mu_i} = u_x \frac{\partial x_i}{\partial \mu_i} + u_g \frac{\partial g_i}{\partial \mu_i} = (u_x - u_g)\left(R_i^* + \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}\right) - u_g\left[\mu_i \frac{\partial R_i^{a*}}{\partial \mu_i} - \Delta_k \frac{\partial k_i}{\partial \mu_i}\right] \leq 0, \tag{28}$$

with Δ_k as defined in (19) again.

In order to gain deeper insights into how both policy instruments are optimally used by the governments, we start by analyzing the instruments separately for two special cases. In Subsection 4.1, firms use both internal debt and royalty payments, but governments can only set the thin capitalization rule. Royalty taxation is absent ($\mu_i = t_i$). This scenario captures the EU Interest and Royalty Directive and the current situation within the EEA. In contrast, we restrict the model in Subsection 4.2 to royalties and assume that internal debt is not available ($\lambda_i = 0$). Hence, we focus on the royalty tax and on transfer pricing as the only means to discriminate between multinationals and domestic firms.[22] Finally, we derive the optimal combination of the instruments when both the thin capitalization rule and the withholding tax on royalties are available (Subsection 4.3).

4.1 The case of a thin capitalization rule only

If the government in country i cannot impose a withholding tax on royalty payments, we have $\tau_i = 0$ so that $\mu_i = t_i$. In such a scenario, the government will use the thin capitalization rule $\lambda_i > 0$ and discriminate between national and multinational firms

[22] This scenario is related to Peralta et al. (2006) who analyze the optimal monitoring of transfer pricing as additional instrument for tax competition. But, these authors only focus on a binary choice where the governments either do not monitor at all (so that all profits will be shifted) or enforce perfect monitoring (and shut down profit shifting).

whenever

$$\left.\frac{\partial u(x_i, g_i)}{\partial \lambda_i}\right|_{\lambda_i=0,\mu_i=t_i} > 0. \tag{29}$$

This condition transforms into the requirement that capital demand is sufficiently elastic with respect to debt financing, that is, the incentives to engage in tax competition are sufficiently strong. More precisely, an optimally positive thin capitalization rule $\lambda_i^* > 0$ requires (see Appendix A.2 for the derivation)

$$\varepsilon_{kt} - \frac{1-\alpha_i^*}{1-\alpha_i^* - R_i^*}\frac{\varepsilon_{\alpha t}}{\kappa n} + \frac{R_i^*}{1-\alpha_i^* - R_i^*}\,\varepsilon_{Rk}\,\varepsilon_{kt}\,\frac{\varepsilon_{\alpha t}}{\kappa n} > 0, \tag{30}$$

where $\varepsilon_{kt} \equiv -\frac{\partial k_i}{\partial t_i}\frac{t_i}{k_i} > 0$ is the (positively defined) tax elasticity of capital and $\varepsilon_{Rk} \equiv -\frac{\partial R_i^b}{\partial k_i}\frac{k_i}{R_i^*} > 0$ indicates the (positively defined) elasticity of royalty payments with respect to capital investment, while $\varepsilon_{\alpha t} > 0$ represents the leverage elasticity as defined in Proposition 1.

A first insight is that condition (30) collapses to $\varepsilon_{kt} > \frac{\varepsilon_{\alpha t}}{\kappa n}$ whenever there are no royalty payments (i.e., $R_i^* = 0$) which fully corresponds to the finding in Haufler and Runkel (2012). In the general case with royalty payments $R_i^* > 0$, but no royalty taxes ($\mu_i = t_i$), the condition for engaging in tax competition is tightened compared to Haufler and Runkel (2012). Relative to their model, additional capital investment generates less tax revenue because part of the generated revenue is deducted as royalty payment and avoids home taxation. This is captured by $\frac{1-\alpha_i^*}{1-\alpha_i^*-R_i^*} > 1$ in the second term. The new effect is mitigated, but not reversed, by the fact that higher capital investment reduces the arm's-length royalty payment *per unit* of capital so that the loss in revenue via royalty payments is reduced, all else equal. The net effect still tightens the requirements for engaging in tax competition and granting some deductibility for internal debt. All losses in tax revenue weigh more the larger is the underprovision with public goods which is measured via the leverage elasticity $\varepsilon_{\alpha t}$.

We can rewrite (30) in a more compact form as

$$\varepsilon_{kt} > \frac{1-\alpha_i^*}{1-\alpha_i^* - R_i^*(1-\varepsilon_{Rk}\,\frac{\varepsilon_{\alpha t}}{\kappa n})}\frac{\varepsilon_{\alpha t}}{\kappa n}, \tag{31}$$

where $1-\alpha_i^* - R_i^*(1-\varepsilon_{Rk}\,\frac{\varepsilon_{\alpha t}}{\kappa n}) > t_i(1-\alpha_i^* - R_i^*) > 0$. The latter inequality holds because the firm does not have any incentive to choose external debt and royalties such that the tax base becomes negative (as the tax system does not grant 'negative' tax payments). If condition (31) is fulfilled, the optimal thin capitalization rule in absence of royalty taxation will be inefficiently lax. We summarize as

Proposition 2a *In a non-cooperative symmetric Nash equilibrium where withholding taxes on royalty payments are not available ($\mu_i = t_i$), the government will set the thin* *capitalization rule inefficiently lax ($\lambda_i^* > 0$) whenever tax competition is sufficiently high, i.e., when* $\varepsilon_{kt} > \frac{1-\alpha_i^*}{1-\alpha_i^*-R_i^*(1-\varepsilon_{Rk}\frac{\varepsilon_{\alpha t}}{\kappa n})}\frac{\varepsilon_{\alpha t}}{\kappa n}$.

Whenever the government has incentives to engage in tax competition and uses its thin capitalization rule, $\lambda_i > 0$, the optimal level of deductible internal debt λ_i^* is implicitly defined by the optimal share of debt financing ($d_i = \alpha_i^* + \lambda_i$) relative to taxable profit per unit of capital $(1 - \lambda_i - \alpha_i^* - R_i^*)$. In optimum, this fraction is given by the elasticity rule (see Appendix A.3 for the derivation)

$$\frac{\alpha_i^* + \lambda_i}{1 - \lambda_i - \alpha_i^* - R_i^*} = \frac{\varepsilon_{kd}}{\left(1 + \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)\varepsilon_{\alpha t}}\kappa n, \qquad (32)$$

where $\varepsilon_{kd} \equiv \frac{\partial k_i}{\partial \lambda_i}\frac{\alpha_i^*+\lambda_i}{k_i} > 0$ is the elasticity of capital demand with respect to total leverage $d_i = \alpha_i^* + \lambda_i$. As an increase in tax deductibility increases capital investment and, therefore, reduces the arm's-length royalty per unit of capital, we have that $\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i} < 0$.

