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# Cross-border loss offset can fuel tax competition*

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**Abstract**

Following recent court rulings, cross-border loss compensation for multinational firms has become a major policy issue in Europe. This paper analyzes the effects of introducing a coordinated cross-border tax relief in a setting where multinational firms choose the size of a risky investment and host countries non-cooperatively choose tax rates. We show that coordinated cross-border loss compensation may intensify tax competition when, following current international practice, the parent firm's home country bases the tax rebate for a loss-making subsidiary on its own tax rate. In equilibrium, tax revenue losses may thus be even higher than is implied by the direct effect of the reform. In contrast, tax competition is mitigated when the home country bases its loss relief on the tax rate in the subsidiary's host country.

**Keywords:** cross-border loss relief, tax competition, multinational firms

**JEL Classification:** H25, H32, F23

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# 1 Introduction

Since the 2005 *Marks and Spencer* ruling by the European Court of Justice (ECJ), cross-border loss compensation for multinational firms has become an important policy issue in Europe. In this case the ECJ decided that the U.K. based parent company should not be prevented from deducting the losses of its subsidiary in another EU member state, if all loss offset possibilities in the host country of the subsidiary have been exhausted and the losses in the host country are therefore 'final losses'.[1] As a result of this decision, it is likely that EU member states will be legally obliged to offer some form of cross-border tax relief to multinational businesses. This will constitute a major change in current international tax systems, as most EU countries currently permit loss offset only between entities that reside in the same jurisdiction.[2]

In the wake of the *Marks and Spencer* ruling, the European Commission has presented alternative measures for providing a coordinated cross-border loss relief, which differ primarily in whether the loss transfer from the subsidiary to the parent country would be temporary or definitive (see European Commission, 2006). Moreover, a full cross-border loss offset would be a direct implication of introducing a common consolidated corporate tax base (CCCTB) in the EU, which has recently been proposed by the European Commission (2011). The European Commission has also made it very clear that the introduction of cross-border loss compensation will *not* be accompanied by a harmonization of corporate tax rates. Therefore, an important question is whether, and how, the introduction of cross-border loss offset affects the degree of corporate tax competition in Europe.[3]

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[1]Nevertheless the ECJ permitted the U.K. government to deny the parent company of *Marks and Spencer* to deduct the losses incurred by its subsidiaries in Belgium, France and Germany from its positive taxable profits in the United Kingdom, because it did not consider the subsidiaries' losses to be 'final'. See Lang (2006) for a critical discussion of the ECJ's argument and Boulogne and Slavnic (2012) for a review of further court decisions that have clarified the interpretation of 'final losses'.

[2]At present, only four out of 27 EU member states (Austria, Denmark, France and Italy) apply tax schemes that permit a cross-border loss offset. See European Commission (2006).

[3]Corporate tax rates have fallen around the world, but the reduction has been particularly strong in Europe. Between 1995 and 2011, statutory corporate tax rates fell from 35% to 23% in the average of the EU-27 countries, and thus substantially more than in the non-EU member states of the OECD (see Eurostat 2011, Tables II-4.1 and II-4.2). Moreover, recent empirical work confirms the existence of strategic interaction in corporate tax setting among OECD countries in general, but in particular among the member states of the European Union (Devereux et al. 2008; Davies and Voget, 2008).

Despite its immediate policy relevance, the issue of cross-border loss compensation has so far received only very little attention in formal theoretical analyses. In this paper we contribute to filling this gap. We set up a symmetric two-country framework with two representative multinational enterprises (MNEs), which have their parent company in one of the countries and a subsidiary in the other. Both MNEs endogenously choose the size of a risky investment project. Hence our model captures the positive effects on multinationals' investment incentives, which are regarded as the major economic advantage of cross-border loss compensation (European Commission, 2006). The two governments non-cooperatively choose their tax rates to maximize domestic tax revenues when, following current international practice, the parent and the subsidiary of a multinational firm are taxed as independent entities. A particular focus of our analysis lies on the question of how the introduction of a coordinated form of cross-border loss offset will affect the governments' non-cooperative tax choices.

In our benchmark scenario, we assume that the parent country of the MNE bases the tax rebate on its own, *home country* tax rate. This corresponds to the current practice in those countries that offer a unilateral cross-border loss offset to resident MNEs (see footnote 2). Moreover, this scheme also underlies the European Commission's proposals for a coordinated cross-border tax relief. We show that when this scheme is applied, an increase in loss offset opportunities is likely to lead to falling tax rates in equilibrium, and hence to intensified tax competition, at least when loss offset is almost complete in equilibrium. The fall in equilibrium tax rates will in turn cause tax revenue losses for each country to be even larger than is implied by the direct effect of the reform. The reason underlying this result is simple: maintaining a high corporate tax rate becomes more costly under cross-border loss compensation, because it induces a higher tax rebate to the resident MNEs. We conclude that if this scheme is realized, introducing cross-border tax relief may further fuel the ongoing tax competition in Europe.

We then show that these negative side effects of cross-border loss compensation can be avoided under an alternative loss offset scheme where tax rebates are instead based on the tax rate in the subsidiary's *host country*. In contrast to the benchmark scheme, equilibrium tax rates will rise in this case following the reform. This is because an increase in each country's own tax rate is not accompanied by higher tax rebates to loss-making subsidiaries, but more generous loss offset provisions increase the investment of both MNEs, and thus the corporate tax bases of both governments. As a result, tax revenue losses will be smaller under this alternative scheme than is implied by the direct effect of enhanced cross-border loss compensation.

We analyze the robustness of our results by considering alternative government objective functions, an endogenous risk choice by the MNEs, and asymmetries between the competing countries. A particularly relevant setting arises when tax rates differ between countries. In this case the low-tax country would use a higher tax rate for loss rebates than for taxing positive profits in its territory, if the alternative system is applied universally. These redistributive effects can be avoided if each country applies the minimum of the tax rates in the parent and the subsidiary country to the losses incurred by the subsidiaries of its resident MNE. At the same time, this minimum rule will increase tax revenues in both countries, relative to the universal application of loss offset at the parent country's tax rate.

In the related literature, most theoretical and empirical studies have analyzed the effects of incomplete loss compensation in a closed economy setting. Theoretical analyses have focused mostly on the effects on investment and risk-taking decisions over time (e.g. Eeckhoudt et al., 1997; Pantheghini, 2001). The empirical literature has estimated the response of investment decisions to tax law asymmetries in a national setting, where positive profits are immediately taxed, whereas the tax value of a loss is can only be offset against positive incomes. This asymmetry has long been known to cause important, negative effects on the investment and risk-taking decisions of firms (Altshuler and Auerbach, 1990; Devereux et al., 1994).

In recent years, a few papers have analyzed loss offset in an international setting, but this literature is still very small. Among the empirical studies, Niemann and Treisch (2005) perform a Monte Carlo simulation analysis of the unilateral introduction of cross-border loss compensation in Austria (see footnote 2). Fuest et al. (2007) estimate the tax revenue effects of a switch to a complete cross-border loss offset under the CCCTB and find that, in the EU average, the corporate tax base falls by 20% as a result of this change. Dressler and Overesch (2013) analyze the impact of national loss offset regimes on MNEs' investment decisions and find mixed empirical support for the claim that generous loss offset provisions increase foreign direct investment.

Little is known, however, about how the introduction of cross-border loss offset shapes national corporate tax policies in a setting of international tax competition. Gérard and Weiner (2003, 2006) study this issue in a framework where MNEs are taxed under formulary apportionment, but they do not derive the full equilibrium changes in tax rates that follow from the reform. Closest to our paper is Kalamov and Runkel (2012), who derive the non-cooperative equilibrium when countries compete over both tax rates and the rate of cross-border loss offset. Their analysis uses a framework where countries base cross-border tax relief on their own tax rates. The authors find that the loss offset parameter is set to zero in the decentralized equilibrium when countries compete for real investment, but at a positive level when they compete to attract profits. The focus of our analysis is different, as we analyze the coordinated introduction of cross-border loss relief in a setting without profit shifting, and compare its effects under alternative loss offset regimes.

This paper is structured as follows. Section 2 introduces the framework for our analysis. Section 3 analyzes the effects of cross-border loss offset under the benchmark scheme, where the tax rebate is based on the tax rate in the parent's home country. Section 4 carries out the same analysis under the alternative loss offset scheme, where the tax rate of the subsidiary's host country is used for the tax rebate. Section 5 numerically compares the effects of loss offset under these two schemes. Section 6 analyzes several extensions of our baseline model. Section 7 concludes.

# 2 The framework

We consider a simple one-period model of two small countries, labeled 1 and 2. There are two representative MNEs, each with a parent company in one country and with a subsidiary in the other country. We label firm $i \in \{1, 2\}$ by the country in which the parent is located. Capital is perfectly mobile internationally and is supplied to the firms by the international capital market at an exogenous interest rate normalized to one. Finally, we assume in our baseline model that both firms and countries are perfectly symmetric. This excludes redistributive tax revenue effects that arise from tax rate differentials in a setting with cross-border loss compensation. Hence our benchmark model focuses squarely on the efficiency of firms' investment choices and governments' tax policies. Asymmetries between countries will be introduced in Section 6.3.

The two MNEs produce a homogeneous good for the world market, at a world price normalized to one. Production occurs with capital and a fixed factor, leading to the production function $f(k_i)$, with $f_k > 0$ and $f_{kk} < 0$. Hence pure profits arise from decreasing returns to scale in production.

Each MNE chooses the level $k_i$ of a risky investment. We assume, for simplicity, that this investment choice is made only by the subsidiary of firm $i$ (which is located in country $j$). In our baseline model, the investment is successful with an exogenous probability $p$, and unsuccessful with probability $(1-p)$.[4] These probabilities are identical for both MNEs. The parent company of each firm has an exogenous profit income equal to $\overline{G}_i$, which is sufficient to cover all possible losses of the subsidiary.[5] The MNEs behave in a risk-neutral way and maximize their net expected payoff.

Corporate income taxes are modeled as proportional taxes on profits. We assume that taxes are imposed by the source country of the investment.[6] This implies that country $j$ taxes the profits of the subsidiary of firm $i$, whereas the parent country of this firm, $i$, exempts this income from tax. Moreover, our analysis focuses on the effects that cross-border loss offset introduces under the current principle of *separate accounting*, where the parent and the subsidiary of a multinational firm are taxed as separate entities.[7]

The essential element of our model is the cross-border loss offset within the MNE. In our static model, losses incurred in one country cannot be offset against positive future profits in the same country. Hence the one-period model highlights the role of cross-border loss offset by effectively turning all losses incurred in one country into 'final losses' (see the introduction). Specifically, we postulate that if the investment project of firm $i$'s subsidiary is unsuccessful, then a fraction $0 \leq \alpha \leq 1$ of the losses can be deducted from the exogenous taxable profit income of the parent firm in country $i$. Our analysis thus focuses on a setting where the losses of a subsidiary can be deducted from positive profits made by the parent company. In practice this is the setting in which cross-border loss offset is most likely to be introduced, because it minimizes the possibility that the MNE can abuse loss offset provisions.[8]

[4]In Section 6.2 we allow firms to endogenously choose the success probability of the investment.

[5]Alternatively, we could assume that the parent company of each MNE takes the same decisions as the subsidiary. This, however, would reduplicate the decisions taken within each MNE, increasing the complexity of the analysis without adding additional insights.

[6]The source principle of taxation, where the profits of a subsidiary are tax-exempt in the country of the parent firm, is followed by the overwhelming majority of OECD countries. One of the few exceptions is the United States which is, however, also contemplating a switch to the exemption method. See Becker and Fuest (2010) for a recent discussion and analysis.

