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Technology Transfer and Spillovers in International Joint Ventures*

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Abstract

This paper analyzes the effects of a potential spillover on technology transfer of a multinational enterprise and on the host country policy. In particular, we examine how both parties' incentives can be controlled through the ownership structure in an international joint venture. In contrast to existing arguments we show that spillovers must not always have negative effects on technology transfer and they may be efficiency improving. Moreover, there are circumstances where a joint venture is mutually beneficial. Surprisingly, however, we find that despite the prospect of spillovers a joint venture is sometimes not in the interest of a host country.

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1 Introduction

Multinational firms are frequently confronted with restrictions about the ownership structure of their foreign operation by local governments. In particular, developing and transition countries often impose shared ownership agreements, hoping that this might facilitate beneficial technology spillovers for their local industries. Multinationals, on the other hand, are not always happy about such forced international joint ventures, precisely because of the risk of involuntary spillovers.[1]

In this paper we examine whether it is indeed in the local government's best interest to impose a joint venture agreement and whether it is in the multinational's interest to oppose such a requirement. For this purpose we study how the ownership structure of a multinational subsidiary affects the multinational's incentives to transfer technology and the local government's incentive to support the multinational's activities.

The ownership structure is particularly important when the multinational's competitive advantage stems from intangible assets or technological leadership. Sharing of ownership gives rise to the possibility of technology spillovers. This might be due to the fact that it is difficult to write a contract exactly specifying all aspects of the joint venture and the rights to use the intangible assets or technology. The problem of spillovers should be reduced when the multinational enterprise (MNE) owns a substantial part of the foreign firm.[2] Thus, the two levels of ownership, wholly owned versus partially owned, should have different implications for the transfer and diffusion of technology. In order to minimize the potential loss through a spillover a MNE would prefer full ownership of its local subsidiary. But there also exist good reasons why the MNE would voluntarily agree to share ownership. Maybe otherwise the full return of the intangible assets or of the superior technology cannot be achieved because the MNE lacks local experience. Moreover, direct investments are subject to sovereign risks.

[1] Such restrictions have been and still are prominent in countries like Russia, China, India, Indonesia, the Republic of Korea and many others (UNCTC [1987]). Moreover, in privatization practice governments often retained a substantial share of the privatized assets (Bortolotti, Fantini and Siniscalco [2003], Maw [2002]).

[2] This argument is in line with the property rights approach put forward in the seminal papers by Grossman and Hart [1986] and Hart and Moore [1990]. Ownership entitles the owner with all residual rights of control over all aspects of the asset.

This issue is particularly important in countries in transition. A government can, for example, choose to indirectly expropriate the assets of a direct investment through excessive taxation. By sharing ownership the MNE might be able to reduce the problem of lack of local experience or the sovereign risk problem.

There exists a large and growing literature on the transfer of knowledge and technology between countries and its impact on the productivity of domestic firms.[3] Two channels for the transfer of know-how can be distinguished: International trade and FDI. International trade can be a source of spillovers through demonstration effects when domestic firms learn the innovative content of imported goods. Coe and Helpman [1995], Coe, Helpman and Hoffmaister [1997], and Lichtenberg and van Pottelsberghe de la Potterie [1998] examine the influence of foreign trade partners' R&D on domestic total factor productivity. The empirical results confirm that foreign R&D influences domestic productivity and that the more open countries are to international trade the more they benefit.[4] FDI as a channel of technology transfer has been examined in Kokko [1994], Borensztein, De Gregorio and Lee [1998], Aitken and Harrison [1999] and Xu [2000].[5] The empirical results of theses studies are substantially different.[6] Kokko, Borensztein et al. and Xu show that positive spillovers are more likely if the technology gap between foreign and domestic firms is not too large and if there exists a minimum threshold of human capital.[7] Aitken and Harrison find negative spillovers from foreign investment on domestically owned plants and state that the gains from FDI appear to be entirely captured by joint ventures.[8]

There also exists some work on the interaction of spillovers and the ownership structure

[3]See Saggi [2001] or Blomström and Kokko [1998] for recent surveys on international technology transfer and spillovers.

[4]Keller [1998] doubts the importance of international trade patterns and shows that randomly created trade patterns also give rise to positive international R&D spillovers, which are often larger and explain more of the variation in productivity across countries. Keller [2002] finds that benefits from foreign spillovers decline with geographical distance.

[5]The earliest statistical studies of FDI and intra-industry spillovers are Caves [1974] and Globerman [1979].

[6]Görg and Strobl [2001] review the literature on multinational companies and productivity spillovers. They argue that the empirical methods used and whether cross-section or panel analysis is employed may have an effect on the empirical results.

