Spillovers and International Competition for Investments*

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Abstract

Two jurisdictions compete to attract shares of the investment budget of a large multinational enterprise, whose investments confer positive spillovers on national firms. The firm has private information about its efficiency and about spillovers. It is shown that the firm may gain from governmental tax coordination. Relative to a cooperative tax agreement, tax competition may induce excessive investments in the country where the positive spillover effects are lowest. Also, with sufficiently asymmetric spillovers, investments under competition will be excessively spread out, not properly concentrated to the country where spillovers would be largest. Equilibrium outcomes in the taxation game depend on the firm's ownership structure, and the firm as well as the governments may wish to influence this structure to affect the equilibrium.

1 Introduction

National governments compete to attract investments from multinational enterprises (MNEs), in particular from enterprises that may generate positive spillover effects (positive externalities) for national firms. Given the characteristics of MNEs[1], e.g. technically complex

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[1] MNEs tend to be important in industries characterized by a high value of intangible assets, a large share of professional and technical workers in their work force, products that are new or technically complex, and high levels of product differentiation and advertising (Markusen 1995).

products, there is every reason to believe that such a firm is better informed about its operations than are any of the national governments that it relates to. The international nature of an MNE and the high number of interfirm transactions also make it hard for tax authorities to observe true income and costs. Countries that try to attract investments from such a firm, must then take informational asymmetries into account in their policy design.

An interesting and from a policy perspective important issue is whether competition leads to misallocations in the sense of investments becoming too much spread out, not properly concentrated in the country where they would yield the largest spillovers. The model presented in this paper shows that tax competition does have this effect when the MNE has private information regarding spillovers, and these spillovers are sufficiently asymmetric between countries. Comparing non-cooperative and cooperative investments in such cases, we find that non-cooperative investments are either higher in both countries, or higher (respectively lower) than cooperative investments in the country where spillovers are low (respectively high). With highly asymmetric spillovers there is thus a tendency for tax competition to induce investments that are either overall too high, or skewed towards overinvestments in the country with low spillovers combined with underinvestments in the country with high spillovers.

To avoid a damaging race-to-the-bottom tax competition, countries may strive to coordinate their tax policies. We examine the likely effects of tax harmonization, by comparing investment and profit levels in cooperative and non-cooperative tax equilibria. We find, among other things, that there is lower investment – and lower profits for the firm – under competition than under coordination if spillovers are small, investments are not too close substitutes, the cost of public funds is small, and/or domestic owner shares are large. The latter observation indicates that international cross-ownership is to the benefit of the firm.

When the MNE has private information, its ownership structure affects the outcome of the tax competition game because national owner shares influence the national governments' motives to extract rents from the firm. (This may explain why governments are concerned with local ownership; many countries attempt to secure minimum national ownership stakes in firms that invest locally, e.g. by indigenisation requirements.) In the case of asymmetric spillovers, we find that the firm prefers a larger owner share by shareholders in the country where the spillovers are largest. Total welfare, however, is largest when ownership is split more equally among investors in the two countries.

We consider a multi-principal regulation model of an MNE. The MNE (the agent) allocates its real investment portfolio between two jurisdictions, and has an option of redirecting parts of the investments from one of the jurisdictions to the other. The firm is assumed to have private information about its net operating profits and its productivity in the two countries. It is also assumed to have superior information about the potential positive spillovers that its activity may generate. As a part of a tax bargaining strategy the firm may then have an incentive to misrepresent its earning potential and the extent of spillovers in each individual country. Also, having investment opportunities in several countries, the MNE may try to reduce tax payments in each country by an implicit threat of directing a larger fraction of its investment to the neighbouring country. The governments' challenge in this setting is to cope with private information in taxing MNEs, and at the same time encourage investment-induced spillovers on national firms.

After this introduction the model is presented in section 2. Sections 3 and 4 consider cooperative and non-cooperative equilibria, respectively, and discusses related literature. Spillover effects are analysed in detail for parametric functions in section 5, and section 6 concludes.

2 The model

We model a tax bargaining situation between a unique, large MNE (agent) and two independent countries (principals).[2] There is strategic tax competition between the two countries where the firm is located, which is captured by a common agency framework. The MNE invests K_1 in country 1 and K_2 in country 2, yielding global profits (before taxes) $\Pi(K_1, K_2, \theta)$, where θ is an efficiency parameter.[3] Investments are substitutes:

$$\frac{\partial^2 \Pi}{\partial K_1 \partial K_2}(K_1, K_2, \theta) < 0$$

There are various reasons for assuming substitutability. First, there may be interaction effects in terms of joint costs, i.e. global profits may be of the form $\Pi(K_1, K_2, \theta) = N_1(K_1, \theta) + N_2(K_2, \theta) - C(K_1 + K_2)$ where $C(K_1 + K_2)$ denotes joint costs, and $N_i(K_i, \theta)$ denotes operating profits for the affiliate in country i. Convex costs imply economic

[2] Alternatively, the model can be interpreted as describing multi-principal regulation of an internationally mobile industry with a continuum of small firms with different efficiency types for investments in the two countries and with different extent of local spillovers.

[3] In addition there may be sunk investments in both countries.

interaction effects between the two affiliates; an increase in investments in one of the countries implies higher marginal joint costs, and thus lower marginal (global) profits from investments in the other country. These joint costs may have different interpretations. First, $K = K_1 + K_2$ may represent scarce human capital, e.g. management resources or technical personnel, where we assume that the MNE faces convex recruitment and training costs. Second, K may represent real investments, where $C(K)$ are management and monitoring costs of the MNE. Economic management and coordination often become more demanding as the scale of international operations increase, i.e. $C(K)$ is likely to be convex. Finally, instead of – or in addition to – interaction effects from joint costs, there may in the case of imperfect competition be interaction effects in terms of market power. For example, if the two affiliates sell their output on the same market (e.g. in a third country), their activities are substitutes: high investments (and output) in affiliate 1 reduce the price obtained by affiliate 2.

The countries compete to attract scarce real investments from the MNE, and design their respective tax systems with a view to this competitive situation. The affiliates of the MNE are separate and independent entities, which means that they are subsidiaries and thus taxed at source. Letting r_1 and r_2 denote, respectively, the taxes paid to the two countries, the post-tax global profits of the firm are given by

$$\pi = \Pi - r_1 - r_2. \tag{1}$$

The firm has private information about θ. It is presumed that if the firm is efficient in one country it is also an efficient operator in the other country. The efficiency type is distributed on $[\underline{\theta}, \bar{\theta}]$ according to the cumulative distribution function $F(\theta)$, with density $f(\theta) > 0$, where $\underline{\theta}$ denotes the least and $\bar{\theta}$ the most efficient type. The probability distribution satisfies the monotone hazard rate condition.[4] Efficient types have higher operating profits than less efficient types, both on average and at the margin: $\frac{\partial \Pi}{\partial \theta} > 0$ and $\frac{\partial^2 \Pi}{\partial \theta \partial K_j} > 0$, $j = 1, 2$. The joint return function has sufficiently decreasing marginal returns on capital so that it is optimal for the firm to invest in both countries.

The firm's investments contribute some positive spillovers/externalities $\tilde{E}_j(K_j, \theta)$ to each country. The magnitudes of these externalities are known by the firm, but not by the authorities. These are also assumed to be positively correlated with the firm's productivity;

[4] This condition is satisfied by most usual probability distributions, e.g., the normal, uniform, logistic and exponential distributions.

so $\partial\tilde{E}_j(K_j,\theta)/\partial\theta > 0$.

The MNE and the governments are risk neutral. For all efficiency types the affiliate's net operating profits in each country are sufficiently high so that both governments always want to induce the domestic affiliate to make some investments in their home country. Domestic consumer surpluses in the two countries are unaffected by changes in the MNE's production level, since the firm is assumed to be a price taker (or its market is outside the two countries). The governments have utilitarian objective functions: the social domestic welfare generated by an MNE of efficiency type θ is given by a weighted sum of the domestic taxes paid by the firm, the positive spillovers it generates (for other domestic firms), and the MNE's global profits:

$$W_j = (1+\lambda_j)r_j + \tilde{E}_j(K_j,\theta) + \alpha_j\pi, \quad j = 1,2,$$

where λ_j is the general equilibrium shadow cost of public funds in country j, and α_j is the owner share of country j in the MNE.[5] We have $\lambda_j > 0, \ j = 1,2$, since marginal public expenditure is financed by distortive taxes. By inserting for Eq.(1), the social welfare function for country 1 can be restated as

$$W_1 = (1+\lambda_1)\left(\Pi(K_1,K_2,\theta) - r_2 + E_1(K_1,\theta)\right) - (1+\lambda_1-\alpha_1)\pi, \tag{2}$$

where $E_j(K_j,\theta) = \frac{1}{1+\lambda_1}\tilde{E}_j(K_j,\theta)$. The social welfare consists of two terms. The first term is domestic social welfare under commonly known information, i.e. the welfare we would get if the government were able to tax away all the residual income of the MNE. The government's revenue is in this case given by the MNE's net operating profits minus foreign source tax, plus the "adjusted" value of spillovers, and multiplied by $(1+\lambda_1)$ to obtain a welfare measure. The second term of the welfare function corrects for the loss of social welfare that stems from private information, i.e. the welfare loss to the country caused by the MNE keeping parts of the rent. The loss caused by imperfect rent extraction is equal to the MNE's global rent multiplied by the difference between the welfare weights for income accruing to the MNE and the national government. The social welfare function for country 2 is analogous. Assuming that $\lambda_1 = \lambda_2 = \lambda$,

$$W = (1+\lambda)\left(\Pi(K_1,K_2,\theta) + E_1(K_1,\theta) + E_2(K_2,\theta)\right) - (1+\lambda-\alpha_1-\alpha_2)\pi \tag{3}$$

[5] The shadow cost of public funds is taken as exogenously given in our partial analysis. It can be endogenised by a general equilibrium model, without affecting the qualitative results. See Laffont and Tirole (1993), chapter 4.

is the cooperative welfare function.