[7]In contrast, Gérard and Weiner (2003, 2006) base their analysis of cross-border loss offset on a system of *formulary apportionment*, where the total profits of a MNE are aggregated and then allocated to the various host countries according to a predetermined formula. It is well-known that the tax incentives for national governments can be very different under separate accounting and under formulary apportionment (see e.g. Riedel and Runkel, 2007).

[8]If a parent company's losses can be deducted from the profits of a subsidiary, then the MNE will

Finally, we focus on the coordinated introduction of cross-border loss offset in both countries. From a policy perspective, this is motivated by the developing legal standards in Europe, which are likely to introduce common rules for cross-border loss relief in the EU member states. From an analytical perspective, no country has an incentive to set a positive level of cross-border loss offset in our framework, corresponding to the empirical observation that only very few countries grant cross-border tax relief unilaterally (see footnote 2).[9]

# 3 Benchmark: Loss offset at the home country's tax

In this section, we analyze the implications of cross-border loss-offset under the benchmark scheme where the MNE's home country applies its own tax rate to grant cross-border tax relief to the domestic firm for the losses incurred by its foreign subsidiary. This scheme is currently applied by the countries that offer a unilateral cross-border loss offset and it also underlies the European Commission's proposals for the coordinated introduction of cross-border tax relief.

## 3.1 Firms and governments

Given the corporate tax rates $t_i$ and $t_j$, the expected after-tax profits of the multinational firm based in country $i$ are

$$E(\pi_i) = (1 - t_i)\overline{G}_i + (1 - t_j)p[f(k_i) - k_i] - (1 - \alpha t_i)(1 - p)k_i \qquad \forall\, i \neq j. \tag{1}$$

The first term in (1) describes the exogenous profits of the parent company, net of the tax rate applied in the parent firm's home country $i$. The second term captures the net profits of firm $i$'s subsidiary in country $j$ in the case where the investment is

often have a choice in which country to offset the losses. If the tax rebate is based on the tax rate in the country granting the tax relief, the MNE has an incentive to offset the parent's losses in the host country with the highest tax rate. For this reason, there is considerable skepticism against a 'downward' cross-border tax relief, in contrast to the 'upward' tax relief that we consider here. See European Commission (2006).

[9] This is different in the analysis of Kalamov and Runkel (2012), who incorporate tax competition for profit shifting by the MNEs. When countries only compete via foreign investment, however, the decentralized equilibrium in their analysis involves zero levels of cross-border loss offset (see their Proposition 1).

successful. Investment is assumed to fully depreciate in the process of production so that investment costs must be deducted from the value of output.[10] The third term captures the losses incurred by the subsidiary when the investment is unsuccessful, which occurs with probability $(1-p)$. In this case the value of output is zero and the before-tax loss is simply $k_i$. This loss is reduced by the tax relief granted in the parent's home country $i$, where the tax credit depends on country $i$'s tax rate and on the internationally coordinated loss offset factor $\alpha$.

Maximizing (1) with respect to $k_i$ implicitly defines the subsidiary's optimal investment level by

$$f_{k_i} - 1 - \frac{(1-p)}{p(1-t_j)}\,(1-\alpha t_i) = 0 \qquad \forall\, i \neq j. \tag{2}$$

In the absence of uncertainty $(p=1)$, the third term on the left-hand side of (2) is zero and the optimal investment level is implicitly determined by the usual condition that the marginal product of capital, $f_k$, equals the exogenous world interest rate of unity. In the presence of uncertainty, but in the absence of taxes, the marginal productivity of capital in case of success must rise by $(1-p)/p$, in order to compensate the risk-neutral investor for the possibility of failure. This decision is distorted by a tax system that taxes positive profits but grants no tax relief for losses incurred. If no cross-border loss offset occurs at all $(\alpha = 0)$, the marginal product of capital must rise by $(1-p)/[p(1-t_j)]$. This implies an underinvestment by the subsidiary that is the more severe, the higher is country $j$'s tax rate. Introducing cross-border loss offset counteracts this distortion, but it will only fully eliminate it when the loss offset parameter $\alpha$ equals one and tax rates in both countries are identical.

From (2), the effects of taxes on the firm's optimal investment choice $k_i$ are:

$$\frac{\partial k_i}{\partial t_i} = -\frac{\alpha(1-p)}{p(1-t_j)f_{k_i k_i}} \geq 0, \qquad \frac{\partial k_i}{\partial t_j} = \frac{(1-\alpha t_i)(1-p)}{p(1-t_j)^2 f_{k_i k_i}} < 0, \tag{3}$$

$$\frac{\partial k_i}{\partial t_i} + \frac{\partial k_i}{\partial t_j} = \frac{[1-\alpha+\alpha(t_j-t_i)](1-p)}{p(1-t_j)^2 f_{k_i k_i}} \leq 0. \tag{4}$$

Equation (3) shows that an increase in country $j$'s tax rate leads to less capital investment by the subsidiary of firm $i$.[11] In contrast, by increasing the expected tax rebate,

[10] We assume, for simplicity, that all capital costs are fully deductible from the corporation tax.

[11] Recall that the subscript $i$ refers to the headquarter country of multinational $i$, but the subsidiary's investment occurs in country $j$. Therefore the well-known negative effect of source-based taxes on investment is given by $\partial k_i/\partial t_j$ in our notation.

an increase in the tax rate of country $i$ increases capital investment by firm $i$'s subsidiary when the loss offset parameter $\alpha$ is strictly positive. From equation (4) we see that when both tax rates are simultaneously increased, the negative effect of $t_j$ on $k_i$ dominates, unless cross-border loss offset is complete and tax rates are identical in the initial equilibrium.

Turning to the two governments, we postulate in our benchmark model that governments set tax rates to maximize their corporate tax revenues. This objective captures the concern about tax revenues that features prominently in both policy debates and court decisions on cross-border loss offset. From a theoretical perspective, the assumption that the profit income of MNEs does not enter the governments' objective function corresponds to a setting where the residents of each country invest their capital in perfectly diversified global portfolios.[12] The implications of an extended government objective that also incorporates the profits of home-based multinationals are considered in Section 6.1.

Country $i$'s tax base consists of the exogenous profit income $\overline{G}_i$, less the share $\alpha$ of the losses made by the subsidiary of firm $i$ if its investment fails. To these are added the profits made by the subsidiary of firm $j$ when this firm's investment is successful. Tax revenues in each country are thus given by

$$T_i = t_i\{\overline{G}_i - \alpha(1-p)k_i + p[f(k_j) - k_j]\} \equiv t_i B_i \quad \forall\, i \neq j. \tag{5}$$

Maximizing with respect to $t_i$ gives country $i$'s optimal tax rate in implicit form:

$$t_i^* = \frac{B_i[\alpha, t_i(\alpha), t_j(\alpha)]}{-\Omega_i[\alpha, t_i(\alpha), t_j(\alpha)]} > 0 \quad \forall\, i, \tag{6}$$

where the profit tax base $B_i$ is given in (5) and

$$\Omega_i \equiv \left[p(f_{k_j} - 1)\,\frac{\partial k_j}{\partial t_i} - \alpha(1-p)\,\frac{\partial k_i}{\partial t_i}\right] < 0 \tag{7}$$

collects the sum of effects that an increase in $t_i$ has on country $i$'s tax base via the investment decisions of both representative MNEs. From the firms' investment responses (3), these effects are all negative. The optimal tax policy thus follows a straightforward inverse elasticity rule: it rises with the total value of country $i$'s tax base $B_i$, but falls in the aggregate response of the tax base to a tax increase in country $i$.

[12]Empirically, globally diversified portfolios are a plausible scenario when most of the small country's capital is invested through financial intermediaries, such as pension funds or insurance companies.

## 3.2 The effects of cross-border loss offset

The core question of our analysis is how a coordinated increase in the loss offset parameter $\alpha$ affects optimal tax rates and equilibrium tax revenues. For tax rates, totally differentiating (6) and using the symmetry of countries yields[13]

$$\frac{\mathrm{d}t^*}{\mathrm{d}\alpha} = \frac{1}{\phi}\left(\frac{\partial B}{\partial \alpha} + t\,\frac{\partial \Omega}{\partial \alpha}\right), \tag{8}$$

where we show in the appendix that $\phi > 0$.

The first term in (8) gives the change in each country's tax base following an increase in the loss offset parameter $\alpha$. To sign this effect we derive the impact effects of a change in $\alpha$ on investment levels.[14] Implicitly differentiating (2) shows that increased cross-border loss compensation raises investment by both subsidiaries:

$$\frac{\partial k}{\partial \alpha} = -\frac{t(1-p)}{(1-t_j)pf_{kk}} > 0. \tag{9}$$

Incorporating the investment responses of both firms, the net change in each country's tax base following an increase in $\alpha$ is then given by

$$\frac{\partial B}{\partial \alpha} = -(1-p)k - (1-\alpha)\,\frac{t(1-p)^2}{(1-t)^2 pf_{kk}}. \tag{10}$$

The first term in (10) gives the negative, direct effect on each country's tax base that results from the increased tax rebate to the loss-making subsidiary of its resident MNE. The second term captures the indirect effects through the induced change in both MNEs' investment behavior. The expansion of risky activities in firm $i$'s subsidiary reduces country $i$'s expected tax base, because the government of country $i$ participates only in the losses, but not in the profits of this subsidiary. Matters are reversed for the subsidiary of firm $j$, where country $i$ taxes the increased profits in case of success, but does not share in the losses if the investment fails. As long as loss offset is incomplete ($\alpha < 1$), the latter effect dominates and country $i$'s tax base rises, on net, from the higher investment activities of both firms.

In general, it is therefore not possible to sign the change in each country's tax base that results from an increase in $\alpha$. The net effect can be signed, however, when cross-border loss compensation is almost complete and $\alpha \to 1$. In this case, the indirect

[13]Since the symmetry assumption is used at this point, we drop country indices in the following when no confusion is possible.

[14]By impact effect we mean the direct effect of the exogenous parameter change, without taking into account the induced changes in governments' tax policies.

effects in (10) sum to zero. Intuitively, the symmetry of the model implies that a rise in $\alpha$ leads to equal increases in the investment levels of both firms. From the firms' optimal investment condition, we then get that the expected increase in the tax base from a successful investment of subsidiary $j$ is exactly offset by the expected loss of an unsuccessful investment of subsidiary $i$. Finally, country $i$'s tax rate on the positive profits of firm $j$ equals the effective subsidy rate for the losses of firm $i$, $\alpha t_i$, when loss offset is complete ($\alpha = 1$). Hence only the negative direct effect remains in this case and

$$\left.\frac{\partial B}{\partial \alpha}\right|_{\alpha \to 1} = -(1-p)k < 0. \tag{11}$$

In the following we will refer to this direct effect as the *mechanical effect* of the reform.

Next, we analyze the effect of improved loss offset opportunities on the elasticity of each country's tax base, as given by $\Omega$. To differentiate (7) with respect to $\alpha$, we use the first-order condition for capital investment (2) and the impact effect of cross-border loss offset on capital investment (9). Further differentiating the tax sensitivities of capital investments in (3) with respect to $\alpha$ gives[15]

$$\frac{\partial \Omega}{\partial \alpha} = \frac{-2(1-p)^2}{(1-t)pf_{kk}} \left[ \frac{t(1-\alpha t)}{(1-t)^2} - \alpha \right]. \tag{12}$$

The sign of (12) is ambiguous, in general. On the one hand, a higher loss-offset parameter implies that the sensitivity with which firm $j$ responds to a tax increase in country $i$ is reduced, as this firm will now receive a higher loss offset in its home country. This corresponds to the positive first effect in the squared bracket. On the other hand, a rise in $\alpha$ increases the tax base loss that country $i$ faces from a domestic tax increase due to the higher loss compensation it has to offer the subsidiary of its home-based firm. This is the negative second effect. The latter effect dominates when loss offset is almost complete ($\alpha \to 1$) and the tax rate is not too high initially ($t < 0.5$).[16] The sign of (12) is then negative, implying that a rise in $t$ leads to a larger tax base loss when cross-border loss offset is improved. Using this result along with (11) in (8) gives conditions that are *sufficient* (but not necessary) to ensure that improved cross-border loss offset will reduce equilibrium tax rates in both countries. This is stated in:

[15]Here and in the following, we ignore third derivatives of the production function and thus treat $f_{kk}$ as a constant.