Equation (32) is a classic Ramsey rule that trades off the revenue gains from additional investment, measured by ε_{kd}, against the net loss in tax revenue from granting tax deductibility for existing capital investment. The cost measure takes into account that higher capital investment reduces arm's-length royalty payments, $0 < 1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i} < 1$. The welfare impact of the net revenue costs depends on the level of underprovision of public goods, which is measured via the tax elasticity of leverage $\varepsilon_{\alpha t}$ again, see Proposition 1.

The more elastic capital investment is, the higher will be the optimal deductibility rate for internal debt. In contrast, the higher the leverage elasticity is, the stronger the underprovision and the costlier it is to grant tax deductibility. Therefore, a more elastic external leverage tightens the optimal thin capitalization rule. If the technological advantage of multinationals is so large that domestic firms effectively do not have a share in overall production (i.e., if $\kappa \to 0$), there is no longer a need to differentiate between multinational and domestic firms. Hence, the thin capitalization rule will be set at its lower bound (and become negative if possible). We summarize our result as

Proposition 2b *The optimal thin capitalization rule trades off tax-revenue gains from attracting additional capital against losses in revenue from subsidizing existing investment. The presence of royalty payments works in favor of stricter thin capitalization rules, i.e., less tax competition, because royalties reduce the gains from additional capital investment.*

4.2 Pure transfer pricing and the royalty tax

Next, we turn to the scenario in which the government can set a withholding tax on royalty payments, $\tau_i \geq 0$ and $0 \leq \mu_i \leq t_i$, but where internal debt is not available so that the government does not have the thin capitalization rule at its disposal, i.e.,

$\lambda_i = 0$. We know from the benchmark case in a cooperative equilibrium that the efficient choice of the withholding tax is $\tau_i^c = t_i^c$ so that there is no deductibility of royalties, $\mu_i^c = 0$. In a non-cooperative equilibrium, the government will engage in tax competition and allow for some deductibility if $\frac{\partial u(x_i,g_i)}{\partial \mu_i}\Big|_{\mu_i=0,\lambda_i=0} > 0$. After rearranging the first-order condition (28), we find that this is the case, whenever (see Appendix A.4 for the derivation)

$$\frac{\partial u(x_i, g_i)}{\partial \mu_i}\Big|_{\lambda_i=0,\mu_i=0} = R_i^b \left[k_i \varepsilon_{kt} - \frac{u_g - u_x}{u_g} \right] > 0. \tag{33}$$

At $\mu_i = 0$, there is no abusive transfer pricing so that $R_i^{a*} = 0$. Then, two insights follow directly from condition (33). First, profit shifting is only of second order at $\mu_i = 0$ and does not matter for the decision to grant some deductibility of royalty payments in order to attract capital. Second, a necessary condition for an inefficiently low royalty tax is a positive arm's-length royalty payment $R_i^b > 0$. If the royalties are only used for profit shifting ($R_i^b = 0$), relaxing the royalty tax from $\mu_i = 0$ (i.e., $\tau_i = t_i$) does not generate any inflow of capital, because $\frac{\partial k_i}{\partial \mu_i} = 0$ for $R_i^b = R_i^{a*} = 0$, cf. equation (13). Accordingly, the royalty tax is no instrument for tax competition, and it is preferable to maintain a strict non-deductibility policy in order to prevent profit shifting.

In all cases with positive arm's-length payments on intellectual property ($R_i^b > 0$), the government will reduce the royalty tax below the corporate tax and attract some foreign capital investment with $\mu_i > 0$ if, after utilizing equation (26) to replace $\frac{u_g - u_x}{u_g}$ (see Appendix A.4),

$$\kappa n \varepsilon_{kt} > \varepsilon_{\alpha t}. \tag{34}$$

An inefficiently lax deductibility rate $\mu_i > 0$ is optimal whenever the underprovision of public goods is not too severe, which is equivalent to assuming a sufficiently convex agency cost function of external debt, i.e., $\varepsilon_{\alpha t}$ to be sufficiently low (cf. equation (22)). Alternatively, capital investment must respond sufficiently elastic to tax incentives, or the technological advantage of multinational firms (i.e., $1/\kappa$) must not be too large. In these cases, the expansion of the tax base via additional capital investment overcompensates the loss in tax revenue from subsidizing existing capital via some deductibility of royalty payments. We summarize this result as

Proposition 3a *In a non-cooperative symmetric Nash equilibrium where internal debt cannot be used for tax purposes and thin capitalization rules are not available ($\lambda_i = 0$), the government will set the deductibility rate for royalties inefficiently high ($\mu_i^* > 0$) whenever (i) there is a positive arm's-length royalty payment, i.e., $R_i^b > 0$, and (ii) tax competition is sufficiently strong, i.e., $\kappa n \varepsilon_{kt} > \varepsilon_{\alpha t}$.*

If the government decides to set its royalty tax below the efficient level under cooperation, the optimal deductibility rate $\mu_i > 0$ follows from (see Appendix A.5)

$$\mu_i = \kappa n \; \frac{\frac{\Delta_k}{R_i^*}\varepsilon_{k\mu}}{\varepsilon_{\alpha t}(1-\varepsilon_{Rk}\;\varepsilon_{k\mu}) + \varepsilon_{R\mu}(1-\frac{\varepsilon_{Rk}\;\varepsilon_{k\mu}}{k_i})}. \tag{35}$$

where $\varepsilon_{k\mu} \equiv \frac{\partial k_i}{\partial \mu_i}\frac{\mu_i}{k_i} \geq 0$ is the capital elasticity with respect to tax deductibility of royalty payments μ and $\varepsilon_{R\mu} \equiv \frac{\partial R_i^{a*}}{\partial \mu_i}\frac{\mu_i}{R_i^*} > 0$ represents the elasticity of royalty payments with respect to their deductibility rate.

The government allows for deductibility of royalties in order to induce higher capital investment and benefit from higher tax revenue Δ_k per unit of newly installed capital (see the numerator). The downside of such a policy is once more that existing capital also becomes subsidized. These windfall gains are more costly, the higher the original underprovision problem is (measured via $\varepsilon_{\alpha t}$ once more). In addition, allowing for deductibility fosters profit shifting which reduces tax revenue further. Both negative effects are mitigated by the fact that higher capital investment reduces the arm's-length royalty rate per unit of capital. This is captured by the two terms in parentheses in the denominator. The deductibility rate will be the lower the more responsive abusive royalty payments react to an increase in the deductibility rate, that is the higher is $\varepsilon_{R\mu} > 0$. As in the case where only the thin capitalization rule can be used, there is no need to differentiate between multinational and domestic firms if the technological advantage of multinationals is so large that domestic firms effectively do not have a share in overall production. Hence, the deductibility rate on royalties will be set to zero if $\kappa \to 0$. We summarize these findings as

Proposition 3b *The optimal deductibility rate for royalties trades off tax-revenue gains from attracting additional capital against losses in revenue from higher profit shifting and subsidizing existing investment.*

If the multinationals could not use their intellectual property for profit shifting, only the tax-competition motive would be present and the standard result on withholding taxes (e.g., Bucovetsky and Wilson, 1991) applied.