Inserting $\pi(\theta) = 0$ in (3) and maximising with respect to. K_1 and K_2, we obtain *the first-best global allocation*, given by $\frac{\partial \Pi}{\partial K_1} + \frac{\partial E_1}{\partial K_1} = \frac{\partial \Pi}{\partial K_2} + \frac{\partial E_2}{\partial K_2} = 0$. This allocation is obtained in the case of cooperating principals and commonly known information. The solution can be attained by imposing type-dependent taxes that correct for the externalites and at the same time extract the firm's rents.

3 The second-best cooperative equilibrium

When the agent possesses private information and the principals cooperate, they seek to maximise the joint welfare given by Eq.(3), subject to incentive and participation constraints. The participation constraints make sure that the firm finds investments in the two countries profitable, compared to investment opportunities in other countries. The incentive constraints stem form the fact that the company has private information, making it difficult for the governments to ascertain the true tax potential. A firm of type θ can, by mimicking a less efficient type $\theta - d\theta$, obtain profits $d\pi = \frac{\partial \Pi}{\partial \theta} d\theta$, so the tax scheme must allow for such profits (rents). Incentive compatibility thus requires

$$\pi'(\theta) = \frac{\partial \Pi(K_1(\theta), K_2(\theta), \theta)}{\partial \theta}. \tag{4}$$

It can be shown that sufficient conditions for incentive compatibility are that $dK_j(\theta)/d\theta \geqslant 0, j = 1, 2$. We see from Eq.(4) that the firm's rent is increasing in θ, i.e. to be willing to self-select, efficient types must be rewarded with a higher rent than inefficient types. Maximizing joint welfare subject to (4) yields the following equations for the optimal investment portfolio:[6]

$$\frac{\partial E_j(K_j, \theta)}{\partial K_j} + \frac{\partial \Pi(K_1, K_2, \theta)}{\partial K_j} = \frac{1 + \lambda - \alpha_1 - \alpha_2}{1 + \lambda} \frac{\partial^2 \Pi(K_1, K_2, \theta)}{\partial \theta \partial K_j} \frac{1 - F(\theta)}{f(\theta)}, \ j = 1, 2. \tag{5}$$

To interpret these conditions, note that a tax change that induces an investment change dK_j for type θ will affect its rents by $\frac{\partial^2 \Pi}{\partial K_j \partial \theta} d\theta dK_j$, having welfare weight $1 + \lambda - \alpha_1 - \alpha_2$. To preserve incentive compatibility, the same rent differential must be given to all better types, i.e. to a fraction $1 - F(\theta)$ of all types. This rent is costly, and must be weighted against the efficiency gain, which from (2) is given by $(1 + \lambda)(\frac{\partial E_j}{\partial K_j} + \frac{\partial \Pi}{\partial K_j}) dK_j f(\theta) d\theta$. It follows that (5) expresses an optimal trade-off for investment K_j.

[6] For a techical survey of single-principal regulation theory, see Guesnerie and Laffont (1984).

Compared with the first-best global optimum, the presence of private information generates the additional right hand sides of (5), which represent marginal information costs. The investment portfolios are distorted in order to enhance the governments' rent extraction from the MNE, which enables the government to reduce distortive taxes elsewhere in the economy. The distortions entail reductions of investment levels in both countries for all types except the most efficient one. At the same time, distortions of the capital allocation decision of the firm implies that the tax base is reduced. The investment portfolios are distorted to the point where the marginal deadweight loss equals the marginal deadweight losses in other sectors of the economy.

The optimal solution in (5) can, under relatively mild conditions, be implemented by a tax schedule $R(K_1, K_2)$ where total tax payments depend only on realized investments. (See e.g. Laffont and Tirole (1986, 1993)).[7] As a second-best response to private information, the optimal policy deviates from a level playing field (tax neutrality). The flexibility imposed by differential tax enforcement enables the governments to raise welfare, relative to what is obtained with a common proportional effective tax rate. The induced investment distortions improve the governments' ability to capture rent by reducing the firm's incentives to exploit its information advantage.

4 The second-best non-cooperative equilibrium

Consider now the case where the governments of the two countries do not cooperate, but rather compete to attract the firm's investments. In this case the MNE relates to each government separately. The governments cannot credibly share information and they act non-cooperatively, i.e. we seek perfect Bayesian Nash Equilibria. We will focus on the regulatory problem of country 1; the decision problem of country 2 is analogous. Country 1 seeks to maximise expected domestic welfare, subject to incentive compatibility constraints and participation constraints for the firm; given the strategy of country 2. In this setting it is natural to assume that each country offers a tax schedule, effectively specifying the firm's tax obligation to that country as function of its investments in the country.[8] So we are

[7] In general, this will require a tax function that is not additive separable. To implement the cooperative solution taxes must thus in general be coordinated such that the marginal tax in one country depends on investments in both countries.

[8] We assume that domestic investment is the key observable variable to each government.

looking for an equilibrium in tax schedules (or menus) $R_1(K_1), R_2(K_2)$.[9] To interpret these tax schedules, we can envision the countries keeping the statutory corporate income tax rates fixed, and offering non-linear depreciation schedules and tax exemptions to attract investments from the MNE. In designing a non-linear corporate income tax scheme for internationally mobile firms, country 1 takes the depreciation schedules of country 2 as given. However, country 1 must take into account that its choice of strategy (tax schedule) may cause investment externalities: a change in the contract of country 1 may affect the agent's investment in country 2, i.e. the agent's choice of K_1 may affect its investment K_2, and thereby make it deviate from the investment level intended for it by country 2. Similar considerations apply for the latter country. A constraint on equilibrium contracts is imposed by the following feasible strategies: to capture a larger fraction of the MNE's rent, each country will attempt to induce the MNE to deviate from the investment level intended for it by the other country. In equilibrium, however, all contracts are incentive compatible.

4.1 Equilibrium investments and taxes.

Country 1 takes the tax function offered by country 2 as given, and realizes that the firm's investments $K_2(\theta)$ in that country satisfy

$$\frac{\partial \Pi}{\partial K_2}(K_1(\theta), K_2(\theta), \theta) - R_2'(K_2(\theta)) = 0. \tag{6}$$

Incentive compatibility requires that (4) must hold for equilibrium profits in this non-cooperative case as well. The decision problem of country 1 can now be seen as maximizing domestic welfare subject to the constraints (4), (6) and $\pi(\theta) \geq 0$.[10] That is, the regulatory problem is similar to the cooperative case, with an additional restriction. Following a procedure similar to Martimort (1992, 1996a) - see the Appendix - one can see that, if the system of differential equations below defines a pair of nondecreasing investment schedules $\{K_1(\theta), K_2(\theta)\}$, and those schedules in addition satisfy a set of implementability

[9] The Revelation Principle (in its usual form) is not generally valid for common agency, so there may exist equilibria in more general message spaces that can not be replicated as an equilibrium in direct revelation mechanisms (Martimort and Stole 1997, Peters 1999). The restriction to tax schedules seems reasonable in the current application.

[10] The constraint (4) is only the first-order condition for the firm's optimal choice of report. Under additional conditions (common implementability conditions) one can check ex post that the first-order condition is sufficient for optimality.

conditions, they constitute a pure-strategy differentiable Nash equilibrium outcome for the common agency game[11]:

$$\frac{\partial E_j}{\partial K_j}+\frac{\partial \Pi}{\partial K_j}=\frac{1+\lambda-\alpha_j}{1+\lambda}\left[\frac{\partial^2\Pi}{\partial\theta\partial K_j}+\frac{\partial^2\Pi}{\partial\theta\partial K_i}\frac{\frac{\partial^2\Pi}{\partial K_i\partial K_j}K_i'(\theta)}{\frac{\partial^2\Pi}{\partial\theta\partial K_i}+\frac{\partial^2\Pi}{\partial K_i\partial K_j}K_j'(\theta)}\right]\frac{1-F(\theta)}{f(\theta)},\ j=1,2. \tag{7}$$

Note that with full information the first best is attained, so the strategic effects introduced are arising form the presence of private information and not from the technology assumptions. To interpret and understand (7), we present here a heuristic derivation of this equilibrium condition. Country 1 takes the other country's tax schedule as given, and recognises that the firm chooses foreign investments K_2, conditional on domestic investments K_1 in accordance with (6). A change in domestic taxes that induces a marginal change in domestic investments will then induce a change in foreign investments given by $\frac{dK_2}{dK_1}=\frac{-\Pi_{12}}{\Pi_{22}-R_2''}$, where Π_{ij} denote second-order partials. Such a change for type θ will thus affect this type's rent differential ($\frac{\partial\Pi}{\partial\theta}d\theta$) by

$$d\pi=\left[\frac{\partial^2\Pi}{\partial\theta\partial K_1}+\frac{\partial^2\Pi}{\partial\theta\partial K_2}\frac{dK_2}{dK_1}\right]d\theta. \tag{8}$$

The same rent differential must be given to a fraction $1-F(\theta)$ of all types. This is costly, and must be weighted against the efficiency gain, which from (2)-(6) is given by $(1+\lambda)(\frac{\partial E_1}{\partial K_1}+\frac{\partial\Pi}{\partial K_1})f(\theta)d\theta$. It follows that (7) expresses an optimal trade-off for country 1 (for $j=1, i=2$), provided that the last term in the square brackets is an adequate representation of the investment response $\frac{dK_2}{dK_1}=\frac{-\Pi_{12}}{\Pi_{22}-R_2''}$. To see that this is the case, note that (6) must hold for all types in equilibrium, and by differentiation of this relation with respect to θ we see that $\frac{-\Pi_{12}}{\Pi_{22}-R_2''}=\frac{\Pi_{12}K_2'}{\Pi_{2\theta}+\Pi_{12}K_1'}$ holds in equilibrium. Hence, (7) is a pair of equilibrium conditions for the investment allocations that follow from the two countries' strategic choice of tax schedules.

To characterize the equilibrium tax functions, note that (6) holds for each type θ. Let $\theta_j(K_j)$ be the type that invests K_j in country j in equilibrium; i.e. $\theta_j()$ is the inverse of the equilibrium investment schedule $K_j(\theta)$; assuming that the latter is invertible (e.g.