[16]The restriction on tax rates is needed because the sensitivity of firm $j$'s investment response rises more steeply in $t$ than the loss compensation for firm $i$. Therefore, a high level of $t$ tends to increase the positive first effect in (12), relative to the second effect.

**Proposition 1a** *Consider a symmetric Nash equilibrium in tax rates where governments maximize tax revenues and the losses of subsidiaries are rebated at the tax rate of the parent's home country. Then a small increase in cross-border loss offset* $d\alpha > 0$ *reduces equilibrium tax rates in both countries, if loss offset is almost complete initially* $(\alpha \to 1)$ *and tax rates are not too high* $(t \leq 1/2)$.

Proposition 1a is confined to a small change in $\alpha$ in the neighborhood of complete loss offset. We can, however, also derive conditions under which a discrete switch from no to full cross-border loss offset (i.e., from $\alpha = 0$ to $\alpha = 1$) lowers the equilibrium tax rates. Using the (implicit) optimal tax rate expression in (6), this requires that $B^1 < B^0$ and $-\Omega^1 > -\Omega^0 > 0$, where the superscripts 1 and 0 refer to the equilibrium values with full loss offset and no loss offset, respectively. Comparing first the numerators in the two discrete equilibria, we get from rearranging the definition of $B$ in (6)

$$B^1 < B^0 \quad \Longleftrightarrow \quad p\left[\frac{f(k^1) - f(k^0)}{k^1 - k^0} - 1\right] < \frac{(1-p)k^1}{k^1 - k^0} \,. \tag{13}$$

On the left-hand side of (13) is the expected average return (net of investment costs) of the incremental investment $k^1 - k^0$ that is induced by a switch from zero to full loss offset. On the right-hand side are the expected losses that the government has to compensate under full loss offset, again relative to the induced change in investment. Overall the condition thus states that corporate tax bases will fall when the expected returns to the additional investment are moderate, relative to the additional risks taken by the firms (and shared by the governments).

Turning to the comparison of denominators, substituting (2), (3) and (9) in (7) and rearranging gives

$$-\Omega^1 > -\Omega^0 \quad \Longleftrightarrow \quad t^0 < 1 - \sqrt{0.5}. \tag{14}$$

Hence, similar to Proposition 1a, an additional constraint is that tax rates must not be too high in the initial equilibrium without loss offset.

If the conditions (13) and (14) are simultaneously fulfilled, it follows from (6) that $t^{*1} < t^{*0}$. This is summarized in:

**Proposition 1b** *When losses of subsidiaries are rebated at the tax rate of the parent's home country, a discrete switch from zero to full cross-border loss offset reduces equilibrium tax rates in both countries, if the expected returns to the additional investment are moderate, relative to the risks involved [as given in* (13)*], and if tax rates are not too high initially* $(t^0 \leq 1 - \sqrt{0.5})$.

These results isolate an important and, as yet, little studied effect of coordinated arrangements to increase cross-border tax relief. Given that governments remain free to set profit tax rates non-cooperatively, improving the international tax deductibility of losses may render international tax competition more aggressive, at least when loss offset is nearly complete. The reason is that cross-border loss offset increases the costs of maintaining a high tax rate when each country grants the loss offset based on its own tax rate. This effect is the stronger the higher is the degree of loss offset $\alpha$.

We now derive the equilibrium change in tax revenues following an increase in $\alpha$. Writing $T_i = T_i[\alpha, t_i(\alpha), t_j(\alpha)]$ and differentiating with respect to $\alpha$ gives[17]

$$\frac{\mathrm{d}T_i}{\mathrm{d}\alpha} = \frac{\partial T_i}{\partial \alpha} + \frac{\partial T_i}{\partial t_j}\frac{\mathrm{d}t_j}{\mathrm{d}\alpha} \quad \forall \quad i \neq j. \tag{15}$$

The first term in (15) captures the direct effect of $\alpha$ on the tax base, and hence tax revenues, for constant tax rates $t_i$. From (10) and (2) this effect can be expressed as

$$\frac{\partial T_i}{\partial \alpha} = t\left[-(1-p)k + \frac{(1-p)(1-\alpha)}{(1-t)}\,\frac{\partial k}{\partial \alpha}\right] \quad \forall \quad i. \tag{16}$$

The first effect in the squared bracket is again the direct or *mechanical effect* of the reform, which is now valued with country $i$'s tax rate. The second term gives the net change in country $i$'s tax revenues through the behavioral responses of both subsidiaries. In case of success, tax revenues in country $i$ increase with an investment expansion of firm $j$, but decrease with a higher investment of firm $i$. The net effect will be positive as long as cross-border loss offset is incomplete. We have already shown, however, that the second effect goes to zero, and the tax base change is unambiguously negative, when $\alpha \to 1$ [see eq. (11)].

To obtain the general equilibrium change in tax revenues, it remains to sign the externality that the induced tax change in the other country $j$ has on country $i$'s tax base. From (5) we can show that this externality is unambiguously positive and country $i$'s tax base will rise following a tax increase in country $j$:

$$\frac{\partial T_i}{\partial t_j} = t_i\left[p(f_k-1)\frac{\partial k_j}{\partial t_j} - \alpha(1-p)\frac{\partial k_i}{\partial t_j}\right] \geq 0 \quad \forall \quad i \neq j. \tag{17}$$

The first effect in (17) shows that a rise in $t_j$ increases investment by firm $j$'s subsidiary, as this firm will now receive a higher tax rebate in the event of a loss. This effect

[17] Note that the effect of country $i$'s own tax rate on its tax revenues $T_i$ is zero from the envelope theorem.

increases the tax base of country $i$. Second, a higher tax rate in country $j$ reduces firm $i$'s investment there and thus reduces the volume of tax rebates that country $i$ has to grant its resident MNE. Hence both effects work in the same direction and the tax externality is always positive. In the symmetric Nash equilibrium, this implies that both countries set their tax rates at inefficiently low levels under the benchmark loss offset scheme, relative to a situation of joint revenue maximization.

Hence, the total effect of the externality depends on how equilibrium tax rates change with increased cross-border loss offset. From Proposition 1a we know that a marginal increase in $\alpha$ will lead to falling tax rates when cross-border loss offset is almost complete and initial tax rates are not too large. In this case the second effect in (15) is thus negative and adds to the negative first effect. Hence equilibrium tax revenues in both countries must fall. Moreover, due to the downward adjustment of tax rates, tax revenue losses in both countries will exceed the revenue losses from the *mechanical effect*. We summarize our findings in:

**Proposition 1c** *When the losses of subsidiaries are rebated at the tax rate of the parent's* <u>*home country*</u>*, then a small increase in cross-border loss offset* $d\alpha > 0$ *lowers equilibrium tax revenues in each country by* <u>*more*</u> *than the mechanical effect, if loss offset is almost complete initially* $(\alpha \to 1)$ *and tax rates are not too high* ($t \leq 1/2$)*.*

Proposition 1c implies that a marginal increase in the degree of cross-country tax relief to the point of full loss offset is definitely undesirable for revenue-maximizing governments, as it reduces both the equilibrium tax base and the optimal rate of corporation tax.

For a *discrete switch* from zero to full cross-border loss offset, tax revenues must unambiguously fall under the conditions summarized in Proposition 1b, as both the tax base and the tax rate are then lower in the equilibrium with $\alpha = 1$, as compared to the case where $\alpha = 0$. Fuest et al. (2007) have isolated the direct tax base effect (mechanical effect) of such a discrete switch and have estimated that this reduces corporate tax revenues in the EU average by roughly 20%. In addition to this direct effect, our analysis incorporates the behavioral responses of both firms and governments. While the investment responses of firms tend to reduce the tax revenue losses borne by governments, their strategic setting of corporate tax rates tends to increase revenue losses when the conditions in Proposition 1b are met.

# 4 An alternative loss offset scheme

## 4.1 Firms and governments

Our analysis in the previous section has shown that introducing cross-border loss offset may intensify tax competition when the MNE's home country bases the tax rebate for the losses of foreign subsidiaries on its own tax rate. This suggests an alternative loss offset scheme, where the home country still grants a tax rebate for the losses of its foreign-based subsidiaries, but applies the tax rate of the subsidiary's *host country* to the loss offset.[18] In the following we analyze this scheme in more detail, focussing again on the issue of how international tax competition is affected by cross-border loss compensation.

With the changed specification of loss compensation, the expected after-tax profits of firm $i$ are given by

$$E(\tilde{\pi}_i) = (1-\tilde{t}_i)\overline{G}_i + (1-\tilde{t}_j)p[f(\tilde{k}_i) - \tilde{k}_i] - (1-\alpha\tilde{t}_j)(1-p)\tilde{k}_i \qquad \forall i \neq j, \tag{18}$$

where the tilde indicates terms under the alternative loss offset scheme. The only difference between (18) and equation (1) in the last section lies in the third term, where losses are now rebated at the tax rate $\tilde{t}_j$ of the subsidiary's host country. The firms' optimal investment decisions are now implicitly determined by

$$f_{k_i} - 1 - \frac{(1-p)}{p(1-\tilde{t}_j)}\,(1-\alpha\tilde{t}_j) = 0 \qquad \forall\, i \neq j. \tag{19}$$

Differentiating (19) with respect to the tax rates $\tilde{t}_i$ and $\tilde{t}_j$ yields

$$\frac{\partial\tilde{k}_i}{\partial\tilde{t}_i} = 0, \qquad \frac{\partial\tilde{k}_i}{\partial\tilde{t}_j} = \frac{(1-\alpha)(1-p)}{p(1-\tilde{t}_j)^2 f_{k_i k_i}} \leq 0 \qquad \forall\, i \neq j, \tag{20}$$

Equation (20) shows that the tax rate of the parent country no longer has any effects on firm $i$'s choices. This is, of course, partly a result of our simplifying assumption that the investment level of the parent company is fixed. At the same time, the tax rate of the host country $j$ now applies to both positive and negative profits. The net effect of $\tilde{t}_j$ on the investment level of firm $i$'s subsidiary is negative when loss compensation is incomplete. If $\alpha = 1$, the distortion arising from source-based capital taxation disappears and $\tilde{t}_j$ becomes a lump-sum tax.

[18] We thank Clemens Fuest for the suggestion to study this alternative scheme.

As before, the objective of both governments is to maximize tax revenues. When country $i$ applies the foreign tax rate $\tilde{t}_j$ to calculate the tax rebate granted to the subsidiary of its home-based MNE, its tax revenues are

$$\tilde{T}_i = \tilde{t}_i\{\overline{G}_i + p[f(\tilde{k}_j) - \tilde{k}_j]\} - \alpha\tilde{t}_j(1-p)\tilde{k}_i \equiv \tilde{t}_i\tilde{B}_i - \alpha\tilde{t}_j(1-p)\tilde{k}_i. \tag{21}$$

Maximizing with respect to $\tilde{t}_i$ gives

$$\tilde{t}_i^* = \frac{\tilde{B}_i(\alpha, \tilde{t}_i, \tilde{t}_j)}{-\tilde{\Omega}_i(\alpha, \tilde{t}_i, \tilde{t}_j)} > 0, \qquad \tilde{\Omega}_i = p(f_{k_j} - 1)\,\frac{\partial\tilde{k}_j}{\partial\tilde{t}_i} < 0. \tag{22}$$

Note, from the definition of $\tilde{B}_i$ in (21), that the tax rebate to the loss-making subsidiary does not enter the numerator of the optimal tax rate $\tilde{t}_i^*$ under this loss offset scheme. This has important effects for the countries' incentives to engage in tax competition.