4.3 Combining thin capitalization rules and royalty taxation

Finally, we will derive the optimal setting of royalty taxes and thin capitalization rules when both instruments are available and can be chosen simultaneously. Thereby, we will make use of the fact that both instruments are linearly dependent when it comes to attracting mobile capital. From equations (12) and (13) follows $\frac{\partial k_i}{\partial \lambda_i} = \frac{t_i}{R_i^*}\frac{\partial k_i}{\partial \mu_i} > 0$.

By applying this relationship in the first-order condition (27) for the optimal thin capitalization rule λ_i and using (27) then in the first-order condition (28) for the optimal deductibility rate μ_i, straightforward rearrangements lead to (see Appendix A.6)

$$\frac{\partial u(x_i, g_i)}{\partial \mu_i} \leq 0 \quad \Rightarrow \quad -u_g \mu_i \frac{\partial R_i^{a*}}{\partial \mu_i} \leq 0 \quad \Rightarrow \quad \mu_i^* = 0. \tag{36}$$

Consequently, the optimal deductibility rate is always zero, the optimal royalty tax rate meets the corporate tax rate, i.e., $\tau_i^* = t_i^*$, and the unilaterally chosen policy under tax competition meets the efficient level under coordinated policies. If the government does not face tax-competition incentives to use its thin capitalization rule (i.e., if $\frac{\partial u(x_i,g_i)}{\partial \lambda_i} < 0$), it does not want to grant any deductibility for royalties either, and $\mu_i^* = 0$ results as a corner solution. Whenever the government uses its thin capitalization rule to attract mobile capital (i.e., if $\frac{\partial u(x_i,g_i)}{\partial \lambda_i} = 0$ and $\lambda_i^* > 0$), there is also an interior solution for the deductibility rate of royalty payments. But, this interior solution is still strict non-deductibility of all royalty payments, that is, $\mu_i^* = 0$.

Strict non-deductibility implies that the multinationals will not engage in abusive transfer pricing so that $\mu_i^* = R_i^{a*} = 0$. Inserting this in the first-order condition (27) and assuming an interior solution for now, the optimal thin capitalization rule can be characterized by the ratio of debt-to-equity financing as (see Appendix A.7)

$$\frac{\alpha_i^* + \lambda_i^*}{1 - \lambda_i^* - \alpha_i^*} = \frac{\varepsilon_{kd}}{\varepsilon_{\alpha t}} \kappa n, \tag{37}$$

where we made use of the measure for public-good underprovision (26) and where, as before, $\varepsilon_{kd} > 0$ and $\varepsilon_{\alpha t} > 0$ represent the elasticity of capital investment with respect to debt financing, and the one of external leverage with respect to capital taxation, respectively.

Underprovision of public goods, triggered by external leverage α_i^* and captured by the leverage elasticity $\varepsilon_{\alpha t}$ in the denominator of equation (37), makes the tax-revenue loss from subsidizing existing capital investment via a relaxed thin capitalization rule expensive. Therefore, a larger leverage elasticity tightens the thin capitalization rule and increases λ_i^*. In contrast, the capital elasticity ε_{kd} measures how successful internal debt financing is in attracting mobile capital and enlarging the tax base. Thus, a larger capital elasticity increases λ_i^* and fosters tax competition via thin capitalization rules. The induced discrimination between domestic and multinational firms becomes more important the more effective capital units (κn) are provided by immobile firms. In contrast, if multinational firms have a huge technological advantage so that production by domestic firms becomes negligible ($\kappa \to 0$), there is no need to discriminate between firms, and the capital tax rate becomes the only instrument for tax competition, once again.

Put together, royalty taxation only focuses on profit shifting and shuts it fully down by denying any deductibility of royalty payments. This also avoids any problem of evaluating what the fair arm's-length payment on the intellectual property is. Hence, all problems raised by intangibles and the digital economy, as discussed in OECD (2015b), are avoided. The price for this simplification is an investment distortion, see equation (13), because the royalty tax falls on real costs R_i^b. However, this distortion can be fully neutralized by relaxing the thin capitalization rule and granting a higher deductibility of internal debt. Importantly, the arm's-length component is not required to determine the optimal thin capitalization rule either, cf. equation (37). The leverage elasticity $\varepsilon_{\alpha t}$ does not depend on royalty payments, and the capital elasticity ε_{kd} does not directly depend on royalties and can be determined empirically.

In combination, profit shifting is prevented, but an efficient position in the competition for mobile capital is still preserved. Indeed, comparing the optimal thin capitalization rule (37) to the rule in equation (32), which is set if there is no royalty tax available, we see that the revenue-reducing effect of royalty payments does not enter in (37). Thus, an optimal thin capitalization rule with royalty taxation will be laxer than one in absence of royalty taxation.

When does the government want to use its thin capitalization rule for tax competition? When we evaluate the first-order condition (27) at $\mu_i^* = 0$ and utilize the underprovision measure (26), we find that (see Appendix A.8)

$$\left.\frac{\partial u(x_i, g_i)}{\partial \lambda_i}\right|_{\lambda_i=0,\mu_i=0} > 0 \quad \Rightarrow \quad \varepsilon_{\alpha t} < \kappa n \cdot \varepsilon_{kt}. \tag{38}$$

The thin capitalization rule will be inefficiently lax whenever the underprovision of public goods is not too severe; the condition is identical to the one for a lax deductibility rate in the restricted equilibrium without internal debt, cf. equation (34).

We summarize our main findings in this subsection as

Proposition 4 *In a symmetric Nash equilibrium with tax competition and a complete set of instruments, the optimal royalty tax rate targets profit shifting and always meets its efficient level $\tau_i^* = t_i^* > 0$. In contrast, the thin capitalization rule is set inefficiently lax ($\lambda_i^* > 0$) in order to accommodate tax-competition incentives, whenever external leverage is sufficiently tax-inelastic with $\varepsilon_{\alpha t} < \kappa n \cdot \varepsilon_{kt}$. The capital tax rate t_i^* is inefficiently low.*

Denying tax deducibility for royalty payments (i.e., $\mu_i^* = 0$), eliminates profit shifting via the intellectual property. All competition for mobile capital is relegated to the thin capitalization rule which is set inefficiently lax, whenever the underprovision of public goods is not too severe and capital investment reacts sufficiently on tax incentives ($\varepsilon_{\alpha t} < \kappa n \cdot \varepsilon_{kt}$). Thereby, compensating for the negative mechanical effect that the royalty tax exerts on the extensive margin of capital investment weakens the thin capitalization rule further.