[11] We get the result, traditional for common agency models, that the total tax payments of the MNE are uniquely determined in equilibrium, but not the distribution between the two countries. The latter would be determined outside the model by a bargaining game between the two governments, and will not affect the results of the model.

strictly increasing). Substituting $\theta = \theta_j(K_j)$ in (6) then implies

$$R_j'(K_j) = \frac{\partial \Pi}{\partial K_j}(K_j, K_i(\theta_j(K_j)), \theta_j(K_j)). \tag{9}$$

This relation determines marginal tax rates for all investment levels that can be realized in equilibrium. Note that the tax schedule for an individual country must, for a given tax system in the other country, balance two concerns: (i) to induce production efficiency and (ii) to extract rents from the firm. The first calls for negative tax rates (subsidies) to correct for external spillovers from the firm, the second for positive tax rates to reduce investments and thereby facilitate rent extraction by relaxing the incentive constraints. The equilibrium conditions (7) show that there are no distortions from the first-best 'at the top' (for type $\bar{\theta}$). It follows that the marginal tax rates given by (9) are negative for investments near $\bar{K}_j = K_j(\bar{\theta})$; in fact we have $R_j'(\bar{K}_j) = \frac{\partial \Pi}{\partial K_j}(\bar{K}_j, \bar{K}_i, \bar{\theta}) = -\frac{\partial E_j}{\partial K_j}(\bar{K}_j, \bar{\theta})$. These marginal subsidies induce an efficient firm – which by assumption also generates high spillovers – to increase its investments beyond what would otherwise have been privately optimal. The concern to induce production efficiency thus dominates for such 'high' investments. In order to extract rents from the firm, less efficient types should be induced to invest less, and marginal taxes may for that reason be positive for lower investment levels K_j.

4.2 Tax competition vs. tax harmonization.

What would be the effect of a tax harmonization between the two countries? Comparing the cooperative and the non-cooperative investment solutions, given by Eqs. (5) and (7), respectively, we see that the latter contains an additional term, which accounts for the interaction effect of common agency. This term is negative,[12] and represents a second-order rent effect which calls for *increasing* domestic investments. By imposing taxes that induce an increase in the MNE's domestic investments, the government of country j can cause investments to fall in country i (we have $\frac{dK_i}{dK_j} < 0$), which has the effect, ceteris paribus, of increasing the tax revenue of country j (a fiscal externality).

Apart from differences due to the strategic (fiscal) effect, the cooperative and non-cooperative solutions also differ because in the latter case neither of the governments internalise the profits that accrue to investors in the other country (equity externalities).

[12] The numerator is positive and we know from the necessary second-order conditions for common implementability that the denominator is negative.

For this reason the motive to extract rents is always stronger in the non-cooperative case. This is reflected in the different weights that appear on the right-hand sides of equations (5) and (7); $1 + \lambda - \alpha_j > 1 + \lambda - \alpha_j - \alpha_i$. The equity externalities lead to more aggressive rent collection by the governments, which implies more severe distortions, i.e. lower investments than in the cooperative case. Note that lower investments imply lower profits (rents) for the firm, see (4), and hence that tax competition may harm the firm if the equity effect dominates. These considerations can be summarized as follows:

Proposition 1 *When two countries compete to attract a large share of an MNE's investment budget, and when there is private information about net operating profits, efficiency and external spillovers, the distortion of the investment portfolio is in equilibrium determined by a trade-off between a first-order (conventional) and a second-order (strategic interaction) rent effect. Compared with the cooperative solution, strategic interaction among governments introduces fiscal externalities and equity externalities, having opposite effects on investment levels. Hence, it cannot be generally determined whether tax harmonization leads to higher or lower investments and profits for the firm.*

The strategic effected associated with common agency is well known, see e.g. Stole (1992). An effect somewhat similar to the equity externality can be found in Martimort (1996b), where multiple regulators have biased objectives favoring an interest group. The externality effects are different, however, since the decisions considered there are complements, while ours are substitutes. Our model and results are also different by focusing on spillover effects - subject to private information - and asymmetric equilibria. This is further commented below. Equity effects are in part determined by owner shares, and in Olsen and Osmundsen (1999a) it is analysed how the distribution of ownership between residents of different countries affects the symmetric tax policy equilibrium, and what distribution yields the most favorable equilibrium outcome. The present analysis extends that paper by introducing spillovers, and focuses mainly on a different issue, namely on how the firm's information about such spillovers, and in particular asymmetric spillovers, affects the relative merits of competitive and cooperative tax regimes. We also extend the analysis of optimal ownership to a setting with externalities and asymmetric equilibria.

To develop some intuition for how spillovers affect the tax equilibrium, it is instructive to take the first-best investment allocation as a starting point, and consider the governments' incentives to deviate from this allocation. We consider first the case of fully symmetric countries, i.e., symmetric technologies and owner shares.

Symmetric countries. First note that in order to implement first-best investments, each country's tax function must satisfy $-R'(K(\theta)) = \frac{\partial E}{\partial K}(K(\theta), \theta)$, where subscripts are subsumed due to symmetry. Marginal taxes must be negative and equal to marginal spillover effects in magnitude, and this must hold for every type θ. It follows that the slope of each marginal tax schedule must satisfy $-R'' = E_{11} + E_{1\theta}\frac{1}{K'(\theta)}$, where subscripts here denote partials, and $K'(\theta)$ can be found from the conditions defining first-best investments. This yields

$$-R'' = E_{11} + \frac{E_{1\theta}}{E_{1\theta} + \Pi_{1\theta}}(-E_{11} - \Pi_{11} - \Pi_{12}) \tag{10}$$

Assuming a concave total surplus (so $E_{11} + \Pi_{11} \leq 0$), we see that $-R'' > 0$; i.e. the marginal tax schedule, $R'(K)$, slopes downward (marginal subsidy schedule slopes upward), unless spillovers are strongly convex. For concreteness we consider this case. Marginal subsidies are then larger for larger investment levels, and this is necessary to induce better types to invest sufficiently more than less efficient types. Note that as marginal spillovers become more strongly dependent on type–i.e. as $E_{1\theta}$ gets bigger–the marginal subsidy schedule becomes steeper; marginal subsidies must then increase more rapidly with investments in order to induce bigger investment differences between types.

Now consider one country's incentive to deviate from the tax functions that implement first-best investments. A move on the part of country 1 to marginally reduce domestic investments will give rise to a benefit (rents extracted from the firm) that is proportional to $\Pi_{1\theta}[1 + \frac{dK_2}{dK_1}]$. The firm's strategic investment response is determined by (6), and it follows from this relation that the response is stronger, the steeper is the marginal tax schedule in country 2. This implies that as marginal spillovers become more strongly dependent on type–i.e. as $E_{1\theta}$ gets bigger–the firm's (negative) investment response becomes stronger, and the country's incentive to deviate in turn becomes weaker.

This reasoning indicates that stronger spillover effects (bigger $E_{1\theta}$) leads in the symmetric case to weaker incentives for each country to deviate from first-best investments. By a direct calculation we see that there is an incentive to deviate as long as

$$\frac{2\Pi_{12}}{E_{11} + \Pi_{11} + \Pi_{12}} < \frac{\Pi_{1\theta}}{E_{1\theta} + \Pi_{1\theta}} \tag{11}$$

The left-hand side of the inequality is a measure of substitutability between investments in the two countries; the ratio is zero for independent investments ($\Pi_{12} = 0$), it is equal to 1 for perfect substitutes ($E_{11} + \Pi_{11} = \Pi_{12}$), and it is generally between 0 and 1 for less than perfect substitutes. For sufficiently strong substitutes, or for a sufficiently strong spillover effect $E_{1\theta}$, the inequality becomes an equality, and neither country has then any incentive to deviate from the first-best.[13] Any induced distortion dK_i of domestic investments will then be met by the firm by an offsetting change of foreign investments ($dK_j = -dK_i$), and this will leave the firm's rents unaltered. These considerations indicate that in such limiting cases no distortions from first-best investments will take place in equilibrium.

If on the other hand the countries cooperate and harmonize their tax policies, there is no strategic effect and the countries then do have an incentive to reduce investments in order to capture rents. Comparing investments under the two tax regimes, we should thus expect that *investments are lower under tax coordination compared to tax competition when spillovers are strongly dependent on types, and/or when investments are close substitutes across countries*. This is confirmed by the formal analysis of a parametric specification in Section 5. That analysis also shows that the converse relation holds when spillovers are weak and/or investments are not close substitutes. In the latter case tax competition leads to lower investments than tax coordination; the equity effect then dominates the fiscal (strategic) effect.[14]

It is worth noting that the firm's information regarding external spillovers ($E_{1\theta}$) and its information regarding internal profits ($\Pi_{1\theta}$) affect the countries' tax policies, and hence the non-cooperative equilibrium, in very different ways. The former weakens each country's incentive to deviate from the first-best, the latter strengthens these incentives. The strengthening of incentives to deviate works through two channels; first through the conventional rent extraction effect–just as in the cooperative case–and secondly through a weakening of the strategic effect. The strategic effect is weakened because a stronger dependence of profits on information–a larger $\Pi_{1\theta}$–reduces the slope of the marginal tax (subsidy) schedules that support the initial (first-best) allocation (see 10), and this reduction weakens the firm's investment response. The opposing effects of information regarding external spillovers and internal profits are confirmed by the formal analysis in Section 5.

Asymmetric spillovers. Consider now the case of asymmetric spillovers, and to

[13] One can check that the weak version of the inequality is a necessary condition for local concavity of the firm's after-tax profit function, i.e. for implementability. If this condition should not hold, it will not be possible to implement the first-best by a pair of differentiable tax functions that depend only on the respective investments in the two countries. We will only consider cases where the condition does hold.

[14] This is obviously true in the extreme case where investments are completely independent; $\Pi_{12} = 0$, since the strategic effect then vanishes.

consider a strong form of asymmetry, suppose there are spillovers in only one country, say country 1 (so $E_2(K_2, \theta) = 0$). The countries are otherwise symmetric. Consider again the governments' incentives to deviate from first-best investments. In this case, the tax functions that implement the first-best satisfy $R_2'(K_2) = 0$ and $-R_1'(K_1) = \frac{\partial E_1}{\partial K_1}(K_1, \theta)$. The marginal tax schedule is flat (zero) in country 2, and it is downward sloping in country 1. Recall that the strategic investment effect for country 1 depends on the slope of the marginal tax schedule in country 2, and vice versa, and that the effect is stronger, the steeper is the relevant marginal tax schedule. From the relative slopes of these schedules it now follows that the (negative) strategic effect for country 1 is weaker than that for country 2.[15] A weak strategic effect implies a strong incentive to deviate: the rent that can be extracted by a marginal deviation is proportional to $1 + \frac{dK_2}{dK_1}$. So country 1 has a stronger incentive to deviate from the first-best than has country 2. A profitable deviation entails taxes that reduce investments for low-efficiency types; hence the tax schedule in country 1 must be made even steeper than it was initially.