[7]While a certain technology gap obviously is necessary for spillovers to occur, this finding seems to limit the assumption (e.g. in Findlay [1978] or Wang and Blomström [1992]) that spillovers grow with the size of the technology gap.

[8]Other studies which found evidence for negative spillovers include Haddad and Harrison [1993] or Djankov and Hoekman [2000].

in joint ventures. Blomström and Sjöholm [1999] analyze the effects of shared ownership on technology transfer and spillovers. They argue that, as generally believed, local participation with multinationals reveals their proprietary knowledge and in that way facilitates spillovers. This in turn might provide less incentive for the multinational to transfer technology and management skills. Their empirical results show that domestic establishments benefit from spillovers in terms of productivity levels, but the degree of foreign ownership does not affect the extent of it. In contrast, Dimelis and Louri [2002] find evidence that the degree of foreign ownership matters, and productivity spillovers are found to be stronger when foreign firms are in minority positions.[9] Nakamura and Xie [1998] consider a situation with bilateral spillovers. They argue that full ownership and joint ventures should differ with respect to the diffusion of technology. The ownership share should reflect the relative importance of the intangible assets which the partners bring into the joint venture. Their empirical results confirm that imports from the foreign mother and the share of exports from total revenue have a significant positive effect, while R&D expenditures of the local partner have a significant negative effect on MNE's share.

The other strand of literature that is related to our approach concerns the effects of sovereign risks on foreign direct investment.[10] Eaton and Gersovitz [1983] discuss a reputation model of FDI with many potential investors. If the host country taxes excessively, potential future investors are deterred and the host country loses access to foreign capital. In a companion paper, Eaton and Gersovitz [1984] show that the threat of nationalization may induce the foreign investor to choose an inefficient technology which makes nationalization less attractive to the host country.[11]

Schnitzer [2002] analyzes the choice between FDI and a combination of debt finance and a licensing agreement in the presence of sovereign risk. One result of this static model is that

[9]Explanations for the contrasting results of these studies could be the different development levels of the economies examined and differing econometric methodologies used.

[10]Not relevant for our discussion is the problem of sovereign debt. See Eaton [1993] and Eaton and Fernandez [1995] for recent surveys.

[11]Similar issues have been addressed in the literature on incomplete contracts. The classical notion of the hold-up problem goes back to Williamson [1985].

the sovereign risk problem can be alleviated if the host country and the foreign investor form a joint venture.[12] In particular, it is shown that there are circumstances where a joint venture can be efficiency improving and where the MNE voluntarily agrees to it. This is caused by the fact that by sharing ownership the host country is given an incentive to reduce taxation.[13]

We ask in particular: How does a potential spillover affect the incentive for a MNE to transfer technology and the policy incentives of the host country? Moreover, we examine how the incentives of both parties can be controlled through the ownership structure in an international joint venture. A spillover directly reduces the profit of the multinational and benefits a domestic (state-owned) firm. We make a distinction between the potential for a spillover and the effective spillover. The potential for a spillover determines the potential benefit to a domestic firm and is taken as exogenously given. The effective spillover contains the benefit that actually occurs and this is endogenously determined. The extent of the effective spillover depends on the technology transfer and on the ownership structure. We argue that the better the transferred technology and the larger the domestic ownership share, the larger will be the effective spillover. With respect to the host country policy we analyze two different scenarios: In scenario 1, the host country chooses the total amount of taxes to be paid and has thus the option to expropriate the entire return stream of the project. In scenario 2, the host country does not impose a tax but has the option to invest in local infrastructure. The difference between the two scenarios is that the tax can only be raised if the project was successful, while the investment in infrastructure is undertaken independently of the project's success. Thus, the investment cannot be interpreted as just a negative tax, i.e. a subsidy. This implies a substantial difference in the strategic choice of the two policies and their impact on technology transfer. In particular, taxation may serve as a perfect substitute for a spillover, while an infrastructure investment in general cannot perfectly compensate for a spillover.

[12] Schnitzer [1999] shows in a dynamic model of FDI how cooperation may be sustained. In particular, it is shown that sovereign risk may induce over- as well as underinvestment. Moreover, the frequently observed phenomenon of tax holidays is discussed.

[13] Konrad and Lommerud [2001] show that asymmetric information between the MNE and the host country as regards intra-firm trade between the MNE and its foreign affiliate is another possibility to alleviate the hold-up problem in FDI. By selling shares of the affiliate to locals the host government is given a further incentive to reduce taxation.