Our analysis and Proposition 4 challenge the traditional view that withholding taxes are highly distortive and face a race to the bottom under tax competition. The crucial point here is that governments face both competition for physical capital and shifting of paper profits. Then, it is optimal to devote the withholding tax to profit shifting and to concentrate all competition for mobile capital in the thin capitalization rule. The policy implications are twofold. First, the ban of royalty taxes in many double tax treaties and in the EU Interest and Royalty Directive is counterproductive and welfare-deteriorating. It prevents countries from insulating themselves against intensified tax competition for paper profits, see the emergence of patent boxes with preferential tax treatment of income from intellectual property (cf. Table 1). With enacting a patent box with a 12.5% tax rate and no nexus, the U.S., in December 2017, made another major step towards intensified paper-profit competition.[23] After Brexit, the U.K., which already hosts an aggressive patent box with a 10% tax rate, might follow (Economist, 2017; Shaxson, 2017). Therefore, counter-policies will become even more important in the future and royalty taxes seem to provide a simple and efficient instrument that additionally overcomes the problem of identifying arm's-length payments in a digital economy (OECD, 2015b). Second, for royalty taxes to be efficient, it is necessary to allow for more internal debt shifting, viz., weaker thin capitalization rules. While there are good reasons for the OECD's (2015a, Action 4) push for stricter regulation of thin capitalization, the results in this subsection indicate that some leeway needs to remain and overshooting in regulation needs to be avoided.

5 Conclusion

This paper analyzes a model with both profit shifting via royalty payments on intellectual property and international competition for mobile capital. Two symmetric countries host immobile domestic and mobile multinational firms and their set of policy instruments consists of statutory capital tax rates, thin capitalization rules, and withholding taxes on royalties. Thin capitalization rules are used to limit profit shifting through internal debt. Withholding taxes on royalties target profit shifting through abusive transfer prices on royalty payments. All three instruments can be used for tax competition.

We find that under tax competition, both statutory capital tax rates and thin capitalization rules are set inefficiently low. In contrast, unilaterally optimized royalty taxes are chosen at their Pareto-efficient level and set equal to the capital tax rate. Consequently, all tax competition by a positive discrimination of multinationals, relative to domestic firms, takes place via thin capitalization rules. Royalty taxation only focuses on profit shifting in intellectual property and eliminates any incentive for transfer pricing. As the royalty tax also falls on the arm's-length payment for the intellectual property, however, it causes a negative investment effect. But, this effect is fully neutralized by an additi-

[23] See H.R. 1, 115th Congress, "An Act to provide for reconciliation pursuant to titles II and V of the concurrent resolution on the budget for fiscal year 2018." (2017)

onal weakening of the thin capitalization rule so that the country remains competitive and royalty taxation effectively does not distort investment.

This result surprises as, in general, one may expect that optimal withholding taxes on royalties also face the traditional 'race to the bottom' under tax competition for mobile capital and distort factor allocation. Thus, our findings question both the standard view that withholding taxes are always inefficient and the ban of royalty taxes in double tax treaties and the EU Interest and Royalty Directive. The crucial differences to standard models on withholding taxes are that we incorporate profit shifting in intellectual property, which effectively can only be targeted by royalty taxes, and analyze withholding taxes in combination with thin capitalization rules. Weakening thin capitalization rules can compensate for all disadvantageous effects of royalty taxation.

The policy implications of our results are strong. The ban of royalty taxes in double tax treaties and particularly in the EU Interest and Royalty Directive appears detrimental to both national and supra-national welfare. At the same time, thin capitalization regulation should not become too restrictive. With the combination of tough royalty taxes and weakened thin capitalization rules, countries would have an effective and efficient tool to insulate themselves against competition for paper profits without harming their position in the competition for mobile real investment. Since competition for paper profits on intellectual property seems to intensify (see, for example, the new tax-aggressive patent box in the U.S. tax code since 2018), the availability of such a tool is likely to become even more important in the future. Furthermore, our results suggest a simple fix to the problem of determining the correct arm's-length payment on intellectual property in a digital economy (OECD, 2015b). In order to specify the appropriate regulation of transfer payments, knowledge about this component would be necessary, but is hardly available. The use of royalty taxes and denying any deductibility of royalties circumvents this problem as the arm's-length component does not matter for the withholding tax. It is not necessary for determining the optimal thin capitalization rules either.

Although we believe that our analysis provides a strong case in favor of royalty taxes (combined with relaxed thin capitalization rules), we want to stress that our model rests on a few simplifications that have to be taken into account for the implementation of royalty taxes. First, our analysis focused on traditional safe harbor rules while many countries, e.g., in the EU, follow the OECD proposal in Action 4 of the BEPS Action Plan (OECD, 2015a) and implement earnings stripping rules now. The latter approach of restricting interest payments relative to an earnings measure cannot be easily incorporated into the standard model of tax competition. But, in our context, the main role of a (weak) thin capitalization rule is to attract capital investment and compensate for royalty tax payments that fall on the arm's-length remuneration of intellectual property. These aims can be achieved both by safe harbor rules and earnings stripping rules so that we are optimistic that our results carry over to other settings.

Second, domestic firms also use patents, licensed by other firms, and might have cross-border royalty payments that are not related to profit shifting. As these national firms cannot use internal debt for tax planning, they cannot be compensated by a weak thin capitalization rule and would face a substantial tax payment on real costs. Third, in a static model, it is rational for a single country to treat innovation as exogenous and to neglect R&D investment in its policy considerations. In a dynamic context, denying royalty deductions and taxing arm's-length payments on intellectual property might, however, have adverse effects on R&D activities in multinationals and innovation in general.

An elegant way to circumvent these problems might be to implement the royalty tax in form of a royalty stripping rule which would be designed similarly to an earnings stripping rule for interest deductions. Legally, the advantage of defining some allowance for royalty payments and introducing a ceiling relative to an earnings measure (e.g., EBITDA) would be to bypass the ban of royalty taxes in double tax treaties and the EU Interest and Royalty Directive.[24] Economically, defining the ceiling such that the average royalty payment of domestic firms to third parties remains tax deductible avoids burdening these firms. Finally, a threshold relative to earnings allows productive and innovative firms to deduct a larger compensation for their effective intellectual property. This should mitigate negative effects on R&D investment and innovation. Modeling the details of such a royalty stripping rule, in particular how to avoid double taxation of royalty income, as well as the impact on R&D investment and innovation (i.e., technological change) are beyond the scope of this paper, however, and constitute interesting avenues for future research.