These considerations indicate that there may be a tendency for country 1–where spillovers are present–to implement a steep marginal tax schedule, effectively taxing low-efficiency firms and subsidizing high-efficiency ones, and for country 2 to implement a relatively flat and low-level marginal tax schedule. Such a tax configuration can be an equilibrium because it induces a relatively much stronger strategic effect in country 2 than in country 1. The low marginal taxes in country 2 is an optimal response when the strategic effect is strong. The steep marginal tax schedule in country 1 is an optimal response when the strategic effect is weak. Together the two schedules thus constitute an equilibrium.[16]

In Section 5 we demonstrate, for a parametric specification of the model, that such equilibria obtain for a range of parameters. Note the implications for investments. In country 1 any type of firm (except the very best one) is subsidized less at the margin–and

[15] The firm's before-tax profits are symmetric between countries. It is the differentiated tax treatments–positive subsidies in country 1, zero subsidies in country 2–that generate the firm's asymmetric response pattern.

[16] Something similar can occur if spillovers are symmetric, but operating profits depend asymmetrically on the firm's type, e.g. $\Pi_{1\theta} > \Pi_{2\theta}$. Other things equal, a given investment distortion will then enable more rents to be extracted in country 1 than in country 2. The equilibrium may thus entail a steeper marginal tax schedule in country 1 (to induce larger distortions there) than in country 2. Parametric examples exhibiting these features can be constructed.

some types considerably less–than under the scheme implementing first-best investments. Moreover, any type of firm is only slightly taxed at the margin in country 2. The firm therefore invests less in country 1. This makes investments in country 2 relatively more attractive, and since it is taxed only slightly there, investments in country 2 may increase relative to first-best investments. This explains why *there may be overinvestments relative to first-best investments in the country with no spillovers, and underinvestments in the other country.* Since the cooperative solution–due to the absence of strategic effects–always entails lower investments in both countries compared to the first-best, it then follows that there is *overinvestments in the country with no spillovers also compared to the cooperative solution.* In such cases tax competition thus leads to misallocations–relative to a cooperative solution–in the form of investments not being sufficiently concentrated in the country where they would generate the largest spillovers. This is analysed more precisely in Section 5. First we discuss related literature.

4.3 Related literature

Our model features contract substitutes and national principals that, due to equity considerations rationally assign only partial weights to the firm's rents (parts of the rents accrue to foreign investors). The equity externalities counteract the tendency to overinvestment that otherwise arise from strategic considerations. A similar effect is present in a model by Martimort (1996b), which has (perfect) contract complements and principals that put excessive weights on the firm's rents due to favoritism. The counteracting tendencies of insufficient (excessive) profit weights and strategic effects due to contract substitutes (complements) are similar in the two models, but their foci are very different. The main point in Martimort's paper is to show that sharing powers between non-benevolent regulators may be socially better than entrusting all regulatory powers to only one of them. We focus on the relations and relative influences of symmetric as well as asymmetric spillover effects, owner shares and the firm's substitution possibilities. These issues are not discussed in Martimort's paper.

We emphasize private information about spillover effects and productivity, i.e. we do not specifically address the issues of intra-firm trade and transfer pricing. For an analysis of transfer pricing regulation see, e.g. Bond and Gresik (1996).[17] In that article

[17] A home and a host country use trade taxes to regulate an MNE which has private information about the cost of an intermediate good that is sold from the parent to a subsidiary in the host country.

the competing governments control complementary activities, whereas in our model the relevant activities are substitutes. Our economic focus is different, and by addressing the issues of spillover effects and externalities, our analytical perspective is different. We also get different qualitative results. Bond and Gresik find that under private information the firm's activity level and information rents always are lower when the principals compete than when they cooperate, and that the activity level always is highest in the first-best case. We find that the activity level (investments) and rents under competition may be either higher or lower than under cooperation. We also show that the activity level under common agency may even exceed the first-best level in one country.

Our model is in some respects an extension of Osmundsen, Hagen and Schjelderup (1998); a partial model where a single principal regulates a continuum of mobile firms that have private information about their mobility costs. That analysis presumes a passive foreign government, which may be unrealistic since it implies a transfer of tax revenue from the foreign country to the home country. We extend the model to take into account strategic interaction between the governments, and by accounting for externalities.

Our model is also related to Laussel and Lebreton (1995), who analyse taxation of a large investor which possesses an exogenous amount of capital that it may allocate in two locations.[18] We extend this analysis by allowing for spillover effects and national ownership, which affects the qualitative results by introducing equity externalities. Moreover, in our model the level of capital is endogenous, and whereas the firm has private information about the amount of capital it possesses in Laussel and Lebreton, we focus on private information about spillover effects and efficiency.[19]

A different, yet related multiprincipal regulatory problem is analysed by Mezzetti (1997), who considers a case where an agent has private information about his *relative* productivity in the tasks he performs for two principals. In contrast, our focus is on private information about the *absolute* efficiency level. Also, we introduce spillover effects. Another difference is that we address a case of substitutes, whereas in Mezzetti's model

[18] A similar setup is found in Haaparanta (1996), but under perfect information. Haaparanta analyses a subsidy game where two governments, maximising the net wage income, compete to attract investments of a single firm.

[19] Our model is also somewhat related to Biglaiser and Mezzetti (1993), in which two principals competes for the exclusive services of an agent that has private information about his or her effort and productivity. Whereas we focus on a multinational enterprise that divides its activities between several countries, Biglaiser and Mezzetti analyse a case where a worker must work full time for a single company.

there is complementarity between the agent's tasks. The results also differ in important ways. Whereas Mezzetti finds that the agent's information rent is always higher under tax competition than under cooperation, we find that the rent may be lower in come cases. Moreover, Mezzetti's model exhibits countervailing incentives; this is not the case in our model.[20]

5 A parametric specification

By assuming specific functions, explicit regulatory mechanisms may be derived. We solve for the case of quadratic/linear functions and a uniform distribution. We further assume here that the firm's private investment returns are symmetric between the two countries. The specific functional forms are:

$E_j(K_j, \theta) = e_j \theta K_j$

$\Pi(K_1, K_2, \theta) = (m\theta + k)\Sigma_j K_j - \frac{1}{2} q \Sigma_j K_j^2 - \frac{1}{2} a (K_1 + K_2)^2$, with $m, k, q, a > 0$; and

$f(\theta) = 1, \qquad \theta \in [0, 1]$.

For the *first-best allocation* we get two equations; $\frac{\partial \Pi}{\partial K_j} + \frac{\partial E_j}{\partial K j} = 0$, $j = 1, 2$, which yield the solutions

$$K_{jF}(\theta) = \frac{(m + e_j)(q + a) - (m + e_i) a}{(q + a)^2 - a^2} \theta + \frac{kq}{(q + a)^2 - a^2} \equiv K'_{jF} \cdot \theta + L_{jF}, \qquad (12)$$

where the identity defines the slope (K'_{jF}) and intercept (L_{jF}) of this linear relation. We assume $(m + e_j)(q+a) - (m + e_i) a > 0$, $i, j = 1, 2$, implying that the first-best investment levels are increasing in θ in both countries.

The *cooperative solution* as given by Eq. (5) also yields investment levels that are linear in θ; specifically $K_{jC}(\theta) = K'_{jC} \cdot \theta + L_{jC}$, where $K'_{jC} = K'_{jF} + \gamma \frac{mq}{(q+a)^2 - a^2}$, $\gamma = \frac{1+\lambda-\alpha_1-\alpha_2}{1+\lambda}$, and L_{jC} is such that there is no distortion from the first-best allocation for the best type ($\theta = 1$). We see that the cooperative investment schedule in each country is steeper than the corresponding first–best schedule ($K'_{jC} > K'_{jF}$). Hence there is *underinvestment* in both countries relative to first-best investment levels.

[20] In Olsen and Osmundsen (1999b) we extend the present model (in absence of spillover effects) to include an outside option, and this option is also seen to generate countervailing incentives; i.e. incentive constraints bind 'upwards' as well as 'downwards' on the type interval. The different information structures in the two models have quite different implications, though; whereas Mezzetti obtains equilibria that are unique and exhibit pooling for a range of intermediate types, we obtain non-unique and fully separating equilibria.

The equations that define *the non-cooperative (common agency) equilibrium* in this parametric model also have linear solutions $K_j(\theta) = L_j + K_j' \cdot \theta,\ j = 1, 2$. By insertion one can derive a pair of equations for the slope parameters (K_j'), see the appendix.[21] In order to qualify as a common-agency equilibrium, the linear solutions must in addition be commonly implementable (see the appendix).

The equilibrium non-cooperative tax schedules can then be derived explicitly from (9). Marginal tax rates are seen to be positive for low investments, and decreasing with increasing investments in equilibrium. For the investment levels chosen by the most efficient type of firm, the marginal investment tax is negative (a subsidy) and equal in magnitude to the marginal spillover effect for this type in both countries.

5.1 The fully symmetric case

We solve now for the fully symmetric case, where in addition to the assumptions above we assume symmetric externality effects ($e_1 = e_2 = e$) and symmetric owner shares: $\alpha_1 = \alpha_2$. The *first-best allocation* is then symmetric between countries, and we see that investments are higher, the stronger are the spillovers. The *cooperative solution* also yields investment levels that are symmetric, and we know from the previous section that this solution yields underinvestment in both countries.