## 4.2 The effects of cross-border loss offset

To analyze the effects of cross-border loss offset, we proceed as in the last section to determine the effects on optimal tax rates [see eq. (8)].[19] The impact effect of a change in $\alpha$ on investment is again unambiguously positive under the alternative loss offset scheme. An important difference to the analysis in the previous section is, however, that the loss offset parameter $\alpha$ now affects $\tilde{B}_i$ only through the investment level of firm $j$. Hence we get:

$$\frac{\partial\tilde{k}}{\partial\alpha} = -\frac{\tilde{t}(1-p)}{(1-\tilde{t})pf_{kk}} > 0, \qquad \frac{\partial\tilde{B}}{\partial\alpha} = p\,(f_k - 1)\,\frac{\partial\tilde{k}}{\partial\alpha} > 0. \tag{23}$$

The higher loss offset granted by country $j$ increases investment by firm $j$'s subsidiary in country $i$, thus increasing country $i$'s tax base. At the same time, the higher loss offset increases the loss compensation that country $i$ has to pay its own subsidiary. While this reduces country $i$'s net tax revenues, it does not reduce the tax base, with which country $i$'s tax rate is multiplied [see eq. (21)]. Hence, there is no negative *mechanical effect* on the tax rate in this case. In stark contrast to our previous specification [see eq. (11)], we thus get the global result that the numerator of each country's optimal tax expression is unambiguously rising in $\alpha$ under the alternative loss offset scheme.

Turning to the denominator of $\tilde{t}_i^*$ in (22), differentiating with respect to $\alpha$, using (19), (20) and (23) and simplifying yields:

$$\frac{\partial\tilde{\Omega}}{\partial\alpha} = \frac{-(1-p)^2}{p(1-\tilde{t})^3 f_{kk}}[1 + \tilde{t}(1-2\alpha)] > 0. \tag{24}$$

[19] The changed level of $\tilde{\phi} > 0$ is derived in Appendix 1.

The dominant effect on $\tilde{\Omega}$ resulting from an increase in $\alpha$ is that firm $j$'s investment will respond less sensitively to a tax increase in country $i$, as the loss offset opportunities in the parent country $j$ are improved. In contrast, the higher loss compensation paid by country $i$ is not relevant for $\tilde{\Omega}$. Noting that $\tilde{\Omega}_i < 0$ from (22), the elasticity with which country $i$'s tax base responds to tax changes in $\tilde{t}_i$ is thus unambiguously falling in $\alpha$. This yields:

**Proposition 2a** *Consider a symmetric Nash equilibrium in tax rates where governments maximize tax revenues and losses of subsidiaries are rebated at the tax rate of the subsidiary's host country. Then a small increase in cross-border loss offset $d\alpha > 0$ increases equilibrium tax rates in both countries for any initial level of $\alpha$.*

In contrast to Proposition 1a in the previous section, Proposition 2a states that country $i$'s optimal tax rate is unambiguously and monotonically rising in $\alpha$ when countries grant cross-border tax relief at the rate of the subsidiary's host country. As a result it must also be true that a *discrete switch* from zero to full cross-border loss offset unambiguously raises equilibrium tax rates. The core reason for this result is that an increase in the loss offset parameter has no negative direct effect on optimal tax rates in both countries. At the same time, the induced investment expansion of MNEs increases tax bases in both countries and thus offers an incentive to increase tax rates.

To compute the equilibrium changes in tax revenues, we follow (15) and first consider the direct effect, ignoring for now the tax rate changes induced by enhanced cross-border loss offset. The direct effect on tax revenues is:

$$\frac{\partial \tilde{T}_i}{\partial \alpha} = \tilde{t} \left[ -(1-p)\tilde{k} + \frac{(1-p)(1-\alpha)}{(1-\tilde{t})} \frac{\partial \tilde{k}}{\partial \alpha} \right]. \tag{25}$$

The structure of (25) is analogous to the corresponding direct effect in the previous section [see eq. (16)]. For given tax rates, the *mechanical effect* in the first term has the same negative negative impact on tax revenues as under the benchmark scheme. The second term is positive whenever loss offset is incomplete so that the returns to higher capital investments are taxed, on net, by the two governments. When $\alpha \to 1$, however, the second effect goes to zero and only the negative first effect remains.

Finally, we turn to the tax externality $\partial \tilde{T}_i / \partial \tilde{t}_j$. This can be calculated from government $i$'s tax revenues by differentiating (21) with respect to $\tilde{t}_j$, using (20). This gives:

$$\frac{\partial \tilde{T}_i}{\partial \tilde{t}_j} = \frac{-\tilde{t}\alpha(1-\alpha)(1-p)^2}{p(1-\tilde{t})^2 f_{kk}} - \alpha(1-p)\tilde{k}.$$

The first effect in this expression is analogous to our analysis in the previous section [see eq. (17)]. It is strictly positive for $0 < \alpha < 1$, as an increase in $\tilde{t}_j$ reduces the investment of firm $i$'s subsidiary, and therefore reduces the expected tax rebate of country $i$. There is a counteracting second effect, however, which is specific to the tax rebate being based on the tax rate in the subsidiary's host country. By raising its tax rate, the host country $j$ can raise the rate at which country $i$ has to grant tax relief to the subsidiary of its home-based MNE. Taken in isolation, this effect thus provides an incentive for strategic overtaxation under the alternative loss offset scheme.

We can show, however, that the incentive for overtaxation will never dominate under the alternative loss offset scheme. Substituting the optimal value of $\tilde{t}^*$ from (22) and using (19) and (20), we can rewrite the tax externality as

$$\frac{\partial \tilde{T}_i}{\partial \tilde{t}_j} = \frac{\alpha}{(1-\alpha\tilde{t})} \Big[ \bar{G}(1-\tilde{t}) + p[f(\tilde{k}) - \tilde{k}](1-\tilde{t}) - \tilde{k}_i(1-\alpha\tilde{t})(1-p) \Big] > 0, \qquad (26)$$

since the term in the large squared bracket equals the expected profits of firm $i$ in eq. (18), which are necessarily positive. Hence the net tax externality is always positive and both countries set tax rates at inefficiently low levels under the alternative loss offset scheme (as was the case under the benchmark scheme). Intuitively, the dominant effect is that an increase in $\tilde{t}_j$ reduces the investment of country $i$'s resident MNE in country $j$. This volume effect reduces the expected total loss compensation that country $i$ has to pay in equilibrium, despite the fact that it has to apply a higher tax rate $\tilde{t}_j$ to offset the losses of its resident MNE.

Since we know from Proposition 2a that tax rates are monotonously rising in $\alpha$ under the alternative loss offset regime, the indirect effect of a change in $\alpha$ on country $i$'s tax revenues in eq. (15) is therefore unambiguously positive. Together with the non-negative second effect in (25), this ensures that the responses of both firms and governments lead to tax revenue losses in equilibrium that are smaller than is implied by the *mechanical effect* of the reform. In contrast to the benchmark loss offset scheme, this is a global result that holds for any initial level of $\alpha$. This is summarized in:

**Proposition 2b** *When the losses of subsidiaries are rebated at the tax rate of the subsidiary's host country, then a small increase in cross-border loss offset $d\alpha > 0$ lowers equilibrium tax revenues in each country by less than the mechanical effect, for any initial level of $\alpha$.*

Since Proposition 2b holds for any initial level of $\alpha$, we can also conclude that the tax revenue shortfalls triggered by a *discrete switch* from zero to full cross-border loss offset will definitely be lower under this scheme than is implied by the mechanical effect. Under the benchmark scheme, in contrast, tax revenue losses are possibly enlarged by behavioral effects for a discrete switch from zero to full loss offset, and they will be enlarged, at the margin, in the neighborhood of the full loss offset equilibrium (Proposition 1c). These differences are primarily driven by the contrasting incentives to adjust optimal tax rates under the two loss offset regimes.

# 5 Comparing the two loss offset regimes

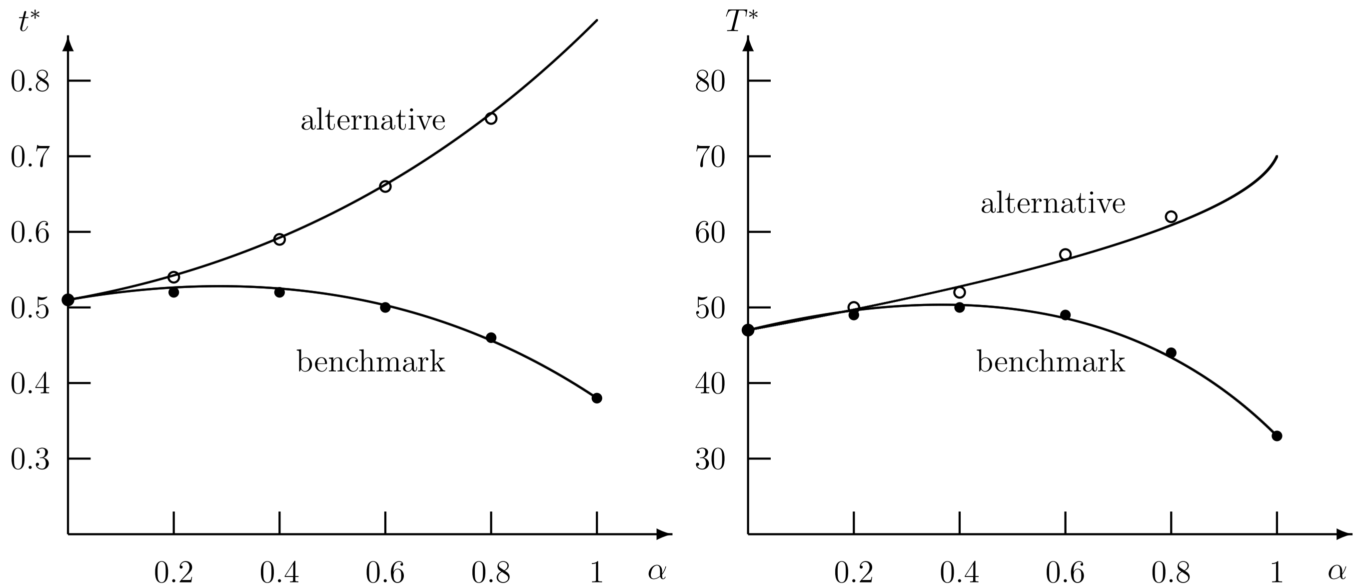
Our theoretical analysis in the previous sections was limited by the fact that results for the benchmark loss offset scheme could only be derived for specific cases. In the following we therefore complement the theoretical analysis with some numerical simulations that compare tax rates and tax revenues under the two loss offset schemes for all possible levels of $\alpha$. For this purpose we specify the production function of both representative firms as $f(k_i) = Ak_i^{\varepsilon}$. We present simulation results for two cases, depending on whether the exogenous probability of success is high ($p = 0.8$) or low ($p = 0.5$). The success probability is important because it determines the expected size of the *mechanical effect* under both loss offset systems [see the first terms in (16) and (25)]. This effect is the larger the lower is the success probability of the investment and hence the larger are the cross-border losses that have to be compensated. The results of our simulations are summarized in Figure 1.