[24]For example, since January 1, 2018, Germany has a provision that restricts the deductibility of royalty payments, see §4j, German Income Tax Act. But, it becomes effective only for payments to low-tax countries and the limitation is calculated by a relative tax difference. Thus, it does neither correspond to our royalty tax, nor to a limitation rule relative to earnings.

A Appendix

Throughout the Appendix we make use of the following elasticity definitions:

1. Elasticity of external leverage with respect to the capital tax: $\varepsilon_{\alpha t} \equiv \frac{\partial \alpha_i^*}{\partial t_i} \frac{t_i}{1-\lambda_i-\alpha_i^*}$
2. Elasticity of capital with respect to the capital tax (positively defined): $\varepsilon_{kt} \equiv -\frac{\partial k_i}{\partial t_i} \frac{t_i}{k_i}$
3. Elasticity of royalty payments with respect to capital investment (positively defined): $\varepsilon_{Rk} \equiv -\frac{\partial R_i^b}{\partial k_i} \frac{k_i}{R_i^*}$
4. Elasticity of capital demand with respect to total leverage $d_i = \alpha_i^* + \lambda_i$: $\varepsilon_{kd} \equiv \frac{\partial k_i}{\partial \lambda_i} \frac{\alpha_i^* + \lambda_i}{k_i}$
5. Elasticity of capital demand with respect to tax deductibility of royalty payments: $\varepsilon_{k\mu} \equiv \frac{\partial k_i}{\partial \mu_i} \frac{\mu_i}{k_i}$
6. Elasticity of royalty payments with respect to their deductibility rate: $\varepsilon_{R\mu} \equiv \frac{\partial R_i^{a*}}{\partial \mu_i} \frac{\mu_i}{R_i^*}$

A.1 Proof of Proposition 1

Aggregate welfare is $W^c = u(x_i, g_i) + u(x_j, g_j)$. The first-order condition with respect to the statutory capital tax then reads

$$\frac{\partial W^c}{\partial t_i} = u_x \left(\frac{\partial x_i}{\partial t_i} + \frac{\partial x_j}{\partial t_i} \right) + u_g \left(\frac{\partial g_i}{\partial t_i} + \frac{\partial g_j}{\partial t_i} \right) = 0$$

which gives, using eqs. (16a), (17a), (18a), and (20a),

$$\frac{u_g}{u_x} = \frac{\kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*)}{\kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - (1+\kappa n) t_i^* \frac{\partial \alpha_i^*}{\partial t_i}} > 1. \tag{A.1}$$

The effect of a change in the thin capitalization rule on welfare is

$$\frac{\partial W^c}{\partial \lambda_i} = u_x \left(\frac{\partial x_i}{\partial \lambda_i} + \frac{\partial x_j}{\partial \lambda_i} \right) + u_g \left(\frac{\partial g_i}{\partial \lambda_i} + \frac{\partial g_j}{\partial \lambda_i} \right) = (u_x - u_g) t_i < 0$$

where we have used eqs. (16b), (17b), (18b), (20b), and $u_x < u_g$ according to (A.1). The thin capitalization rule λ_i is, therefore, optimally set to zero. The effect of a change in the deductibility rate for royalties on welfare is

$$\frac{\partial W^c}{\partial \mu_i} = u_x \left(\frac{\partial x_i}{\partial \mu_i} + \frac{\partial x_j}{\partial \mu_i} \right) + u_g \left(\frac{\partial g_i}{\partial \mu_i} + \frac{\partial g_j}{\partial \mu_i} \right) = (u_x - u_g) R_i^* - u_g \mu_i \frac{\partial R_i^{a*}}{\partial \mu_i} < 0$$

where we have used eqs. (16c), (17c), (18c), (20c), and again $u_x < u_g$ according to (A.1). The deductibility rate for royalties is optimally set to zero, that is, the withholding tax on royalties is optimally set to its maximum, i.e., $\tau_i^c = t_i^c$. Using $\lambda_i^c = 0$ and $\mu_i^c = 0$ we can rewrite (A.1) as

$$\frac{u_g}{u_x} = \frac{1}{1 - \frac{\partial \alpha_i^*}{\partial t_i} \frac{t_i^*}{1-\alpha_i^*}} > 1$$

which replicates the result of Haufler and Runkel (2012; Proposition 1). □

A.2 Derivation of Eqs. (30) and (31)

With (16b) and (18b) we rewrite $\left.\frac{\partial u(x_i,g_i)}{\partial \lambda_i}\right|_{\lambda_i=0,\mu_i=t_i}$ as

$$\left.\frac{\partial u(x_i,g_i)}{\partial \lambda_i}\right|_{\lambda_i=0,\mu_i=t_i} = u_x\left(t_i + \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right) + u_g\left(-t_i - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i} + \Delta_k \frac{\partial k_i}{\partial \lambda_i}\right).$$

Using the first-order condition for the corporate tax rate, i.e.,

$$\frac{u_g}{u_x} = \frac{\kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}}{\kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i} - (1+\kappa n)t_i \frac{\partial \alpha_i^*}{\partial t_i} + \Delta_k \frac{\partial k_i}{\partial t_i}} > 1$$

we can rewrite $\left.\frac{\partial u(x_i,g_i)}{\partial \lambda_i}\right|_{\lambda_i=0,\mu_i=t_i}$ as

$$u_x\left(t_i+\mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right) + \frac{u_x\left(\kappa n(1-\alpha_i^*)+1-\alpha_i^*-\mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}\right)}{\Gamma}\left(-t_i-\mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}+\Delta_k \frac{\partial k_i}{\partial \lambda_i}\right)$$

where $\Gamma = \kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i} - (1+\kappa n)t_i \frac{\partial \alpha_i^*}{\partial t_i} + \Delta_k \frac{\partial k_i}{\partial t_i} > 0$ by the first-order condition for the corporate tax rate. Applying $\lambda_i = 0$ and $\mu_i = t_i$ the tax wedge on capital becomes $\Delta_k = t_i(1-\alpha_i^* - R_i^*)$. Moreover, we use $k_i = 1 + \kappa n$ to rearrange the expression as

$$\frac{t_i u_x}{\Gamma}\left[\left(1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)\Gamma - \left(k_i(1-\alpha_i^*)-t_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}\right)\left(1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}-(1-\alpha_i^*-R_i^*)\frac{\partial k_i}{\partial \lambda_i}\right)\right].$$