For the *non-cooperative case*, the equilibrium solutions $K_j(\theta) = K_j' \cdot \theta + L_j,\ j = 1, 2$, are symmetric and can be found explicitly, see the appendix. In order that the solution be commonly implementable, it is necessary and sufficient that K_j' satisfies $0 \le 2\frac{a}{m}K_j' \le 1$. Straightforward algebra shows that this amounts to $\frac{e}{m} \le \frac{q}{2a}$.[22]

Comparing the first-best and the common agency investment schedules we find that here is underinvestment in common agency (relative to FB) when $\frac{e}{m} < \frac{q}{2a}$, and that equilibrium investments approach first-best investments when $\frac{e}{m} \to \frac{q}{2a}$. This accords with the intuition developed in Section 4.2. Based on the absence of strategic effects in the coordinated case, it was there further argued that tax coordination should be expected to yield lower investments than tax competition when spillover effects are strong and/or investments are close substitutes across countries (i.e. when $\frac{q}{2a} - \frac{e}{m}$ is small in the present parametric model). Using the explicit solutions to the model we can confirm that this is

[21] The intercept parameters (L_j) can be determined by the condition that there should be no distortions for the best type ($\theta = 1$).

[22] This condition is equivalent to (the weak version of) condition (11) above, since $\frac{q}{a} = \frac{\Pi_{12}}{\Pi_{11}} - 1$.

the case (see the appendix):

Proposition 2 *In the symmetric uniform-quadratic case, both tax competition (common agency) and tax coordination (single agency) induce underinvestment relative to first-best investments. There is lower investment – and hence lower profits for the firm – under competition than under coordination if spillovers are small, investments are not too close substitutes, the cost of public funds is small, and/or domestic owner shares are large; more precisely if and only if* $\frac{q}{a} + 4 > \frac{1+\lambda}{\alpha_1}(\frac{e}{m} + 2)$. *Otherwise, i.e. for larger spillovers, investments that are closer substitutes, a larger cost of public funds and/or smaller domestic owner shares, there is higher investment under tax competition than under tax coordination. As spillovers become sufficiently large (as* $\frac{e}{m} \to \frac{1}{2}\frac{q}{a}$*), the competitive equilibrium investment levels become equal to first-best investments.*

Going from a competitive to a coordinated tax setting, two types of externalities are internalized. First, fiscal externalities are adjusted for, so each of the countries will not try to expand its tax base at the expense of the other. Coordination in this respect thus calls for higher marginal taxes, lower investments and lower profits. Second, the coordinated governments account for the dividends to shareholders in both countries, i.e. equity externalities are internalized. This implies a higher welfare weight for the MNEs profits (a lower motive to capture rent), and higher investment levels and profits. Thus, the two effects go in different directions. We are able, however, to tell under what conditions which of the effects will be dominating. For given technology we see that there is underinvestment – and hence lower profits for the firm – under tax competition than under tax coordination when the domestic owner share (α_1) is high, i.e. international cross-ownership is to the benefit of the firm.[23] High domestic owner shares imply weak equity externalities, and this tends to yield lower investments and profits under competition than under coordination. This result deviates from the tax competition literature that presumes kommonly known information, where the firm (agent) benefits from competition between principals.

Other things equal, smaller spillovers will generate underinvestment in the competitive tax regime. Lower spillovers reduce investments both under competition and under

[23] Note that the symmetry assumptions imply $\alpha_1 \leq \frac{1}{2}$ and thus $\frac{1+\lambda}{\alpha_1} \geq 2$. For $\alpha_1 = \frac{1}{2}$ and $\lambda = 0$ the condition for underinvestment reduces to $\frac{q}{a} \geq 2\frac{e}{m}$, which is the condition for implementability. Thus, for a feasible technology the condition for underinvestment in the proposition is satisfied if α_1 is high and λ is low.

coordination, but more so in the former case. The reason for this is that lower spillovers reduce the strategic effect, and as this effect becomes weaker, equilibrium investments are reduced.

For larger spillovers there will be higher investments and higher profits under tax competition than under tax cooperation. Larger spillovers intensify the competition to attract valuable investments, leading to overinvestments relative to the cooperative solution. A technology that allows for easier substitution of investments between the two countries (i.e. where $\frac{q}{a} + 1 = \frac{\Pi_{11}}{\Pi_{12}}$ is small) will also lead to higher investments (smaller distortions) under competition relative to coordination.

Both regimes yield investments below the first-best levels, but in the limit, as spillovers become sufficiently large ($\frac{e}{m} \rightarrow \frac{1}{2}\frac{q}{a}$), the competitive equilibrium investments become equal to first-best investments. The latter occurs because in the limit the strategic effects $\frac{dK_i}{dK_j}$ become equal to -1; and for such strong strategic effects there is in equilibrium no incentive for any country to distort investments away from the first best in order to capture rents. In this case, investments in the two countries are perfect *economic* substitutes from the perspective of the firm, and neither of the countries can unilaterally extract information rents from the firm.

5.2 Investments under asymmetric spillovers

We consider now the case of asymmetric spillovers. Otherwise the countries are assumed to be symmetric. An interesting and from a policy viewpoint important issue is whether competition in such a case will lead to misallocations in the sense of investments becoming too much spread out, and not properly concentrated in the country where they would yield the largest spillovers. The model shows that competition does have this effect when spillovers are sufficiently asymmetric between countries. At the same time, the analysis indicates why coordination may be difficult to achieve in this setting: to implement a coordinated solution one country would have to give away investments that confer positive spillovers on national firms.

To simplify the analysis, we shall assume that spillovers are non-existent in one country, here taken to be country 2. So we have $e_1 > 0$, $e_2 = 0$. The firm continues to have private knowledge about the extent of spillovers in the other country. We first illustrate our results by a numerical example.

Example. Suppose $q = a = m$ and $\frac{e_1}{m} = \frac{1}{4}, e_2 = 0$. Then from (12) we find that the first-best investment schedules satisfy $K'_{1F} = \frac{1}{2}$ and $K'_{2F} = \frac{1}{4}$. Suppose further that $\frac{\alpha_1}{1+\lambda} = \frac{2}{5}$, so that $\gamma_1 = \frac{3}{5}$. Then we can check (from the equilibrium conditions, see (14) in the appendix) that the common-agency schedules satisfy $K'_1 = \frac{11}{18}$ and $K'_2 = \frac{1}{4}$. The assumed parameter values thus yield $K'_1 > K'_{1F}$ and $K'_2 = K'_{2F}$, which tells us that the corresponding equilibrium entails *underinvestment relative to the first-best in country 1, and exactly first-best investments in country 2.* (One can check that a stronger spillover effect in country 1 would have generated overinvestment in country 2.)

The associated equilibrium marginal tax schedules can be obtained from (9). We get $R'_1(K_1) = m\frac{17}{22}(\bar{K}_1 - K_1) - \frac{1}{4}m$ and $R'_2(K_2) = m\frac{4}{9}(\bar{K}_2 - K_2)$, where $\bar{K}_1 = \frac{1}{2} + \frac{k}{3m}$ and $\bar{K}_2 = \frac{1}{4} + \frac{k}{3m}$ are the respective investment levels for the most efficient type of firm. In country 2, where there are no spillovers, the marginal tax rate is positive, decreasing and equal to zero for $K_2 = \bar{K}_2$. In country 1 the marginal tax rate is also decreasing, it is further positive for 'small' investments, but negative (a subsidy) for 'large' ones. For $K_1 = \bar{K}_1$ the marginal subsidy in country 1 equals the marginal domestic spillover effect.

Given these tax schedules we compute the strategic investment effects from $\frac{dK_j}{dK_i} = \frac{-\Pi_{12}}{\Pi_{jj} - R''_j}$, and obtain $\frac{dK_2}{dK_1} = -\frac{9}{14}$, $\frac{dK_1}{dK_2} = -\frac{22}{27}$. The latter, applying to country 2, is much stronger than the former, applying to country 1. Country 1 has therefore a much stronger incentive than country 2 to distort investments to capture rents. (By a marginal investment distortion, country 1 can capture rents proportional to $m\frac{5}{14}$, while country 2 by a similar domestic operation only can capture $m\frac{5}{27}$, see (8).) If country 2 imposed zero marginal taxes, then the tax schedule in country 1 would generate underinvestments (relative to the first-best) in country 1, and – by a substitution effect on the part of the firm – overinvestments in country 2. The government of country 2 has a relatively weak incentive to distort these investments to capture rents. The small distortion, achieved by imposing positive, but relatively small marginal taxes, reduces investments in country 2 somewhat, and – for the given parameters – to a level that coincides with what is first-best in that country. Conversely, given country 2's tax schedule, country 1 has a relatively strong incentive to distort domestic investments, and this leads to investments that are lower than the first-best levels in country 1.

Computing the cooperative investment solution (as given in the paragraph following (12)), we find $K'_{1C} = \frac{17}{30}$ and $K'_{2C} = \frac{19}{60}$. We thus have $K'_1 > K'_{1C}$ and $K'_2 < K'_{2F}$, which tells us that the competitive outcome entails *underinvestment in country 1 and* *overinvestment in country 2* relative to the cooperative solution.

The example illustrates that competition may – compared to the cooperative solution – entail too much investments in the country where spillovers are low (here zero, in fact), and not enough investments in the other, high-spillover country. We will now show that in this model competition does, for sufficiently asymmetric spillovers, lead to misallocations in the form of investments being either excessive in both countries, or excessive in the country where spillovers are lowest and at the same time insufficient in the country where spillovers are highest. Moreover, we find that the latter outcome – where investments are too high in the low-spillover country and too low in the high-spillover country – typically occurs if substitution is not too easy ($\frac{q}{a}$ is not too small), domestic owner shares are relatively large and/or the cost of public funds is relatively small. The example above illustrates such a case.

To state the formal result, define $Q = \frac{q}{a} + 1$ and $\varepsilon_1^0 = \frac{(Q-1)Q}{Q+\gamma_1}$. Then we have

Proposition 3 *For the uniform-quadratic case the following holds. If the countries have sufficiently asymmetric spillovers ($E_2(K_2, \theta) \equiv 0$ and $E_1(K_1, \theta) = e_1\theta K_1$ with e_1 close to $m\varepsilon_1^0$) then non-cooperative investments are higher than cooperative investments in the country where spillovers are low, while the corresponding investments in the other, high-spillover country may be lower or higher than the cooperative investments there. They are lower if substitution is not too easy, domestic owner shares are large and/or the cost of public funds is small; more precisely if $\frac{q}{a} > (\frac{1+\lambda}{\alpha} - 1)(1 - \frac{2\alpha}{1+\lambda}) - 1$.*

The appendix contains the proof, which also shows that competitive investments under strongly asymmetric spillovers are excessive relative to the first-best standard in the low-spillover country.