In the upper half of the figure, Case 1 presents the results for the high success probability $p = 0.8$. In the left panel we compare tax rates for the two loss offset schemes. Under the benchmark scheme, tax rates first rise slightly, as the positive effect of increased investment levels dominates the negative mechanical effect. As $\alpha$ continues to rise, however, the mechanical effect becomes stronger and tax rates definitely fall, at the margin, as $\alpha$ approaches unity (see Proposition 1a). Moreover, the figure also shows that the conditions underlying Proposition 1b are fulfilled, and a discrete switch from zero to full loss offset lowers equilibrium tax rates. Under the alternative scheme, in contrast, tax rates are monotonously rising in $\alpha$ (see Proposition 2a) and are above the equilibrium tax rates under the benchmark scheme for any positive level of $\alpha$.[20]

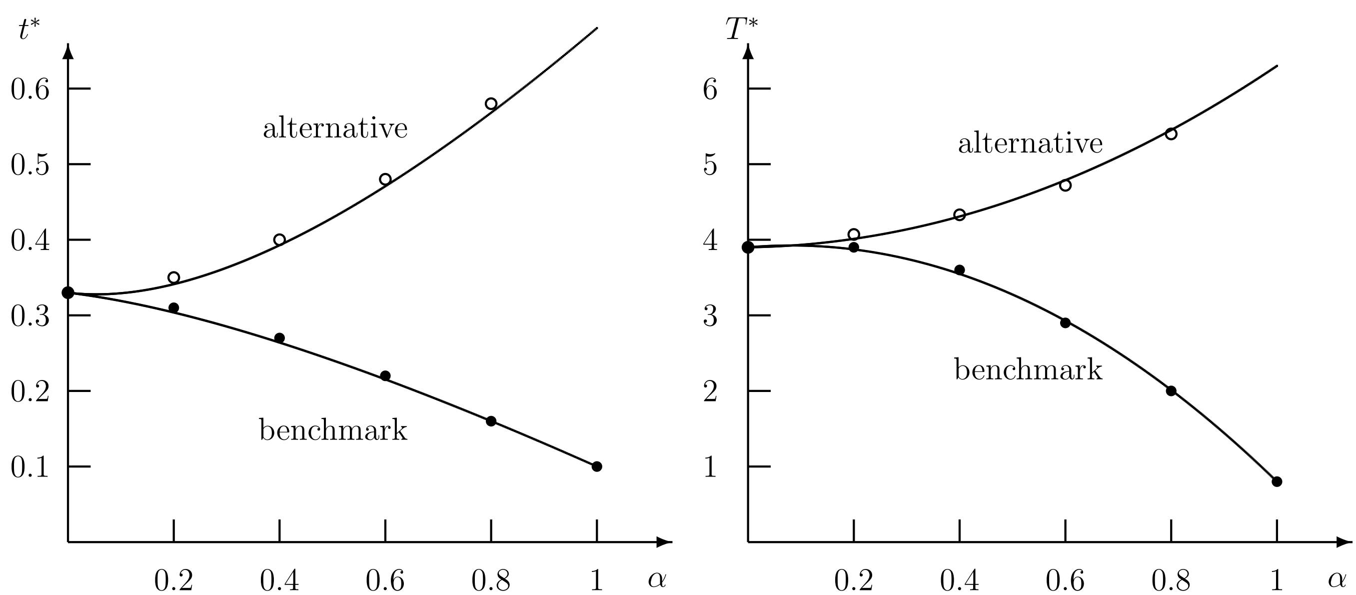
[20]Note that, at $\alpha = 0$, the difference between the two loss offset schemes is inconsequential and the

Figure 1: Tax rate and tax revenue effects of loss offset schemes

Case 1: High success probability ($p = 0.8$)




Case 2: Low success probability ($p = 0.5$)




<u>Notes:</u> $\overline{G} = 0.5,\ A = 5,\ \varepsilon = 0.8$

These differences are mirrored in the tax revenue levels shown in the right upper panel of Figure 1. Under the benchmark scheme, tax revenues initially rise, but then fall as $\alpha$ is further increased (Proposition 1c). Under the alternative scheme, they cannot fall by more than the mechanical effect (Proposition 2b). Indeed, Figure 1 shows that the positive effects of higher tax rates that are induced by rising investment levels may well overcompensate the mechanical effect so that tax revenues are actually rising in $\alpha$. Lastly, but importantly, equilibrium tax revenues under the alternative scheme are always higher than under the benchmark loss offset scheme.

In the lower half of the figure, Case 2 shows the simulation results when the success probability of the investment is relatively low ($p = 0.5$). In this case the mechanical effect is thus stronger than in Case 1. From their common starting point at $\alpha = 0$, tax rates and tax revenues are now monotonously falling under the benchmark loss offset scheme, whereas they monotonously rise under the alternative loss offset scheme. Hence the case where relatively high loss offset compensation is paid by governments accentuates the differences between the two loss offset schemes. Overall, our simulations thus indicate that the equilibria attainable under the alternative loss offset scheme are likely to dominate the equilibria under the benchmark scheme when tax revenue maximization is the objective of governments.

# 6 Discussion and extensions

In this section we extend our analysis in several directions. In Section 6.1 we modify the governments' objective function to account for the profits of home-based multinational firms. In Section 6.2 we allow firms to endogenously choose the success probability of their risky investments. Finally, in Section 6.3 we introduce asymmetries between countries and compare the two alternative loss offset schemes in a setting where redistributive effects between the two countries are present.

## 6.1 Home ownership of multinational firms

We first analyze how the comparison between the benchmark and the alternative loss offset schemes is changed when each government's objective function includes the prof-

equilibria must therefore coincide at this point.

its of the resident multinational.[21] We capture this in our model by incorporating the profits of firm $i$ into country $i$'s government objective function with a weight of $\lambda \leq 1$. National welfare in country $i$ then equals the weighted sum of the net-of-tax profits of firm $i$ and country $i$'s tax revenues. We confine our comparison to the determination of optimal tax rates and their responses to the degree of loss offset $\alpha$.

**Benchmark loss offset scheme.** For this scheme, we get from the firm's net profit equation (1) and tax revenues (5):

$$W_i = \lambda E(\pi_i) + T_i = [\lambda + (1-\lambda)t_i]\overline{G}_i - [\lambda + (1-\lambda)\alpha t_i](1-p)k_i + t_i p[f(k_j) - k_j] + \lambda(1-t_j)p[f(k_i) - k_i] \qquad \forall\, i \neq j.$$

Maximizing with respect to $t_i$ and using (2) and (3) implicitly defines country $i$'s optimal tax rate. Using the superscript $W$ to indicate variables under a welfare objective, country $i$'s optimal tax rate is given by

$$t_i^W = \frac{B_i^W}{-\Omega_i} > 0, \quad B_i^W = (1-\lambda)[\overline{G}_i - \alpha(1-p)k_i^W] + p[f(k_j^W) - k_j^W], \tag{27}$$

and $\Omega_i$ is the same as under tax revenue maximization [eq. (7)].

The change in tax rates following an increase in the loss offset parameter $\alpha$, is again given by (8).[22] The change in $t_i^W$ is positively related to the change in the numerator $B_i^W$ of country $i$'s tax rate expression in (27). Using (9), this is given by

$$\frac{\partial B_i^W}{\partial \alpha} = -(1-\lambda)\left[(1-p)k^W - \frac{\alpha(1-p)^2 t^W}{(1-t^W)pf_{kk}}\right] - \frac{(1-p)^2(1-\alpha t^W)t^W}{(1-t^W)^2 p f_{kk}}. \tag{28}$$

In comparison to the corresponding effects under tax revenue maximization [eq. (10)], the negative first effect is now reduced in size, because the negative effect on government $i$'s tax revenues is partly compensated by additional profits of its home-based multinational. Hence, only the difference in welfare weights $(1-\lambda)$ is relevant for this effect. In contrast, the positive second effect is unchanged in size from (10), as this gives the increase in tax revenues collected by country $i$ from additional investment carried out by the foreign-based multinational $j$. On net this derivative is therefore more likely to be positive under welfare maximization than under tax revenue maximization. In

[21]Recall that the output price of the good produced by the two representative MNEs is fixed in the world market. Consumer surplus is therefore unchanged throughout our analysis.

[22]We assume that the multiplier $\phi^W$ is positive, as under tax revenue maximization (Appendix 1).

the extreme case where $\lambda = 1$, the negative first effect disappears altogether, and the derivative will be unambiguously positive.

The effects of a rise in $\alpha$ on the denominator $\Omega_i$ of country $i$'s tax rate expression in (27) have already been calculated in (12), and have been shown there to be ambiguous. In particular, this effect is positive when $\alpha$ is very low initially. Hence, for low initial levels of $\alpha$, tax rates will indeed rise following an increase in loss offset under the benchmark scheme when governments weigh tax revenues and the profit income of its resident multinational equally. This result contrasts with our analysis in Section 3. For higher levels of $\alpha$, however, there is again a tendency towards falling tax rates, as in the case where governments maximize tax revenues.

**Alternative loss offset scheme.** For the alternative scheme, we get from the firm's profit equation (18) and tax revenues (21):

$$\tilde{W}_i = \lambda E(\tilde{\pi}_i) + \tilde{T}_i = [\lambda + (1-\lambda)\tilde{t}_i]\overline{G}_i - [\lambda + (1-\lambda)\alpha\tilde{t}_j](1-p)\tilde{k}_i + \tilde{t}_i p[f(\tilde{k}_j) - \tilde{k}_j]$$
$$+ \lambda(1-\tilde{t}_j)p[f(\tilde{k}_i) - \tilde{k}_i] \qquad \forall\ i \neq j.$$

From (19) and (20), country $i$'s optimal tax rate under the alternative loss offset scheme is implicitly defined by

$$\tilde{t}_i^W = \frac{\tilde{B}_i^W}{-\tilde{\Omega}_i} > 0, \quad \tilde{B}_i^W = (1-\lambda)\overline{G}_i + p[f(\tilde{k}_j^W) - \tilde{k}_j^W], \tag{29}$$

and $\tilde{\Omega}_i$ is again identical to the case of revenue maximization [eq. (22)].

Comparing $\tilde{B}_i^W$ in (29) to the corresponding expression under tax revenue maximization [eq. (21)] shows that the only difference lies in the constant first term. Together with the unchanged denominator $\Omega_i$, this implies that the effects of changes in $\alpha$ on the optimal tax rate are the same as under tax revenue maximization [see (23) and (24)] and lead to unambiguously rising tax rates for all initial levels of $\alpha$. Hence Proposition 2a carries over to the case where governments maximize a weighted sum of tax revenues and the resident MNE's net profits.

To summarize, introducing a more general welfare objective for the government changes the results only under the benchmark loss offset scheme, making it less likely that governments respond to higher loss offset opportunities by lowering their corporate taxes strategically. Nevertheless, it remains true that tax responses may be negative, at least when loss offset is almost complete, whereas they are always positive when the alternative loss offset scheme is employed. Moreover, there are several reasons why governments will value tax revenues more than the profits of home-based MNEs. A first reason is that public goods must be financed by distortionary taxes, implying that one Euro of tax revenues has a higher value for the government than one Euro of private income. Secondly, MNEs are typically not fully owned by the residents of the country in which they are headquartered.[23] Finally, an important argument in the present context is that most governments have already raised substantial concern about the revenue losses that an improvement in loss offset opportunities may entail. In sum, these arguments imply that the relative weight $\lambda$ given to the profits of domestically owned firms may be fairly small for the particular policy issue discussed here.

## 6.2 Endogenous risk choice of firms

As a second extension of our baseline model, we now let the multinational firms choose the risk-return characteristics of their investments, as given by the success probability $p$. We postulate that, along the technological frontier, there is an infinite number of investment projects that differ in their success probability, where a riskier investment delivers a higher return in case of success.[24] The production function is then given by $f(p, k)$ with first-order derivatives $f_k > 0$ and $f_p < 0$ and second-order derivatives $f_{kk} < 0$ and $f_{pp} \leq 0$. Furthermore risk taking $(1 - p)$ and capital investment $k$ are assumed to be complements, $f_{kp} < 0$, implying that the safer is an investment, the lower is the marginal return on capital.