Substituting for Γ and collecting terms, we can further write

$$\begin{aligned} &\frac{t_i u_x}{\Gamma}\left[-\left(1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)k_i t_i \frac{\partial \alpha_i^*}{\partial t_i} + (1-\alpha_i^*-R_i^*)t_i \frac{\partial k_i}{\partial t_i} + k_i(1-\alpha_i^*-R_i^*)(1-\alpha_i^*)\frac{\partial k_i}{\partial \lambda_i}\right] \\ = &\frac{t_i u_x}{\Gamma}\left[-\left(1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)k_i t_i \frac{\partial \alpha_i^*}{\partial t_i} - \kappa n t_i(1-\alpha_i^*-R_i^*)\frac{\partial k_i}{\partial t_i}\right], \end{aligned}$$

as $\frac{\partial k_i}{\partial t_i} = -\frac{1-\alpha_i^*}{t_i}\frac{\partial k_i}{\partial \lambda_i}$ and $k_i = 1 + \kappa n$. Substituting for the elasticity expressions, we can also write

$$\frac{t_i k_i u_x}{\Gamma}\left[-(1-\alpha_i)\left(1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)\varepsilon_{\alpha t}+\kappa n(1-\alpha_i^*-R_i^*)\varepsilon_{kt}\right]$$
$$= \frac{t_i k_i(1-\alpha_i^*-R_i^*)\kappa n u_x}{\Gamma}\left(\varepsilon_{kt}-\frac{1-\alpha_i^*}{1-\alpha_i^*-R_i^*}\frac{\varepsilon_{\alpha t}}{\kappa n}+\frac{R_i^*}{1-\alpha_i^*-R_i^*}\varepsilon_{Rk}\varepsilon_{kt}\frac{\varepsilon_{\alpha t}}{\kappa n}\right).$$

Since $\Gamma > 0$, we have $\frac{\partial u(x_i,g_i)}{\partial \lambda_i}\Big|_{\lambda_i=0,\mu_i=t_i} > 0$ if and only if

$$\varepsilon_{kt} - \frac{1-\alpha_i^*}{1-\alpha_i^*-R_i^*}\frac{\varepsilon_{\alpha t}}{\kappa n} + \frac{R_i^*}{1-\alpha_i^*-R_i^*}\varepsilon_{Rk}\varepsilon_{kt}\frac{\varepsilon_{\alpha t}}{\kappa n} > 0.$$

Rearranging and collecting terms lead to a compact condition

$$\varepsilon_{kt} > \frac{(1-\alpha_i)\frac{\varepsilon_{\alpha t}}{\kappa n}}{1-\alpha_i-R_i(1-\varepsilon_{Rk}\frac{\varepsilon_{\alpha t}}{\kappa n})}.$$

A.3 Derivation of Eq. (32)

Analogously to Appendix A.2, we use (16b), (18b), and the first-order condition for the corporate tax rate, i.e., (25), to rewrite $\frac{\partial u(x_i,g_i)}{\partial \lambda_i}\Big|_{\lambda_i>0,\mu_i=t_i}$ as

$$u_x\left(t_i+\mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)+\frac{u_x\left(\kappa n(1-\alpha_i^*)+1-\lambda_i-\alpha_i^*-\mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}\right)\left(\Delta_k\frac{\partial k_i}{\partial \lambda_i}-t_i-\mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)}{\Gamma}$$

where $\Gamma = \kappa n(1-\alpha_i^*)+(1-\lambda_i-\alpha_i^*)-\mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}-(1+\kappa n)t_i\frac{\partial \alpha_i^*}{\partial t_i}+\Delta_k\frac{\partial k_i}{\partial t_i} > 0$. Applying $\mu_i = t_i$, and $\Delta_k = t_i(1-\lambda_i-\alpha_i^*-R_i^*)$, substituting for Γ and collecting terms, we can rewrite the expression as

$$\frac{t_i u_x}{\Gamma}\left[-\left(1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)k_i t_i\frac{\partial \alpha_i}{\partial t_i}+(1-\lambda_i-\alpha_i^*-R_i^*)\left(t_i\frac{\partial k_i}{\partial t_i}+k_i(1-\lambda_i-\alpha_i^*)\frac{\partial k_i}{\partial \lambda_i}\right)\right]$$
$$= \frac{t_i k_i(1-\lambda_i-\alpha_i^*)u_x}{\Gamma}\left[-\left(1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)\frac{t_i}{1-\lambda_i-\alpha_i^*}\frac{\partial \alpha_i}{\partial t_i}+\kappa n\frac{1-\lambda_i-\alpha_i^*-R_i^*}{\alpha_i^*+\lambda_i}\frac{\alpha_i^*+\lambda_i}{k_i}\frac{\partial k_i}{\partial \lambda_i}\right],$$
$$= \frac{t_i k_i(1-\lambda_i-\alpha_i^*)\kappa n u_x}{\Gamma}\left[-\left(1+\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)\frac{\varepsilon_{\alpha t}}{\kappa n}+\frac{1-\lambda_i-\alpha_i^*-R_i^*}{\alpha_i^*+\lambda_i}\varepsilon_{kd}\right]=0,$$

as $\frac{\partial k_i}{\partial t_i} = -\frac{1-\lambda_i-\alpha_i^*}{t_i}\frac{\partial k_i}{\partial \lambda_i}$.

Therefore, the optimal share of debt financing $d_i = \alpha_i^* + \lambda_i$, relative to taxable profit per unit of capital, and implicitly the optimal level of deductible internal debt λ_i^* is given by the elasticity rule

$$\frac{\alpha_i^* + \lambda_i}{1 - \lambda_i - \alpha_i^* - R_i^*} = \frac{\varepsilon_{kd}}{\left(1 + \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \lambda_i}\right)\frac{\varepsilon_{\alpha t}}{\kappa n}} > 0.$$

A.4 Derivation of Eqs. (33) and (34)

Using (16c) and (18c), we can rewrite $\left.\frac{\partial u(x_i,g_i)}{\partial \mu_i}\right|_{\lambda_i=0,\mu_i=0} > 0$ as

$$u_x\left(R_i^* + \mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}\right) - u_g\left(\mu_i\frac{\partial R_i^{a*}}{\partial \mu_i} - \Delta_k\frac{\partial k_i}{\partial \mu_i}\right) \quad > \quad 0.$$

Applying $\lambda_i = 0$, $\mu_i = 0$ as well as the definition of the tax wedge, i.e., $\Delta_k = (1-\alpha_i^*)t_i$ leads to

$$-\frac{u_g - u_x}{u_g}R_i^* + (1-\alpha_i^*)t_i\frac{\partial k_i}{\partial \mu_i} > 0.$$