In our model, competition among the countries to attract potentially valuable investments may thus well result in excessive amounts of investments being made in one country, and insufficient amounts being made in the other. This result is in contrast with tax competition models with commonly known information, in which the competition for attracting real investments invariably causes source taxes to fall and investments to rise, see, e.g. Zodrow and Mieszkowski (1986). The results also deviate from symmetric regulation models, such as Laussel and Lebreton (1995).

5.3 Ownership, profits and welfare.

The last section showed that for highly asymmetric spillovers, but otherwise symmetric technologies and owner shares, the tax equilibrium tends to entail excessive investments in the country where spillovers are lowest. Due to the equity externalities the equilibrium outcome depends on the firm's ownership structure. This raises the question whether the firm may have incentives to influence this structure in order to affect the tax equilibrium. In this section we show that the firm does have such incentives; in particular, for asymmetric spillovers it is seen that the firm would prefer to have a majority of its owners in the high-spillover country. Moreover, we investigate whether the ownership configuration most preferred by the firm is also the one most preferred by the societies at large, and show that there is in general a conflict of interest between the firm and the governments with respect to this issue.

A joint venture with a local firm is one example of how a firm may influence the national distribution of its ownership. The ownership structure is otherwise most easily affected for non-listed firms. The initial owners may in this case carefully select its investors to obtain the preferred national distribution of ownership. In the case of a wider dispersion of owners, a stable ownership structure can be enhanced by initially approaching long term investors. To promote an advantageous national distribution of shares, the firm may undertake direct placement of shares among long term investors in the country holding a too low equity share. As for the governments, the national distribution of equity shares may be affected by regulations, by personal income tax design, or by direct government equity acquisitions or sales. With respect to regulations, some countries have imposed ownership restrictions, e.g. on foreign ownership of financial institutions. More targeted policies in use are indigenisation requirements, meaning that the host government requires an investor to share ownership of an affiliate with residents in the host country (see Katrak (1983)).

For a setting with no spillovers and a symmetric technology Olsen and Osmundsen (1999a) show that a balanced ownership structure is optimal for the firm as well as for the two host countries. In that setting the balanced structure protects the firm against highly distortive taxes in the two countries, as local ownership reduces the governments' motive for capturing the firm's rents.[24] Here we extend the analysis of ownership to include

[24] The result has a flavor similar to classical results in the public finance literature, in which convex tax collection costs make it advantageous to spread distortions over many tax objects.

spillover effects and asymmetric equilibria. With spillover effects on national firms each government has an additional motive to attract investments from the MNE. We find that for asymmetric spillovers the firm prefers an unbalanced ownership distribution, and – contrary to the symmetric case – the firm and the governments have opposing views on the optimal ownership pattern.

Note that if the firm is partly owned by investors outside the two countries where it operates, the two countries' motives for rent extraction will be stronger than if the firm has no outside ownership. From the firm's point of view it is therefore advantageous (with respect to maximising its rents) to have all its owners inside the two countries. In the following we consider only this case, i.e., we assume throughout that $\alpha_1 + \alpha_2 = 1$.

Recall that the firm's marginal rents are given by $\pi'(\theta) = \frac{\partial \Pi}{\partial \theta}$, which equals $m(K_1 + K_2)$ for the functional forms assumed here. Suppose now that everything else (including technology) is fixed, and let the owner shares vary, subject to $\alpha_1 + \alpha_2 = 1$. Marginal rents are then clearly largest when shares are distributed such that the total sum of investments, $K_1 + K_2$ is largest. The following result characterizes this outcome. To state the proposition we define 'normalized' spillover parameters $\varepsilon_i = \frac{e_i}{m}$ and recall the definition $Q = \frac{q}{a} + 1$.

Proposition 4 *The firm's equilibrium rents $\pi(\theta)$ under tax competition (common agency) are for every type largest for owner shares given by*

$$\alpha_1 = \frac{1}{2} + h(\varepsilon_1, \varepsilon_2, Q, \lambda), \qquad \alpha_2 = 1 - \alpha_1,$$

where $\frac{\partial h}{\partial \varepsilon_1} > 0$, $\frac{\partial h}{\partial \varepsilon_2} < 0$ and $h() = 0$ for $\varepsilon_1 = \varepsilon_2$. The firm's optimal owner share in country 1 (α_1) is thus increasing in domestic spillovers (ε_1), and decreasing in foreign spillovers (ε_2). It is $\alpha_1 = \frac{1}{2}$ when spillovers are symmetric across countries.

We see that the optimal ownership pattern depends only on the technology parameters $\varepsilon_1, \varepsilon_2, Q$ and the cost of public funds $(1 + \lambda)$. If the spillovers are asymmetric ($\varepsilon_1 \neq \varepsilon_2$), the firm will prefer an uneven distribution of its owner shares. From the point of view of the firm, the country where spillovers are largest is the most favorable. If the firm has a larger owner share in that country, its government will be less eager to extract the firm's rents, and this will increase total investments and thereby the profits of the firm.

A relevant question to consider is whether the ownership pattern preferred by the firm is also the best from a social point of view. The model turns out to generate a simple answer to this question. Measuring total social surplus by $W = W_1 + W_2$ we have the following result:

Proposition 5 *The ownership pattern* (α_1, α_2) *that maximises the firm's rents in common agency will also maximise the (equilibrium) total surplus* $W = W_1 + W_2$ *if and only if* $\alpha_1 = \alpha_2 = \frac{1}{2}$. *If the firm's preferred pattern entails majority ownership in one country, e.g.* $\alpha_1 > \alpha_2$, *the majority owner share is (locally) too large from a social point of view, since then* $\frac{dW}{d\alpha_1} < 0$.

To get some intuition for this result, suppose technologies are symmetric except for $\varepsilon_1 > \varepsilon_2$. As explained above, the firm prefers the owner distribution that maximises (marginal) rents $m(K_1 + K_2)$, which entails $\alpha_1 > \alpha_2$ and $K_1 > K_2$. It turns out that this outcome implies excessively high investments in country 1, in the sense that total welfare would increase if investments had been shifted from country 1 to country 2. But such shifting is precisely what will take place (in equilibrium) if owner shares are reallocated to reduce α_1 and increase α_2. Hence we see that the owner share α_1 which is most preferred by the firm, is in this case too high from a social point of view.

6 Conclusion

With enhanced international mobility of the corporate tax base, tax competition is reinforced and national governments experience more problems in raising revenue. Foreign direct investments have been rapidly increasing, and recent empirical research shows that effective tax rates are important factors for determining the localisation decisions of multinational enterprises (MNEs).[25] We have considered a situation where two jurisdictions compete to attract shares of the investment budget of a large multinational enterprise, whose investments confer positive spillovers on national firms. The competition among the countries to tax the firm's rents is modelled as common agency. An advantage of the common agency approach is that it enables the tax systems to be endogenously determined, based on informational considerations. (In contrast, the tax competition literature typically imposes exogenous constraints on the available tax instruments.)

The firm contributes to local welfare by spillovers, by tax payments and by dividends paid to local investors, and it has private information both about its efficiency and about

[25] See, e.g., Markusen (1995), Devereux and Freeman (1995).

spillovers. In this setting, we compare equilibria under tax competition and tax coordination. We allow for asymmetric equilibria, i.e., cases where spillover effects and national ownership differ between the two countries. It is shown that by going from tax competition to tax coordination, the governments can avoid excessive investments in one of the countries (the country that has the lowest spillovers). Tax coordination can aslo make sure that investments are properly concentrated in the country where spillovers are largest, i.e., avoid that investments are too much spread out. It is also shown that the firm may actually gain by governmental tax coordination, and we demonstrate that the firm and the governments may have different preferences with respect to the national distribution of ownership in the firm.

The tax literature normally assumes that any one firm is too small to affect tax policy in a jurisdiction. We assume that the MNE is a large and unique firm with a high level of spillovers, or that the jurisdictions are small, so that the potential tax revenues and the possible knowledge spillovers from the firm are non-negligible relative to the corporate tax bases and the knowledge bases of the two jurisdictions. An alternative interpretation is that the tax subject in the model is a mobile industry.

We assumed that the firm has private information about its efficiency, whereas its investment levels have been assumed to be subject to commonly known information. Profits may to a large extent may be observable for purely domestic firms, and be captured by a traditional corporate income tax. For multinational firms, transfer pricing may make any attempt to measure profits difficult, so that countries are forced to estimate profits based on what is observable. Our assumption is that investments are the key observable variable, and the tax schemes derived are made contingent on the national investment levels.[26]

It has also been assumed in this paper that the firm cannot completely escape taxation in one country by moving all of its operations to the other country. To understand some of the ramifications of this assumption, suppose instead that such moves are feasible for the firm. This imposes additional participation constraints on the principals; the firm's (equilibrium) rent must then be at least as large as what the firm can obtain by escaping

[26] Privately observed investments that are undertaken *after* the tax system is in place (moral hazard) can be accomodated in the model; the profit function can be interpreted as an indirect function where such investments are chosen optimally, conditional on the observable K_j's. Privately observed investments in place *ex ante* would, however, be a part of the firm's private information. The model represents a case where the aggregate effect of sveral such variables can be captured by a one-dimensional parameter.

any one country. It appears that (at least for some functional forms) these additional constraints will only affect the distribution of rents between the parties: except for lump-sum rent transfers, the equilibrium allocation will be the same as before.[27]

We have assumed that the MNE's efficiency levels are perfectly correlated in the two countries of operation. Uncorrelated efficiency parameters may be relevant if firms invest in different countries to diversify portfolios. Pivate information about investment levels, or uncorrelated information parameters, may represent interesting extensions of the present model. However, each of these extensions would imply a multidimensional screening problem (i.e. a challenge for the government to reveal a vector of parameters subject to private information), which is not yet fully solved, not even in a single-principal setting; see Rochet and Chone (1998).