The results of our model show for both scenarios that a potential spillover need not in general have a negative effect on the incentive to transfer technology. In particular, in contrast to generally believed arguments, we can show that there are situations where a spillover has a positive effect on the transfer of technology, on both parties' payoffs, and on the efficiency of the project. The extent of the effective spillover increases with the domestic firm's ownership share in the joint venture, while the risk of creeping expropriation decreases or the incentive to invest in local infrastructure increases. These effects indicate that an extreme form of ownership (wholly owned or no equity but licensing) should not always be optimal for the MNE since one of the effects might destroy the incentive to transfer technology. Our results confirm for both scenarios that there are circumstances where a joint venture is mutually beneficial. Moreover, we ask whether or not it should always be in the interest of the host country to form a joint venture. This question is of particular interest to countries in Central and Eastern Europe and other transition countries, where sharing of ownership is often required by host country governments. However, we show that there exist cases where it is in the interest of the host country to reduce the domestic firm's ownership share or even not to share ownership.

The paper is organized as follows. The next section sets up the model. Section 3 analyzes the effect of spillovers on technology transfer and the incentives for excessive taxation. In section 4, we derive the results for the case of spillovers and investment by the host country. Section 5 discusses empirical implications of the model, while the final section concludes.

2 The Model

When a multinational enterprise engages in foreign direct investment it is often observed that this is done by forming a joint venture with a local firm. In countries in Central and Eastern Europe the joint venture partner often is a state-owned firm. Sometimes the multinational is forced to give away some share of the project without any compensation which is nothing but some special form of expropriation.

Consider the following relationship between a multinational enterprise (MNE) and a state-owned company in a host country (HC). The MNE seeks to employ an investment opportunity

in HC. This investment cannot be carried out by the domestic firm, because HC does not have enough funds available to finance the investment project and cannot obtain a credit on the international capital market. The investment project requires an initial outlay I. Without loss of generality we assume the riskless world interest rate to be zero. If the project is not carried out, both parties get their outside utilities, which are normalized to zero.[14]

MNE and HC can engage in a joint venture where HC receives some share $1-\alpha$ of the project's net profits. MNE gets the remainder of profits and possesses the control rights of the project. In a first step we assume α to be exogenously given in period $t=1$. Considering the role of the host country in $t=2$ we analyze two different scenarios: In scenario 1, the host country has the option to expropriate the entire return stream through taxation. HC chooses the total amount of taxes, T, to be paid. In scenario 2, we assume that the host country does not impose a tax but has the option to undertake an investment, M, on its own in order for the project to be valuable. HC chooses the amount of M, which directly benefits the project. M may be interpreted as an investment in local infrastructure and has to be spent independently of the project's success. The difference between the two scenarios is that the tax T can only be raised if the project has been successful, while the investment M will be spent independently of the project's success. Thus, M cannot be interpreted as just a negative tax, i.e. a subsidy. In $t=3$ MNE has to engage in additional actions, q, which affect the profitability of the project. For example, MNE may decide on the level of investment in training local workers and managers, in marketing the produced goods, transferring or upgrading technology. In $t=4$ profits are realized. The time structure is summarized in the following figure:

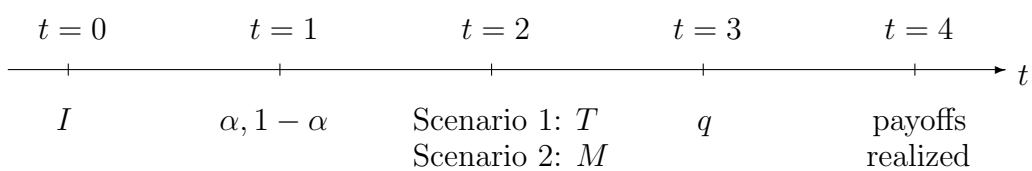

Figure 1: sequence of events

[14]In principle, there are two possibilities to finance and run the project: *debt finance* and *foreign direct investment*. Since we are interested in determining factors of ownership structure in international joint ventures we will consider the case of FDI. See Schnitzer [2002] for an analysis of the choice between FDI and debt finance.

The project's return is stochastic and may be either R or 0. The probability of success is affected by MNE's decision to transfer technology in $t = 3$. Without loss of generality we assume that MNE chooses the probability of success, $q \in (0, 1)$, directly at cost $K(q)$. $K(q)$ is an increasing, strictly convex function with $K'(0) = 0$ and $\lim_{q \to 1} K(q) = \infty$. The last assumption implies that for q sufficiently close to 1, $K'''(q) > 0$. To guarantee uniqueness of the solutions for the following maximization problems, we assume $K'''(q) > 0$ for all $q \in (0, 1)$. We assume that HC does not only share the revenues but also the costs from the subsequent investment into technology transfer. Therefore, it is assumed that a substantial part of these costs will be in local currency and thus HC can share these costs even without access to international capital markets or hard currency.