**Benchmark scheme.** Under the benchmark loss offset scheme, the first-order conditions for the investment level is unchanged from (2). The additional first-order condition for the optimal choice of project risk is

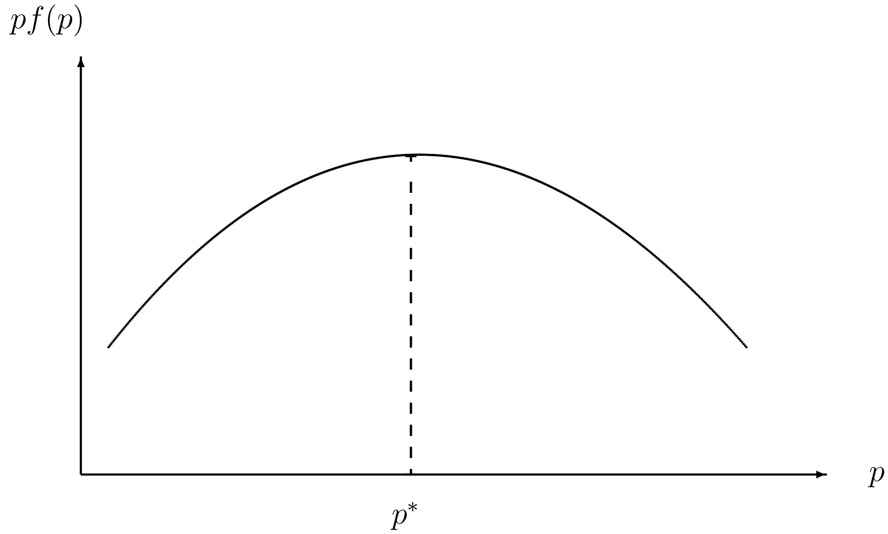
$$f(p_i, k_i) + p_i f_p(p_i, k_i) + \frac{(t_j - \alpha t_i)}{1 - t_j} \, k_i = 0 \qquad \forall \, i \neq j. \tag{30}$$

In the absence of taxes, the third term on the left-hand side is zero and the efficient project choice is determined by the condition $f(p_i, k_i) + p_i f_p(p_i, k_i) = 0$. For a risk-neutral investor this first-order condition maximizes the expected return, $pf(p)$, of the project. This is illustrated in Figure 2, where $p^*$ is the efficient level of project risk.

[23] Huizinga and Nicodème (2006, Table 1), for example, derive a foreign ownership share of more than 20%, on average, for a large sample of 15.000 European firms.

[24] See Haufler et al. (2012) for an analysis using this model element in a different policy setting.

Figure 2: The firm's optimal choice of project risk




Introducing taxes without a full cross-border loss offset leads to a positive third term on the left-hand side of (30) when tax rates are identical. Hence the negative second term must increase, implying a larger value of $p_i$ and hence an inefficiently low level of project risk. In Figure 1 this corresponds to a project choice to the right of the efficient project $p^*$. Introducing cross-border loss compensation will reduce this distortion, and it will fully eliminate it when $\alpha = 1$ and $t_i = t_j$.

The full analysis of the extended model is complex, and is relegated to Appendix 2. It is straightforward, however, to summarize the results of this analysis, because the effects of cross-border loss offset on risk-taking are in many ways parallel to those on the investment levels $k_i$. A higher degree of loss compensation increases risk-taking (i.e., it reduces $p$) and thus the expected return from the investment. This effect increases the (expected) tax base for both countries. At the same time, the expected tax rebates paid to the home-based MNE rise for both countries, due to the higher risk of failure. In a symmetric equilibrium where loss offset is almost complete ($\alpha \to 1$), these effects will just offset each other and only the negative *mechanical effect* of the reform remains [see eq. (11)]. Hence, as in our analysis in Section 3, each country will have an incentive to reduce its tax rate following a rise in $\alpha$, if the level of cross-border loss compensation is already high in the initial equilibrium.

Moreover, each country is again adversely affected by the tax reduction in the other country. In the extended model, the negative effect that a decrease in country $j$'s tax rate has on the tax base of country $i$ is even reinforced through the endogenous choice of a riskier project. A reduction of $t_j$ makes a risky investment more attractive for firm $i$, and the costs of failure are partly borne by firm $i$'s home country via cross-border loss compensation. Hence the parameter range under which an increase in $\alpha$ reduces tax revenues in both countries is enlarged, relative to the benchmark case.[25] Apart from that, the results from Section 3 carry over to this model extension.

**Alternative scheme.** Under the alternative loss offset scheme, the first-order conditions for $\tilde{k}_i$ is given in (19). The first-order condition for the optimal choice of $\tilde{p}$ is

$$f(\tilde{p}_i, \tilde{k}_i) + \tilde{p}_i f_p(\tilde{p}_i, \tilde{k}_i) + \frac{\tilde{t}_j(1-\alpha)}{1-\tilde{t}_j}\,\tilde{k}_i = 0 \qquad \forall\, i \neq j. \tag{31}$$

The effects of increased cross-border loss offset on firms' decisions are analogous to those under the benchmark scheme. Hence an increase in $\alpha$ will tend to raise both investment and risk-taking towards their efficient levels. The induced changes in optimal tax rates are analyzed in detail in Appendix 2. It is shown there that the endogenous choice of $\tilde{p}$ makes it more difficult to unambiguously sign the effects on tax rates and tax revenues for arbitrary levels of $\alpha$. When the initial level of $\alpha$ is sufficiently large, however, Propositions 2a and 2b from Section 4 can be shown to carry over to this extension and both tax rates and tax revenues rise when $\alpha$ is (further) increased. Moreover, as in the baseline model, each country benefits from the tax increase in the other country. In sum, therefore, allowing for an endogenous risk choice of firms leads to some changes in the parameter range for which unambiguous results can be derived, but it does not qualitatively affect the results from the baseline model.

## 6.3 Asymmetric countries and a minimum loss offset rule

Our analysis has so far focused on the case of symmetric countries. This is a suitable benchmark case if one wants to find analytical solutions, but the practical implementation of a coordinated cross-border loss offset rule will almost always involve asymmetries between countries. In this more realistic setting analytical solutions for the tax competition game become overly complex. However, the basic effects arising under each of the two alternative loss offset schemes are easily deduced from the incentives for firms

[25] This is seen from the fact that the restriction on the level of tax rates in Proposition 1c is relaxed in this extended setting. See eq. (A.14) in the appendix.

and governments derived in Sections 3.1 and 4.1, respectively.[26]

A simple way to generate differences in equilibrium tax rates in the model is to vary only the exogenous profit levels $\overline{G}_i$ earned by the parent companies in the two countries. Let country 1's parent firm have the lower level of exogenous profit income so that $\overline{G}_1 < \overline{G}_2$ while keeping the production function for the subsidiaries equal across countries. In this setting country 2 will have the higher equilibrium tax rate. Under the benchmark loss offset scheme, this implies that country 1 will impose a lower tax on the subsidiary of firm 2, but simultaneously grants a lower rate of loss offset to the subsidiary of its resident firm 1. Under the alternative loss offset scheme, however, country 1 has to offer a higher rate of tax relief to the subsidiaries of its resident company 1 than it applies to the positive profits of the subsidiary of the foreign-based firm 2. In this sense, the alternative loss offset scheme implies redistributive losses for the low-tax country whenever equilibrium tax rates differ across countries.

To reduce or even eliminate such redistributive effects, it is suggestive to employ a *minimum rule* under which each country grants a tax rebate that is based on the minimum of the tax rates in the parent and the subsidiary country.[27] A minimum rule thus leads to a mixed system of cross-border tax relief where low-tax countries apply the benchmark scheme, whereas high-tax countries use the alternative scheme.

The basic incentive for the low-tax country 1 to limit the rate of loss offset under the alternative loss offset scheme is easily shown by introducing a separate loss offset rate $t_1^{LO}$, which applies only to the compensation of losses for the resident firm. The expected profits for firm 1 are then

$$E(\pi_1) = (1 - t_1)\overline{G}_1 + (1 - t_2)p[f(k_1) - k_1] - (1 - \alpha t_1^{LO})(1 - p)k_1.$$

From firm 1's first-order condition, its optimal investment (in country 2) is unambiguously rising in the isolated loss offset rate $t_1^{LO}$:

$$\frac{\partial k_1}{\partial t_1^{LO}} = \frac{\alpha(1-p)}{-(1-t_2)pf_{k_1k_1}} \geq 0. \tag{32}$$

[26]Recall that our model set-up for both loss offset schemes (Sections 3.1 and 4.1) has allowed for asymmetries between countries and the symmetry assumption has only been employed to derive the equilibrium effects of cross-border loss offset (Sections 3.2 and 4.2). See footnote 13.

[27]This is similar to the worldwide regime for dividend taxation under the tax credit method where the parent country grants a credit for taxes paid in the subsidiary country, but it does not make positive payments to the firm if the tax rate in the subsidiary country exceeds the tax rate in the parent country. See e.g. Gresik (2001, Sec. 5).

The tax revenue expression for the low-tax country is

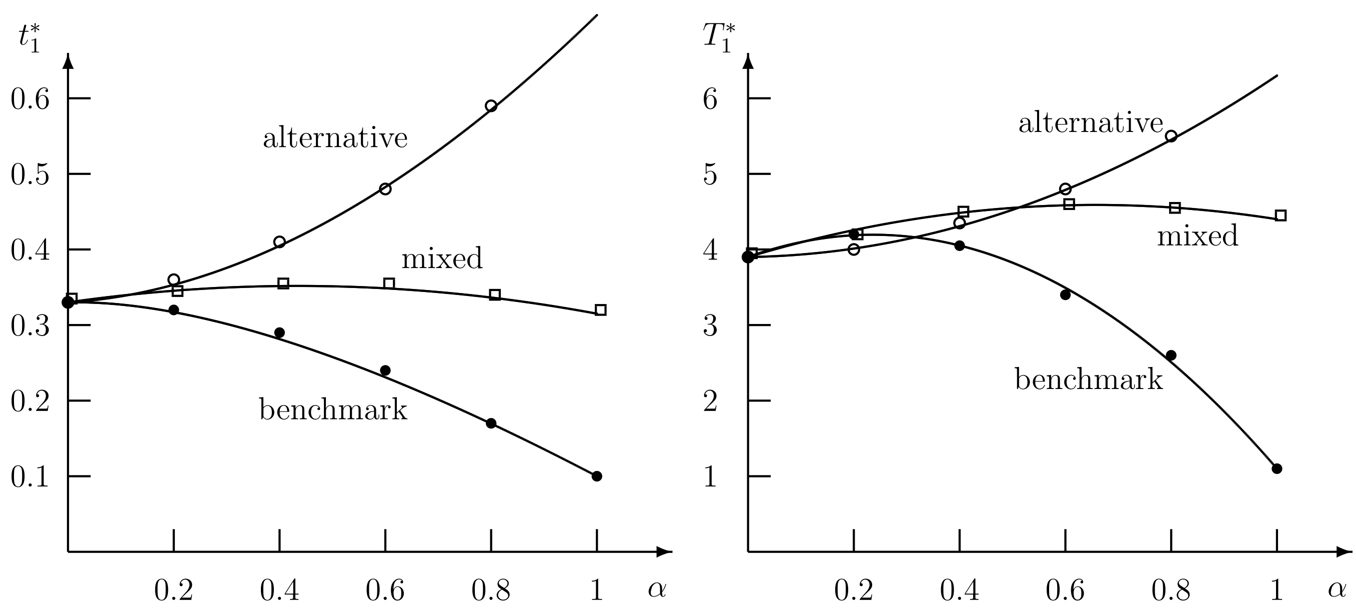
$$T_1 = t_1 \left\{ \overline{G}_1 + p[f(k_2) - k_2] \right\} - \alpha t_1^{LO} (1-p) k_1.$$

Differentiating with respect to $t_1^{LO}$ gives

$$\frac{\partial T_1}{\partial t_1^{LO}} = -(1-p) \left[ k_1 + \alpha t_1^{LO} \frac{\partial k_1}{\partial t_1^{LO}} \right] < 0, \tag{33}$$

which can be unambiguously signed from (32). Hence, reducing the tax rate for loss offset $t_1^{LO}$ raises country 1's tax revenues from both the direct (mechanical) effect, and from the reduced investment of its resident firm in country 2. Note, however, that eq. (33) captures only the first-round effect of a reduction in $t_1^{LO}$ on country 1's tax revenue. It does not incorporate the general equilibrium effects that arise from the changed nature of tax competition with country 2. These effects must therefore be simulated when countries are asymmetric.