Taking into account that $R_i^{a*} = 0$ if $\mu_i = 0$ and, therefore, $R_i^* = R_i^b$ as well as $\frac{\partial k_i}{\partial \mu_i} = -\frac{R_i^b}{1-\alpha_i^*}\frac{\partial k_i}{\partial t_i}$, we can rewrite the condition as

$$R_i^b\left(k_i\varepsilon_{kt} - \frac{u_g - u_x}{u_g}\right) > 0$$

which is (33). For a positive arm's-length royalty payment $R_i^b > 0$ the condition turns into

$$k_i\varepsilon_{kt} - \frac{u_g - u_x}{u_g} > 0.$$

Using eq. (26) gives

$$k_i\varepsilon_{kt} - \frac{k_i t_i\frac{\partial \alpha_i^*}{\partial t_i} - (1-\alpha_i^*)\frac{\partial k_i}{\partial t_i}t_i}{(1+\kappa n)(1-\alpha_i^*)} > 0.$$

Substituting $\varepsilon_{\alpha t}$, ε_{kt}, and $k_i - 1 = \kappa n$ gives eq. (34).

A.5 Derivation of Eq. (35)

With (16c) and (18c) we rewrite $\left.\frac{\partial u(x_i,g_i)}{\partial \mu_i}\right|_{\lambda_i=0} = 0$ as

$$u_x\left(R_i^* + \mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}\right) + u_g\left(-R_i^* - \mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i} - \mu_i\frac{\partial R_i^{a*}}{\partial k_i} + \Delta_k\frac{\partial k_i}{\partial \mu_i}\right) = 0.$$

Using the first-order condition for the corporate tax rate, i.e.,

$$\frac{u_g}{u_x} = \frac{\kappa n(1-\alpha_i^*) + (1-\lambda_i-\alpha_i^*) - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}}{\Gamma} > 1$$

where $\Gamma = k_i(1-\alpha_i^*) - \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i} - (1+\kappa n)t_i\frac{\partial \alpha_i^*}{\partial t_i} + \Delta_k \frac{\partial k_i}{\partial t_i}$ (as $\lambda_i = 0$), we can rewrite $\left.\frac{\partial u(x_i,g_i)}{\partial \mu_i}\right|_{\lambda_i=0} = 0$ as

$$\frac{u_x}{\Gamma}\left[\left(R_i^*+\mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}\right)\Gamma - \left(R_i^*+\mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}+\mu_i\frac{\partial R_i^{a*}}{\partial \mu_i}-\Delta_k\frac{\partial k_i}{\partial \mu_i}\right)\left(k_i(1-\alpha_i^*)-\mu_i^*\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i}\right)\right]=0$$

where $\Delta_k = t_i(1-\alpha_i^*) - \mu_i R_i^*$. Substituting Γ we can rewrite

$$\left(R_i^*+\mu_i^*\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}\right)\left(-k_i t_i\frac{\partial \alpha_i^*}{\partial t_i}+\Delta_k\frac{\partial k_i}{\partial t_i}\right)-\left(\mu_i\frac{\partial R_i^a}{\partial \mu_i}-\Delta_k\frac{\partial k_i}{\partial \mu_i}\right)\left(k_i(1-\alpha_i^*-\mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial t_i})\right)=0.$$

Substituting the elasticities, the first-order condition reads

$$-R_i^*(1-\alpha_i^*)k_i\left[(1-\varepsilon_{Rk}\varepsilon_{k\mu})\left(\varepsilon_{\alpha t}+\frac{\varepsilon_{k\mu}}{\mu R_i^*}\Delta_k\right)+\left(\varepsilon_{R\mu}-\Delta_k\frac{k_i}{\mu_i R_i^*}\varepsilon_{k\mu}\right)\left(1-\frac{\varepsilon_{Rk}\varepsilon_{k\mu}}{k_i}\right)\right]=0.$$

For $R_i^* > 0$ (which is the case with $\mu_i > 0$) the first-order condition simplifies to

$$(1-\varepsilon_{Rk}\varepsilon_{k\mu})\left(\varepsilon_{\alpha t}+\frac{\varepsilon_{k\mu}}{\mu R_i^*}\Delta_k\right)+\left(\varepsilon_{R\mu}-\Delta_k\frac{k_i}{\mu_i R_i^*}\varepsilon_{k\mu}\right)\left(1-\frac{\varepsilon_{Rk}\varepsilon_{k\mu}}{k_i}\right)=0.$$

Rearranging and using $1-k_i = -\kappa n$ gives

$$\mu_i\left[(1-\varepsilon_{Rk}\varepsilon_{k\mu})\varepsilon_{\alpha t}+\varepsilon_{R\mu}\left(1-\frac{\varepsilon_{Rk}\varepsilon_{k\mu}}{k_i}\right)\right]-\kappa n\Delta_k\frac{1}{R_i^*\varepsilon_{k\mu}}=0$$

which directly gives eq. (35).

A.6 Derivation of Eq. (36)

We rewrite the first-order condition for the thin capitalization rule, i.e., (27), by using $\frac{\partial k_i}{\partial \lambda_i} = \frac{t_i}{R_i^*}\frac{\partial k_i}{\partial \mu_i}$ and multiplying with R_i^*/t_i as

$$(u_x-u_g)\left(R_i^*+\mu_i\frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}\right)+u_g\Delta_k\frac{\partial k_i}{\partial \mu_i}=0$$

Taking this into account, we can rewrite the first-order condition for the optimal deductibility rate, i.e., $(u_x - u_g)\left(R_i^* + \mu_i \frac{\partial R_i^b}{\partial k_i}\frac{\partial k_i}{\partial \mu_i}\right) - u_g\left(\mu_i \frac{\partial R_i^{a*}}{\partial \mu_i} - \Delta_k \frac{\partial k_i}{\partial \mu_i}\right) \leq 0$, as

$$-u_g \mu_i \frac{\partial R_i^{a*}}{\partial \mu_i} \leq 0.$$

A.7 Derivation of Eq. (37)

With $\mu_i = 0$ the first-order condition for the thin capitalization rule, i.e., (27), reads

$$(u_x - u_g)t_i + u_g(1 - \lambda_i - \alpha_i^*)t_i \frac{\partial k_i}{\partial \lambda_i} = 0$$

which is equivalent to

$$-\frac{u_g - u_x}{u_g} + (1 - \lambda_i - \alpha_i^*)\frac{\partial k_i}{\partial \lambda_i} = 0.$$

Using eq. (26) we can rewrite

$$\frac{(1 - \lambda_i - \alpha_i^*)t_i \frac{\partial k_i}{\partial t_i} - k_i(1 - \alpha_i^*)\varepsilon_{\alpha t}}{\kappa n(1 - \alpha_i^*) + (1 - \lambda_i - \alpha_i^*)} + (1 - \lambda_i - \alpha_i^*)\frac{\partial k_i}{\partial \lambda_i} = 0.$$

With $\frac{\partial k_i}{\partial t_i} = -\frac{1-\lambda_i-\alpha_i^*}{t_i}\frac{\partial k_i}{\partial \lambda_i}$ and $\frac{\partial k_i}{\partial \lambda_i} = \varepsilon_{kd}\frac{k_i}{\alpha_i^*+\lambda_i}$ rearrangement gives (37).