Appendix

The non-cooperative equilibrium conditions.

Given the tax function offered by country 2, we can use the Revelation Principle to find the optimal response[28] from country 1. The MNE's profits as a function of its report $\hat{\theta}_1$ to country 1 and its true type are given by $\pi(\hat{\theta}_1, \theta) = \Pi(K_1(\hat{\theta}_1), K_2(\hat{\theta}_1), \theta) - R_1(K_1(\hat{\theta}_1)) - R_2(K_2(\hat{\theta}_1))$, where the firm's investments in country 2 satisfy $K_2(\hat{\theta}_1) = \arg\max_{K_2}[\Pi(K_1(\hat{\theta}_1), K_2, \theta) - R_2(K_2)]$. Incentive compatibility requires that the firm reports truthfully ($\hat{\theta}_1 = \theta$), which implies that (4) must hold for equilibrium profits. Integrating by parts, and using (4), the expected welfare in country 1 may be written

$$EW = \int_{\underline{\theta}}^{\bar{\theta}} \{(1+\lambda)\left(\Pi(K_1(\theta), K_2(\theta), \theta) + E_1(K_1(\theta), \theta)\right) - R_2(K_2(\theta))) \\ -(1+\lambda-\alpha_1)\, \frac{\partial \Pi(K_1(\theta), K_2(\theta), \theta)}{\partial \theta} \frac{1-F(\theta)}{f(\theta)} \right\} dF(\theta).$$

[27] Technically, the new participation constraint facing principal j will apparently bind only for the least efficient type. Calzolari (1998) also makes this point. This means that the countries cannot, when they compete, completely tax away all rents from the least efficient type of firm; even this type will keep some (mobility) rents. In this case, therefore, types with low efficiency will in general be better off under tax competition compared to tax coordination. More efficient types apparently may or may not be better off in the competitive regime.

[28] For a given tax function offered by country 2, it is not restrictive to consider only direct truthtelling mechanisms in country 1's best response problem; the Revelation Principle holds for this single-principal problem. Restricting both principals simultaneously to such mechanisms, however, does in general affect the equilibrium.

Maximising the integrand pointwise with respect to K_1 and K_2, subject to (6), yields a first-order condition that takes the form (7) (with $j = 1$ and $i = 2$) when we substitute for $R_2''(K_2(\theta))$ from (6). (The relevant expression for $R_2''()$ is found by differentiating (6) with respect to θ.) This condition characterises the equilibrium contract for country 1.

It should also be checked that the solution is commonly implementable. In particular, it must be optimal for the firm to make the targeted investments $K_1(\theta), K_2(\theta)$. This requires that $\Pi(K_1, K_2, \theta) - \Sigma_j R_j(K_j)$ is locally concave at the point $(K_1, K_2) = (K_1(\theta), K_2(\theta))$. Making use of (6), the necessary local concavity conditions can then be written as $K_1' K_2' \frac{\partial^2 \Pi}{\partial K_1 \partial K_2} + \frac{\partial^2 \Pi}{\partial \theta \partial K_i} K_i' \geq 0$, $i = 1, 2$, and $K_1' K_2' \left(\frac{\partial^2 \Pi}{\partial \theta \partial K_1} \frac{\partial^2 \Pi}{\partial \theta \partial K_2} + \frac{\partial^2 \Pi}{\partial K_1 \partial K_2} \left[\frac{\partial^2 \Pi}{\partial \theta \partial K_1} K_1' + \frac{\partial^2 \Pi}{\partial \theta \partial K_2} K_2' \right] \right) \geq 0$. These conditions are also sufficient in the case of quadratic functions and contract substitutes, provided both investment schedules are nondecreasing (cf. Stole (1992), Thm. 11, p. 22).

For the parametrisations given in Section 5, where $\frac{\partial^2 \Pi}{\partial \theta \partial K_i} = m$ and $\frac{\partial^2 \Pi}{\partial K_1 \partial K_2} = -a$, the implementability conditions amount to

$$0 \leq \frac{a}{m} K_j' \leq 1 \;\; j = 1, 2 \qquad \text{and} \qquad \frac{a}{m} K_1' + \frac{a}{m} K_2' \leq 1. \tag{13}$$

By insertion of $K_j(\theta) = K_j' \cdot \theta + L_j$ in (7), we further see that the slope parameters (K_j') in the parametric model must satisfy

$$(m + e_j) - (q + a) K_j' - a K_i' = -\frac{1 + \lambda - \alpha_j}{1 + \lambda} \left[m + \frac{m a K_i'}{a K_j' - m} \right], \; j = 1, 2, \tag{14}$$

Proof of Proposition 2.

In the symmetric case, first-best investments are given by $K_{jF}(\theta) = \frac{m}{a} \left(\frac{(1+\varepsilon)}{Q+1} \theta + \frac{\frac{k}{m}}{Q+1} \right) \equiv K_{jF}' \cdot \theta + L_{jF}$, where $\varepsilon = \frac{e}{m}$ and $Q = \frac{q}{a} + 1$. The cooperative solution is $K_{jC}(\theta) = K_{jC}' \cdot \theta + L_{jC}$, where $K_{jC}' = K_{jF}' + \frac{m}{a} \frac{\gamma}{Q+1}$, $\gamma = \frac{1+\lambda-2\alpha_1}{1+\lambda}$.

From (14) we find that the non-cooperative equilibrium investments satisfy $K_j' = \frac{m}{a} x$, where

$$x = \frac{1}{2(1+Q)} \left(\varepsilon + 2 + Q + 2\gamma_1 - \sqrt{\varepsilon^2 - 2Q\varepsilon + 4\varepsilon\gamma_1 + 4\gamma_1 + Q^2 + 4\gamma_1^2} \right),$$

and $\gamma_1 = 1 - \frac{\alpha_1}{1+\lambda}$. Comparing the slopes of the investment schedules for the cooperative and the non-cooperative solutions we have

$$1 - \frac{K_{jC}'}{K_j'} = 1 - \frac{\frac{1+\varepsilon+\gamma}{Q+1}}{x} = \frac{-\varepsilon + Q + 2(\gamma_1 - \gamma) - \sqrt{\varepsilon^2 - 2Q\varepsilon + 4\varepsilon\gamma_1 + 4\gamma_1 + Q^2 + 4\gamma_1^2}}{2(Q+1)x},$$

where $\gamma = 1 - \frac{2\alpha_1}{1+\lambda}$, so $\gamma_1 - \gamma = \frac{\alpha_1}{1+\lambda}$. There is underinvestment in common agency relative to the cooperative case iff $K'_j > K'_{jC}$, i.e. iff $-\varepsilon + Q + 2(\gamma_1 - \gamma) > 0$ and $(-\varepsilon + Q + 2(\gamma_1 - \gamma))^2 > (\varepsilon^2 - 2Q\varepsilon + 4\varepsilon\gamma_1 + 4\gamma_1 + Q^2 + 4\gamma_1^2)$. The latter inequality means $-\varepsilon(2\gamma_1 - \gamma) + Q(\gamma_1 - \gamma) + \gamma(\gamma - 2\gamma_1) - \gamma_1 > 0$. Noting that $2\gamma_1 - \gamma = 1$, the last inequality is equivalent to $-\varepsilon + Q(\gamma_1 - \gamma) - \gamma - \gamma_1 > 0$. This yields $K'_j > K'_{jC}$ iff $\frac{q}{a} + 4 > \frac{1+\lambda}{\alpha_1}(\frac{e}{m} + 2)$. QED

Proof of Proposition 3.

As a first step we compare non-cooperative and first-best investments. For that purpose we use the following lemma, which is proved below.

Lemma. *For any $e_1 \geq 0$ such that $\frac{e_1}{m} \leq \varepsilon_1^0 = \frac{(Q-1)Q}{Q+\gamma_1}$, the following holds: Equations (14) yield unique solutions for the slopes K'_1, K'_2 that satisfy the implementability conditions (13). As $e_1 \to \varepsilon_1^0 m$, we have $K'_1 \to \frac{m}{a}$ and $K'_2 \to 0$.*

From this lemma we can conclude that for a spillover parameter e_1 sufficiently close to $m\varepsilon_1^0$ (so that ε_1 is close to ε_1^0), the common-agency investment schedules $K_j(\theta) = K'_j \cdot \theta + L_j$ have slopes $K'_1 \approx \frac{m}{a}$ in country 1 and $K'_2 \approx 0$ in country 2. We now compare these slopes to the slopes of the corresponding first-best schedules.

The latter slopes are, for $\varepsilon_1 = \varepsilon_1^0$, given by $K'_{1F} = \frac{m}{a}\frac{(1+\varepsilon_1^0)Q-1}{Q^2-1}$ and $K'_{2F} = \frac{m}{a}\frac{Q-(1+\varepsilon_1^0)}{Q^2-1}$. Note that $\varepsilon_1^0 < Q - 1$, and hence $(1+\varepsilon_1^0)Q < Q^2$, which implies $K'_{1F} < \frac{m}{a}$. Also $Q - (1+\varepsilon_1^0) = (Q-1)\frac{\gamma_1}{Q+\gamma_1}$, so $K'_{2F} > \frac{m}{a}\frac{1}{Q+1} > 0$. This shows that for ε_1 close to ε_1^0 we have $K'_1 > K_{1F}$ and $K'_2 < K'_{2F}$. Hence for spillovers such that e_1 is close to $m\varepsilon_1^0$, it is the case that the common-agency investment schedules entail overinvestment in country 2 and underinvestment in country 1 relative to first-best investments.