Figure 3: Tax rates and tax revenue effects for a low-tax country (country 1)




Notes: $\overline{G}_1 = 0.5$, $\overline{G}_2 = 5.0$, $A = 5$, $\varepsilon = 0.8$, $p = 0.5$.

Figure 3 presents the results from some representative simulations of the tax competition game under the two 'pure' systems of cross-border loss offset and under the mixed scheme just discussed. The exogenous profit levels of parent companies are set at $G_1 = 0.5$ and $G_2 = 5.0$. All other parameters are kept unchanged from the symmetric case shown in Figure 1. To emphasize the redistributive effects arising under the alternative loss offset scheme, we assume that the success probability of investments is low ($p = 0.5$) and loss compensation is accordingly likely. Our presentation of the results focuses on the low-tax country 1. The full set of simulation results is reported in Appendix 3.

The left panel of Figure 3 shows how country 1's optimal tax rate develops for changing levels of $\alpha$. Under the benchmark loss offset scheme, country 1's tax rate again falls monotonically, as in the symmetric case (Case 2 of Figure 1). Under the alternative loss offset system, country 1's optimal tax rate is fundamentally unchanged from the symmetric case and is monotonously rising in $\alpha$. Under the mixed system the low-tax country 1 applies the benchmark scheme, whereas the high-tax country 2 applies the alternative scheme. In comparison to the case where both countries operate the alternative loss offset scheme, country 1's tax rate is reduced by the switch to the benchmark system, due to the incentive to strategically lower the domestic tax rate. In comparison to the case where both countries use the benchmark scheme, country 1's tax rate is instead increased, because country 2 operates the alternative loss offset scheme and its tax rate is rising in $\alpha$. The higher tax rate of country 2 in turn lowers investments by the subsidiary of firm 1. This reduces loss compensation for the government of country 1 and allows it to raise its optimal tax rate in equilibrium. Hence, under the mixed system, country 1's tax rate lies in between the tax rates of the two 'pure' schemes.

The right panel of Figure 3 shows the tax revenue implications for country 1. For low levels of $\alpha$, tax revenue in country 1 is higher under the benchmark loss offset scheme than under the alternative scheme. In this range, the dominant effect is that country 1 does not have to base its tax rebates on the higher tax rate in country 2 when it uses the benchmark loss offset scheme. As $\alpha$ is further increased, however, the higher tax rates chosen under the alternative loss offset scheme overcompensate this effect and tax revenues for country 1 are thus higher under the alternative loss offset scheme. Finally, the mixed scheme strictly dominates the (pure) benchmark scheme of loss offset from the perspective of country 1, as this country benefits from the higher tax rate chosen by country 2 under the alternative scheme. In comparison to the pure alternative scheme, the mixed system dominates for sufficiently low levels of $\alpha$, whereas the pure alternative system is preferred for high levels of cross-border loss offset.

For the high-tax country 2, the ranking of the three loss offset schemes is instead unambiguous. This country's tax revenues are highest under the pure alternative scheme and lowest under the pure benchmark scheme for all levels of $\alpha$ (see Appendix 3). In sum, then, there is a trade-off between the mixed loss offset scheme and the pure alternative scheme for the low-tax country, as the first scheme reduces negative redistributive effects but also maintains the incentive for downward tax competition. In contrast, the pure benchmark scheme is dominated by one of these alternatives for all levels of $\alpha$. We thus conclude that the benchmark scheme of loss offset remains undesirable from the perspective of revenue-maximizing governments, if asymmetries between countries are incorporated.

# 7 Conclusions

In its 2005 *Marks and Spencer* ruling, the European Court of Justice has established the principle that the parent country of a multinational firm must allow cross-border tax relief for the losses incurred by a subsidiary in a different EU member state, if the losses incurred by the subsidiary are 'final'. Given this ruling, it is very likely that EU member states will be legally obliged to offer some form of cross-border loss offset in the coming years, even though the exact conditions under which this occurs are not yet clear. The critical question is then how to introduce cross-border loss offset in a way that minimizes the negative side effects of this change for member states' tax revenues.

In this paper we have analyzed two alternative schemes of introducing a coordinated form of cross-border loss offset. Under the first, 'benchmark' scheme, each country bases the tax rebate to loss-making subsidiaries of its domestic multinationals on its own corporate tax rate. When this scheme is applied, a coordinated increase in cross-border loss compensation is likely to reduce optimal tax rates, at least when the level of cross-border tax relief is high. In an environment where tax competition is an important concern, as is the case in Europe, our analysis therefore warns that introducing cross-border loss compensation may well aggravate tax competition, by increasing the 'costs' to governments of applying a high corporate tax rate. These behavioral effects imply that the overall tax revenue losses accompanying the introduction of cross-border tax relief are likely to be even larger than the direct (mechanical) effects of the reform.

We also show that a simple change in the scheme of cross-border tax relief will suffice to eliminate these undesirable side effects of the reform. All that is needed is to apply the tax rate of the subsidiary's host country, rather than the parent country's home tax rate, when calculating the tax rebate. In contrast to the benchmark setting, equilibrium taxes are likely to rise under the alternative loss offset scheme when cross-border loss compensation is increased. As a consequence, tax revenue losses will be lower than is implied by the direct effect of the reform. Moreover, this scheme will also exhibit the efficiency-enhancing effects on firms' investment and risk-taking decisions that represent the core advantages of cross-border loss compensation. Finally, the redistributive effects that arise under this scheme when tax rates differ between countries can be reduced or even avoided, if each country is given the option to apply the minimum of the tax rates in the parent and the subsidiary country to the cross-border loss relief.

Our analysis can be extended in several ways. A first extension would be to introduce an intertemporal model of investment and cross-border loss compensation. This would allow, for example, to distinguish between a temporary and a permanent transfer of losses from the subsidiary to the parent country, or to capture loss carryforward provisions in the host country that are limited in time. We doubt, however, that adding these realistic features would overturn the qualitative conclusions of our analysis with respect to the ranking of the different loss offset regimes. A second, and more fundamental, extension would be to endogenize the location decisions of multinational firms, which have been taken as given in the present analysis. In such a setting, countries may have an incentive to grant positive levels of cross-border loss offset in a fully decentralized tax equilibrium, in order to attract headquarter location. An analysis of this case is left for future research.

# Appendix

## Appendix 1: Signing the multiplier $\phi$

**Benchmark scheme.** The variable $\phi$ in equation (8) incorporates all indirect effects of $\alpha$ via the tax rates $t_i$ and $t_j$

$$\phi \equiv -\left(\Omega_i + \frac{\partial B_i}{\partial t_i} + \frac{\partial B_i}{\partial t_j} + \frac{\partial \Omega_i}{\partial t_i} + \frac{\partial \Omega_i}{\partial t_j}\right). \tag{A.1}$$

To sign $\phi$, we first derive from (3)

$$\frac{\partial^2 k_i}{\partial t_i^2} = 0, \quad \frac{\partial^2 k_j}{\partial t_i^2} = \frac{2(1-\alpha t_j)(1-p)}{p(1-t_i)^3 f_{k_j k_j}}, \quad \frac{\partial^2 k_i}{\partial t_i t_j} = \frac{-\alpha(1-p)}{p(1-t_i)^2 f_{k_j k_j}}. \tag{A.2}$$

Using the symmetry condition, (2), (4), and (7) and rearranging terms gives:

$$\phi = \frac{-(1-p)^2}{p(1-t)^4 f_{kk}}[(1-\alpha)^2 + (1+t)(1-\alpha t)^2 + \alpha^2(1-t)^3] > 0. \tag{A.3}$$

**Alternative scheme.** Analogously to (A.1), the multiplier $\tilde{\phi}$ is defined as

$$\tilde{\phi} \equiv -\left(\tilde{\Omega}_i + \frac{\partial \tilde{B}_i}{\partial t_i} + \frac{\partial \tilde{B}_i}{\partial t_j} + \frac{\partial \tilde{\Omega}_i}{\partial t_i} + \frac{\partial \tilde{\Omega}_i}{\partial t_j}\right). \tag{A.4}$$

To sign $\tilde{\phi}$, we derive from (20)

$$\frac{\partial^2 k_j}{\partial t_i \partial t_j} = 0, \quad \frac{\partial^2 k_j}{\partial t_i^2} = \frac{2(1-\alpha)(1-p)}{p(1-t_i)^3 f_{k_j k_j}}. \tag{A.5}$$

Using the symmetry condition, (19), (20), and (22) and rearranging terms, we get

$$\tilde{\phi} = \frac{-(1-p)^2}{p(1-t)^4 f_{kk}}[2(1-\alpha t) + (1-\alpha)t] > 0. \tag{A.6}$$

## Appendix 2: The model with endogenous risk choice by firms

**Benchmark scheme.** Totally differentiating the first-order conditions (2) and (30) leads to the following equation set:

$$\begin{bmatrix} \gamma_1 & \gamma_2 \\ \gamma_2 & \gamma_3 \end{bmatrix} \times \begin{bmatrix} \mathrm{d}k_i \\ \mathrm{d}p_i \end{bmatrix} = \begin{bmatrix} \gamma_4 \\ \gamma_5 \end{bmatrix} \mathrm{d}t_j + \begin{bmatrix} \gamma_6 \\ \gamma_7 \end{bmatrix} \mathrm{d}t_i, \tag{A.7}$$

where

$$\begin{aligned} \gamma_1 &= (1-t_j)p_i f_{k_i k_i} < 0, \qquad \gamma_2 = (1-t_j)[f_{k_i} - 1 + p_i f_{k_i p_i}] + 1 - \alpha t_i \\ \gamma_3 &= (1-t_j)(2f_{p_i} + p_i f_{p_i p_i}) < 0, \qquad \gamma_4 = p_i(f_{k_i} - 1) \geq 0 \\ \gamma_5 &= f(p_i, k_i) + p_i f_{p_i} - k_i < 0, \qquad \gamma_6 = -\alpha(1-p_i) \leq 0 \\ \gamma_7 &= \alpha k_i \geq 0 \end{aligned} \tag{A.8}$$

In this setting, the sign of $\gamma_2$ is ambiguous. We assume in the following that the complementarity between investment and risk-taking, leading to $f_{k_i,p_i} < 0$, is sufficiently strong to make $\gamma_2$ negative. This is a sufficient, but not a necessary condition to unambiguously sign the comparative static effects that follow.