A.8 Derivation of Eq. (38)

Using (27) we can rewrite $\left.\frac{\partial u(x_i,g_i)}{\partial \lambda_i}\right|_{\lambda_i=0,\mu_i=0} > 0$ as

$$(u_x - u_g)t_i + u_g(1 - \alpha_i^*)t_i \frac{\partial k_i}{\partial \lambda_i} > 0.$$

Using eq. (26) it is

$$\frac{(1 - \alpha_i^*)t_i \frac{\partial k_i}{\partial t_i} - k_i(1 - \alpha_i^*)\varepsilon_{\alpha t}}{k_i(1 - \alpha_i^*)} + (1 - \alpha_i^*)\frac{\partial k_i}{\partial \lambda_i} > 0.$$

Substituting ε_{kt} and $\frac{\partial k_i}{\partial \lambda_i} = -\frac{t_i}{1-\alpha_i^*}\frac{\partial k_i}{\partial t_i}$ results in eq. (38) .

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Country	**CIT**[1]	**IP Box**	**WHT on Royalties**[2]	**TCR** type[3]	**TCR** ratio
Australia	30.0	-	30.0	SHR	1.5:1[4]
Austria	25.0	-	20.0	-	-
Belgium	34.0	5.1[5]	30.0	SHR	5:1[6]
Bulgaria	10.0	-	10.0	SHR	3:1[4]
Canada	26.7	-	25.0	SHR	1.5:1[4]
Chile	25.0	-	30.0	SHR	3:1[6]
Croatia	18.0	-	15.0	SHR	4:1[6]
Cyprus	12.5	2.5[7]	0.0	-	-
Czech Republic	19.0	-	15.0[8]	SHR	4:1[6]
Denmark	22.0	-	22.0	SHR/ESR	4:1/80% EBIT[9]
Estonia	20.0	-	10.0	-	-
Finland	20.0	-	20.0	ESR	25% EBITDA[6]
France	34.4	15.0-15.5	33.33	SHR/ESR	1.5:1/25% EBITDA[6,10]
Germany	30.2	-	15.0	ESR	30% EBITDA[4]
Greece	29.0	-	20.0	ESR	30% EBITDA[4]
Hungary	10.8[11]	4.5-9.0	0.0	SHR	3:1[4]
Iceland	20.0	-	20.0	-	-
Ireland	12.5	6.25	20.0	-	-
Israel	24.0	6.0	24.0	-	-
Italy	27.8	13.95	30.0[5]	ESR	30% EBITDA[4]
Japan	30.0	-	20.0	SHR/ESR	3:1/50% EBITDA[4,9]
Korea	24.2	-	20.0	SHR	2:1[4]
Latvia	15.0	-	0.0[12]	SHR	4:1[4]
Lithuania	15.0	-	10.0	SHR	4:1[6]
Luxembourg	27.1	5.76[13]	0.0	SHR	85:15[6]
Malta	35.0	0.0	0.0	-	-
Mexico	30.0	-	30.0	SHR	3:1[4]
Netherlands	25.0	5.0	0.0	-	-
New Zealand	28.0	-	15.0	SHR	60%/110%[9,14]
Norway	24.0	-	0.0	ESR	25% EBITDA[12]
Poland	19.0	-	20.0	SHR	1:1[6]
Portugal	29.5	11.5	25.0[15]	ESR	30% EBITDA[4]
Romania	16.0	-	16.0	SHR	3:1[4]
Slovak Republic	21.0	-	19.0[16]	ESR	25% EBITDA[6]
Slovenia	19.0	-	15.0	SHR	4:1[6]
Spain	25.0	10.0	24.0	ESR	-
Sweden	22.0	-	22.0	-	-
Switzerland	21.2	-	0.0	SHR	asset class specific
Turkey	20.0	-	20.0	SHR	3:1[6]
United Kingdom	19.0[17]	10.0	20.0[18]	-	-
United States	38.9	-	30.0	SHR	1.5:1

Table 1: Corporate tax rates, Intellectual Property (IP) Box rates, and withholding taxes (WHT) on royalties for European countries in 2017.
Sources: Corporate tax rates: Eurostat (2017) and OECD (2017b); IP Box rates: PWC (2017a, 2017b); WHTs on royalties and TCRs: PWC (2017a) and EY (2017).

[1] Statutory corporate income tax rate. Combined tax rate, i.e., central and federal level. [2] WHT on royalties refer to general rates; special Double Taxation Treaty (DTT) may apply in addition.

[3] Safe harbor rule (SHR) or earnings stripping rule (ESR).

[4] Ratio refers to total debt.

[5] The 'old' Patent Box regime has been abolished as of 1July 2016 (grandfathered for five years) and has been replaced by an Innovation Income Deduction regime.

[6] Ratio refers to related party debt.

[7] According to the old system wich is grandfathered until 30 June 2021.

[8] 35.0% if payments are to countries with which no enforceable Double Taxation Treaty (DTT) or Tax Information Exchange Agreement (TIEA) exists.

[9] Refers to related party debt/total party debt; one violation suffices for deduction not to be granted.

[10] Both violations necessary for deduction not to be granted.

[11] Including the local business tax of maximum 2% that applies on the gross operating profit (turnover minus costs) and which is deductible from the CIT. In the typical case of a local tax of 2%, the total tax paid is 2 + (9 x 0.98) = 10.82.

[12] For companies located in a tax haven.

[13] According to the 'old' IP regime with grandfathering until 30 June 2021.

[14] Refers to 'inbound' thin capitalization/refers to worldwide group's debt percentage.

[15] Rate increases to 35% when the income is paid or due to entities resident in black-listed jurisdictions.

[16] 35% rate applies on payments to taxpayers from non-contracting states.

[17] Since 1. April 2017, before 20.0%.

[18] Some types of royalties are not subject to UK WHT, incl. film royalties and equipment royalties.