The cooperative investment schedules have slopes $K'_{jC} = K'_{jF} + \gamma\frac{m}{a}\frac{1}{Q+1}$, where $\gamma = 1 - \frac{2\alpha}{1+\lambda}$. For country 2 $K'_2 < K'_{2C}$ follows from $K'_2 < K'_{2F}$. Setting $e_2 = 0$ and letting $e_1 \to m\varepsilon_1^0$ we find $K'_{1F} \to \frac{m}{a}\frac{(1+\varepsilon_1^0)Q-1}{Q^2-1}$, and hence

$$K'_{1C} \to \frac{m}{a}\frac{(1+\varepsilon_1^0)Q-1}{Q^2-1} + \gamma\frac{m}{a}\frac{1}{Q-1} = \frac{m}{a(Q+1)}\left[\frac{Q^2}{Q+\gamma_1} + 2\gamma_1\right],$$

where the last equality follows from the definition of ε_1^0 and the fact that $\gamma = 2\gamma_1 - 1$. From the lemma above we know that the non-cooperative solution satisfies $K'_1 \to \frac{m}{a}$ in this case. In the limit we thus have non-cooperative investments being lower than cooperative ones in country 1 iff $\frac{m}{a} > \frac{m}{a(Q+1)}\left[\frac{Q^2}{Q+\gamma_1} + 2\gamma_1\right]$. This condition is equivalent to the condition given in Proposition 3

It then only remains to prove the lemma.

Proof of Lemma. Define "normalized" slope parameters $x_j = \frac{a}{m}K'_j$. In terms of these parameters, equations (14) take the form

$$1+\varepsilon_1 - Qx_1 - x_2 = -\gamma_1\left[1+\frac{x_2}{x_1-1}\right], \qquad 1+\varepsilon_2 - Qx_2 - x_1 = -\gamma_1\left[1+\frac{x_1}{x_2-1}\right]. \quad (15)$$

with $\varepsilon_2 = 0$. From the second of these equations it follows that $x_1 = \frac{1-Qx_2+\gamma_1}{1-x_2+\gamma_1}(1-x_2)$ (provided $1 - x_2 + \gamma_1 \neq 0$). Substituting this into the first, we find that x_2 is a root of a third-order equation $Ax_2^3 + Bx_2^2 + Cx_2 + D \equiv P(x_2) = 0$, where

$A = Q^3 - Q, \qquad B = -2Q^2\gamma_1 - Q^2 + \varepsilon_1 Q + 3Q - 2Q^3 + 2Q\gamma_1$

$C = 3Q^2\gamma_1 - 3Q\gamma_1 + Q^3 - 3Q - 2\varepsilon_1 Q - \varepsilon_1\gamma_1 + 2Q^2 - \varepsilon_1\gamma_1 Q$

$D = (\gamma_1+1)\left(\varepsilon_1\gamma_1 + Q - Q^2 + \varepsilon_1 Q\right)$

We look for a solution pair that satisfies the implementability conditions $0 \leq x_j \leq 1$ and $x_1 + x_2 \leq 1$. The polynomial satisfies $P(0) = D$ and $P(1) = \varepsilon_1\gamma_1^2 > 0$. It has a root in $[0,1)$ iff $D \leq 0$, and there is then only one root in this interval. The root is positive when $D < 0$. Note that $D \leq 0$ for $\varepsilon_1 \leq Q\frac{Q-1}{\gamma_1+Q} = \varepsilon_1^0$. For $0 < \varepsilon_1 \leq \varepsilon_1^0$ there is thus a unique root satisfying $0 \leq x_2 < 1$, and the root is $x_2 = 0$ iff $\varepsilon_1 = \varepsilon_1^0$.

It follows that $x_1 = \frac{1-Qx_2+\gamma_1}{1-x_2+\gamma_1}(1-x_2)$ satisfies $0 < x_1 \leq 1$, with $x_1 = 1$ iff $x_2 = 0$. Note also that the formula for x_1 yields $x_1 + x_2 - 1 = \frac{(1-Q)x_2}{1-x_2+\gamma_1}(1-x_2)$. Thus we have $x_1+x_2 \leq 1$ with equality iff $x_2 = 0.$, i.e. iff $\varepsilon_1 = \varepsilon_1^0$. These results prove the lemma. QED.

Proof of Proposition 4.

There are admissible solutions (i.e. solutions that satisfy common implementability) if owner shares are not too different across countries, and if spillovers are not too large ($2\varepsilon_j < Q-1$). We shall first prove that optimal owner shares (given an interior admissible solution) require

$$2x_2 - \frac{\varepsilon_2}{Q-1} = 2x_1 - \frac{\varepsilon_1}{Q-1}. \quad (16)$$

where $x_j = \frac{a}{m}K'_j$. We seek the owner shares that maximise $\sum_j mK_j(\theta)$, or equivalently, minimise $\sum_j mK'_j = \frac{m^2}{a}(x_1+x_2)$. Consider $(1+\lambda)\frac{\partial}{\partial\alpha_1}(x_1+x_2) = -\frac{\partial}{\partial\gamma_1}(x_1+x_2)+\frac{\partial}{\partial\gamma_2}(x_1+$

x_2). At an (interior) optimum we must have $\frac{\partial x_1}{\partial \gamma_1} + \frac{\partial x_2}{\partial \gamma_1} = \frac{\partial x_1}{\partial \gamma_2} + \frac{\partial x_2}{\partial \gamma_2}$. From (15) we get

$$\begin{aligned} \frac{\partial x_j}{\partial \gamma_j} &= \frac{1}{\Delta}\left[1+\frac{x_i}{x_j-1}\right]\left(Q+\gamma_i\frac{x_j}{(x_i-1)^2}\right), \\ \frac{\partial x_i}{\partial \gamma_j} &= \frac{-1}{\Delta}\left[1+\frac{x_i}{x_j-1}\right]\left(1-\frac{\gamma_i}{x_i-1}\right), \end{aligned} \tag{17}$$

where Δ is the determinant of the system (15). Substituting for these derivatives we obtain $\frac{\partial x_j}{\partial \gamma_j} + \frac{\partial x_i}{\partial \gamma_j} = \frac{1}{\Delta}\left[1+\frac{x_i}{x_j-1}\right]\left[\left(Q+\gamma_i\frac{x_j}{(x_i-1)^2}\right)-\left(1-\frac{\gamma_i}{x_i-1}\right)\right]$. The condition for optimal owner shares is therefore $\frac{1}{x_1-1}\left[Q+\gamma_2\frac{x_1}{(x_2-1)^2}-1+\frac{\gamma_2}{x_2-1}\right] = \frac{1}{x_2-1}\left[Q+\gamma_1\frac{x_2}{(x_1-1)^2}-1+\frac{\gamma_1}{x_1-1}\right]$. This yields $(Q-1)(x_2-1)+\gamma_2\left[1+\frac{x_1}{x_2-1}\right] = (Q-1)(x_1-1)+\gamma_1\left[1+\frac{x_2}{x_1-1}\right]$. Substituting from (15) we then get $(Q-1)(x_2-1)-1-\varepsilon_2+Qx_2+x_1 = (Q-1)(x_1-1)-1-\varepsilon_1+Qx_1+x_2$. Rearranging terms yields the condition (16) stated above.

We have now three equations (15 and 16) to solve for the three unknown variables x_1, x_2, γ_1. (Given that $\alpha_1+\alpha_2 = 1$, we have $\gamma_1+\gamma_2 = 2-\frac{1}{1+\lambda} = G$, and γ_2 can be replaced by $G-\gamma_1$.) The system yields $\gamma_1 = \frac{G}{2}+\frac{1}{8}\varepsilon\frac{2(Q-2)-\varepsilon-2\varepsilon_1+2\tau}{(Q-1)(1-\tau)}$, where $\varepsilon = \varepsilon_2-\varepsilon_1$, and $\tau \in (\frac{1}{2}\frac{\varepsilon}{Q-1}, 1)$ is the solution to $\tau^2+B\tau+C = 0$, with $-(Q+1)B = \varepsilon+2G+2\varepsilon_1+2\left(Q+2\right)$ and $(Q+1)C = 2(2+\varepsilon+G+2\varepsilon_1)-\frac{1}{4(Q-1)}\varepsilon^2$. From these relations and $\gamma_1 = 1-\frac{\alpha_1}{1+\lambda}$ we can verify the statements regarding the optimal α_1. QED

Proof of Proposition 5.

For $\alpha_1+\alpha_2 = 1$ we have $W = (1+\lambda)(E_1+E_2+\Pi)-\lambda\pi$ and thus $\frac{1}{1+\lambda}\frac{\partial W}{\partial \alpha_1} = \Sigma_j(\frac{\partial E_j}{\partial K_j}+\frac{\partial \Pi}{\partial K_j})\frac{\partial K_j}{\partial \alpha_1}-\frac{\lambda}{1+\lambda}\frac{\partial \pi}{\partial \alpha_1}$. At the combination α_1, α_2 that is optimal for the firm we have (uniformly in θ) $\frac{\partial \pi}{\partial \alpha_1} = 0$ and so $\frac{\partial W}{\partial \alpha_1}$ has the same sign as $\Sigma_j\gamma_j[m+\frac{maK_i'}{aK_j'-m}]\frac{\partial K_j}{\partial \alpha_1}$. (Here we have substituted for $\frac{\partial E_j}{\partial K_j}+\frac{\partial \Pi}{\partial K_j}$ from the equilibrium conditions (7) and used the quadratic functional forms.) Recall that π is maximised when mK_1+mK_2 is at a maximum, and so at the firm's optimum it holds $\frac{\partial K_1}{\partial \alpha_1} = -\frac{\partial K_2}{\partial \alpha_1}$. Using this fact and the definition $x_j = \frac{a}{m}K_j'$ we then see that $\frac{\partial W}{\partial \alpha_1}$ has the same sign as $\left\{\gamma_1\left[1+\frac{x_2}{x_1-1}\right]-\gamma_2\left[1+\frac{x_1}{x_2-1}\right]\right\}\frac{\partial K_1}{\partial \alpha_1}$. Substituting from (15) we find that the expression in curly brackets may be written as $-\left[1+\varepsilon_1-Qx_1-x_2\right]+\left[1+\varepsilon_2-Qx_2-x_1\right]$, which again is equal to $(\varepsilon_2-\varepsilon_1)+(Q-1)(x_1-x_2)$. Condition (16) shows that the last sum equals $\frac{1}{2}(\varepsilon_2-\varepsilon_1)$. Thus we have found that $\frac{\partial W}{\partial \alpha_1}$ has the same sign as $(\varepsilon_2-\varepsilon_1)\frac{\partial K_1}{\partial \alpha_1}$. It can be seen from the equilibrium conditions (15) that $\frac{\partial K_1}{\partial \alpha_1} > 0$. The statements in the proposition then follow from the properties of the optimal α_1 in Proposition 4.

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