Applying Cramer's rule to the equation system (A.7), the effects of taxes on investment levels and risk choices in each country can be signed as:

$$\frac{\mathrm{d}k_i}{\mathrm{d}t_i} = \frac{\gamma_3\gamma_6 - \gamma_2\gamma_7}{\gamma_1\gamma_3 - \gamma_2{}^2} > 0, \qquad \frac{\mathrm{d}k_i}{\mathrm{d}t_j} = \frac{\gamma_3\gamma_4 - \gamma_2\gamma_5}{\gamma_1\gamma_3 - \gamma_2{}^2} < 0, \tag{A.9}$$

$$\frac{\mathrm{d}p_i}{\mathrm{d}t_i} = \frac{\gamma_1\gamma_7 - \gamma_2\gamma_6}{\gamma_1\gamma_3 - \gamma_2{}^2} < 0, \qquad \frac{\mathrm{d}p_i}{\mathrm{d}t_j} = \frac{\gamma_1\gamma_5 - \gamma_2\gamma_4}{\gamma_1\gamma_3 - \gamma_2{}^2} > 0. \tag{A.10}$$

The effects in $k_i$ in (A.9) correspond to the baseline model. Eq. (A.10) shows that an increase in country $j$'s tax rate leads to less risk-taking by the subsidiary of firm $i$. In contrast, an increase in the tax rate of country $i$ increases risk-taking by firm $i$'s subsidiary when the loss offset parameter $\alpha$ is strictly positive.

The optimal tax rate is determined analogously to (8). We denote variables by a 'hat' symbol and assume the multiplier $\hat{\phi}$ to be positive. The change in country $i$'s tax base following an increase in $\alpha$ is given by

$$\frac{\partial \hat{B}_i}{\partial \alpha} = -(1-p)k - \frac{(1-\alpha)(1-p)^2 t}{(1-t)\gamma_1} - \frac{(1-\alpha)k^2 t}{(1-t)\gamma_3} \tag{A.11}$$

As in the benchmark model, the effect can only be signed when cross-border loss offset is almost complete ($\alpha \to 1$) and countries are symmetric. In this case all indirect effects operating through induced changes in $k_i$ and $p_i$ cancel out, leaving only the negative direct effect of $\alpha$.

The effects of a change in $\alpha$ on $\hat{\Omega}_i$ are also ambiguous, in general. The total change is:

$$\frac{\partial \hat{\Omega}_i}{\partial \alpha} = \frac{\partial \gamma_4}{\partial \alpha}\frac{\mathrm{d}k_j}{\mathrm{d}t_i} + \frac{\partial \gamma_5}{\partial \alpha}\frac{\mathrm{d}p_j}{\mathrm{d}t_i} + \frac{\partial \gamma_6}{\partial \alpha}\frac{\mathrm{d}k_i}{\mathrm{d}t_i} + \frac{\partial \gamma_7}{\partial \alpha}\frac{\mathrm{d}p_i}{\mathrm{d}t_i} + \gamma_4 \frac{\partial(\mathrm{d}k_j/\mathrm{d}t_i)}{\partial \alpha} + \gamma_5 \frac{\partial(\mathrm{d}p_j/\mathrm{d}t_i)}{\partial \alpha} + \gamma_6 \frac{\partial(\mathrm{d}k_i/\mathrm{d}t_i)}{\partial \alpha} + \gamma_7 \frac{\partial(\mathrm{d}p_i/\mathrm{d}t_i)}{\partial \alpha}. \tag{A.12}$$

For $\alpha \to 1$, this expression can be unambiguously signed. Evaluating (A.12) at $\alpha = 1$ and using $\gamma_4|_{\alpha=1} = (1 - p_i)$, $\gamma_5|_{\alpha=1} = -k_i$, $\gamma_6|_{\alpha=1} = -(1 - p_i)$, $\gamma_7|_{\alpha=1} = k_i$ and the symmetry condition $t_i = t_j$ gives

$$\left.\frac{\partial \hat{\Omega}_i}{\partial \alpha}\right|_{\alpha=1} = \frac{-4t_i\gamma_2}{N^2}\{[(1-p_i)\gamma_3 + k_i\gamma_2] + [k_i\gamma_1 + (1-p_i)\gamma_2]\} + \frac{(1-p_i)\gamma_3 + k_i\gamma_2}{N}\left[\frac{2-3t_j}{1-t_j}(1-p_i) + \frac{(\gamma_2 + 1 - t_j)t_j k_i}{(1-t_j)\gamma_3}\right] + \frac{k_i\gamma_1 + (1-p_i)\gamma_2}{N}\left[\frac{2-3t_j}{1-t_j}\,k_i + \frac{(\gamma_2 + 1 - t_j)t_j(1-p_i)}{(1-t_j)\gamma_1}\right], \tag{A.13}$$

where $N = \gamma_1\gamma_3 - \gamma_2^2 > 0$. A sufficient condition for the terms in squared brackets, and therefore for the entire derivative, to be negative is that $t_j \leq 2/3$. Hence we get:

$$\left.\frac{\mathrm{d}\hat{\Omega}_i}{\mathrm{d}\alpha}\right|_{\alpha=1} < 0 \quad \Leftrightarrow \quad t \leq \frac{2}{3}. \tag{A.14}$$

In comparison to the benchmark model [eq. (12)] the range of tax rates for which Proposition 1a obtains is thus enlarged, due to the endogenous risk choice of firms.

To analyze the total change in equilibrium tax revenues, we need to determine the tax externality. This is given by

$$\frac{\partial \hat{T}_i}{\partial t_j} = t_i\left[\gamma_4\,\frac{\mathrm{d}k_j}{\mathrm{d}t_j} + \gamma_5\,\frac{\mathrm{d}p_j}{\mathrm{d}t_j} + \gamma_6\,\frac{\mathrm{d}k_i}{\mathrm{d}t_j} + \gamma_7\,\frac{\mathrm{d}p_i}{\mathrm{d}t_j}\right] > 0. \tag{A.15}$$

As in the baseline model, the tax externality is positive, implying that Proposition 1c carries over to this model extension. In comparison to the baseline model, a rise in $t_j$ further expands country $i$'s expected tax base through a higher risk level chosen by the subsidiary of firm $j$. Moreover, risk-taking by the subsidiary of firm $i$ is discouraged, reducing the expected tax rebates that have to be paid by country $i$'s government.

**Alternative scheme.** Totally differentiating the first-order conditions under the alternative scheme, eqs. (19) and (31), gives the equation set:

$$\begin{bmatrix} \bar{\gamma}_1 & \bar{\gamma}_2 \\ \bar{\gamma}_2 & \bar{\gamma}_3 \end{bmatrix} \times \begin{bmatrix} \mathrm{d}k_i \\ \mathrm{d}p_i \end{bmatrix} = \begin{bmatrix} \bar{\gamma}_4 \\ \bar{\gamma}_5 \end{bmatrix} \mathrm{d}t_j, \tag{A.16}$$

where variables for the alternative scheme are indicated by a bar and

$$\begin{aligned} \bar{\gamma}_1 &= (1-t_j)p_i f_{k_i k_i} < 0, \qquad \bar{\gamma}_2 = (1-t_j)[f_{k_i} - 1 + p_i f_{k_i p_i}] + 1 - \alpha t_j < 0 \\ \bar{\gamma}_3 &= (1-t_j)(2f_{p_i} + p_i f_{p_i p_i}) < 0, \qquad \bar{\gamma}_4 = (1-p_i)(1-\alpha)/(1-t_j) \geq 0, \\ \bar{\gamma}_5 &= -(1-\alpha)k_i/(1-t_j) \leq 0. \end{aligned} \tag{A.17}$$

Following (8), we assume that $\bar{\phi} > 0$. The effect of $\alpha$ on country $i$'s tax base is given by

$$\frac{\partial \bar{B}_i}{\partial \alpha} = -\frac{(1-p)^2(1-\alpha t)t}{(1-t)\bar{\gamma}_1} - \frac{k^2(1-\alpha t)t}{(1-t)\bar{\gamma}_3} > 0. \tag{A.18}$$

The effect of an increase in $\alpha$ on $\bar{\Omega}_i$ is

$$\begin{aligned} \frac{\partial \bar{\Omega}_i}{\partial \alpha} = &- \frac{(1-\alpha)t + (1-\alpha t)]k^2}{(1-t)^2 \bar{N}} \bar{\gamma}_1 - \frac{2(1-p)k[t + (1-\alpha t)\bar{N}]}{(1-t)^2 \bar{N}} \bar{\gamma}_2 \\ &- \frac{(1-p)^2[(1-\alpha)t + (1-\alpha t)]}{(1-t)^2 \bar{N}} \bar{\gamma}_3 - \frac{2(1-\alpha)(1-\alpha t)tk}{(1-t)^2 \bar{N}^2} \bar{\gamma}_1 \bar{\gamma}_2 \\ &- \frac{2(1-\alpha)(1-\alpha t)t(1-p)^2}{(1-t)^2 \bar{N}^2} \bar{\gamma}_3 \bar{\gamma}_2 - \frac{4(1-\alpha)(1-\alpha t)(1-p)tk}{(1-t)^2 \bar{N}} \bar{\gamma}_2^2 \\ &- \frac{(1-p)(1-\alpha)(1-\alpha t)(1+t)k}{(1-t)^2 \bar{N}}, \end{aligned} \tag{A.19}$$

with $\bar{N} = \bar{\gamma}_1 \bar{\gamma}_3 - \bar{\gamma}_2^2 > 0$. The first three terms on the right hand side of (A.19) are positive, the last four are negative. However, if cross-border loss offset is almost complete ($\alpha \to 1$), these effects are negligible. Hence the total effect on $\bar{\Omega}_i$ is positive and therefore also the overall effect of $\alpha$ on the tax rate.

Finally, deriving the tax externality by analogy to (26) gives

$$\frac{\partial \bar{T}_i}{\partial t_j} = \frac{\alpha}{(1-\alpha t)} \left[ (1-t)\bar{B}_i - (1-\alpha t)(1-p)k \right] > 0, \tag{A.20}$$

where $\bar{B}_i$ is given in (A.18). Hence tax revenues unambiguously rise in both countries when $dt_i/d\alpha$ is positive.

## Appendix 3: Simulation results for asymmetric countries

Table A.1: Cross-border loss compensation with asymmetric countries

| | benchmark scheme | | | | alternative scheme | | | | mixed scheme | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\alpha$ | $t_1$ | $t_2$ | $T_1$ | $T_2$ | $t_1$ | $t_2$ | $T_1$ | $T_2$ | $t_1$ | $t_2$ | $T_1$ | $T_2$ |
| 0.0 | 0.33 | 0.41 | 3.89 | 5.55 | 0.33 | 0.41 | 3.89 | 5.55 | 0.33 | 0.41 | 3.89 | 5.55 |
| 0.2 | 0.32 | 0.40 | 4.20 | 5.54 | 0.37 | 0.43 | 4.13 | 5.89 | 0.35 | 0.41 | 4.16 | 5.73 |
| 0.4 | 0.29 | 0.33 | 4.13 | 5.20 | 0.41 | 0.46 | 4.45 | 6.35 | 0.36 | 0.41 | 4.40 | 5.89 |
| 0.6 | 0.24 | 0.27 | 3.42 | 4.23 | 0.48 | 0.54 | 4.88 | 7.00 | 0.36 | 0.41 | 4.55 | 5.88 |
| 0.8 | 0.17 | 0.19 | 2.20 | 2.78 | 0.58 | 0.63 | 5.58 | 8.12 | 0.35 | 0.41 | 4.53 | 5.47 |
| 1.0 | 0.11 | 0.13 | 1.09 | 1.46 | 0.68* | 0.71* | 6.20* | 9.16* | 0.32 | 0.41 | 4.29 | 4.59 |

Notes: $\overline{G}_1 = 0.5$, $\overline{G}_2 = 5.0$; $A = 5$, $\varepsilon = 0.8$, $p = 0.5$.

* values for $\alpha = 0.9$ (no interior solution for $\alpha = 1$)

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