In scenario 2, where HC chooses an investment, M, the cost of investment, $C(M)$, is borne by HC alone. $C(M)$ is an increasing, strictly convex function with $C'(0) = 0$. We assume that HC is able to finance this infrastructure investment in local currency.

If the project is carried out in form of a joint venture there is potential for a spillover S from MNE to HC, where S is exogenously given. The spillover directly reduces the profit of MNE and benefits HC. We assume that the size of the effective spillover depends on two things: First, it depends on the decision to transfer technology and therefore on the probability of success q. Second, the ownership share $1-\alpha$ of HC matters. The first assumption emphasizes that the better the transferred technology the larger is the potential gain from a spillover to HC. The second assumption reflects the fact that the size of the effective spillover depends on the ability to get access to the MNE's technology. The possibility to get a closer look at the special features of the technology and know-how certainly depends on the participation of HC. Thus, the effective spillover is equal to $q(1-\alpha)S$. The spillover can be efficient in the sense that the direct reduction of the multinational's payoff is smaller than the benefit for the domestic firm and vice versa for an inefficient spillover. In order to be able to vary the efficiency of the spillover we introduce an efficiency parameter $\beta > 0$. For $\beta = 1$ the effective spillover is symmetric, i.e. the loss for MNE equals the benefit to HC. If $\beta < 1$ the effective spillover is efficient and vice versa for $\beta > 1$.

We can now define the payoffs for both parties in the two scenarios. In scenario 1, where HC chooses the total amount of taxes, T, to be paid, the parties' payoffs are

$$U^T_{MNE} = q\alpha[R - T] - q(1-\alpha)\beta S - \alpha K(q) - I, \tag{1}$$

and

$$U^T_{HC} = q\Big[(1-\alpha)[R - T + S] + T\Big] - (1-\alpha)K(q). \tag{2}$$

In scenario 2, where HC chooses investment in infrastructure M, payoffs are

$$U^M_{MNE} = q\alpha[R + M] - q(1-\alpha)\beta S - \alpha K(q) - I, \tag{3}$$

and

$$U^M_{HC} = q(1-\alpha)[R + M + S] - C(M) - (1-\alpha)K(q). \tag{4}$$

3 Spillovers and Taxation by the Host Country

Consider MNE's decision on how much to invest into transferring technology in the second stage of the project. MNE maximizes (1). Given the assumptions on $K(q)$ the optimal level of investment q is uniquely characterized by the following first order condition:

$$K'(q^T) = R - T - \frac{1-\alpha}{\alpha}\beta S. \tag{5}$$

Note that $q^T(T,\alpha)$ is a strictly decreasing function of T for all $T \in (0, R - \frac{1-\alpha}{\alpha}\beta S)$. Note further, that it depends directly on α, MNE's share of profits, because of the existence of a spillover.

When HC decides on the level of taxes to be imposed on the project it takes into account the effect of T on $q^T(T,\alpha)$ and thus on his own share of profits. HC maximizes (2). In the Appendix we prove that HC's maximization problem has a unique interior solution $T^T(\alpha) \in (-(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S, R - \frac{1-\alpha}{\alpha}\beta S)$.[15] Hence, the optimal amount of taxes $T^T(\alpha)$ satisfies the

[15] See Lemma 1 in the Appendix.

following first order condition:

$$\frac{dq^T(T)}{dT}\left[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S+T^T\right]+\alpha q^T(T)=0. \tag{6}$$

Note that even if $\alpha = 1$, HC will choose $T^T(1) < R$ such that MNE is induced to choose a positive q. Moreover, it could be optimal for HC to choose a negative tax, i.e. a subsidy. The reason for this is that in some circumstances only by subsidization MNE can be induced to choose a positive q. In these situations the profit share and the effective spillover outweigh the cost of the subsidy for HC.

How are the incentives to transfer technology and to raise taxes affected by the potential spillover S? Intuitively, it should be argued that since a spillover directly reduces MNE's payoff its incentive to invest should decrease. At the same time a spillover should provide an incentive for HC to reduce taxation. However, the parties' decisions are interdependent. Hence, a change in S has a direct effect on $T^T(\alpha)$ and $q^T(T,\alpha)$ and an indirect effect through the change in the respective other variable.

We can show that the direct effects of an increase in S on both decisions are negative as expected. And moreover, the overall effect on $T^T(\alpha)$ is always negative. Thus, the indirect effect on the investment $q^T(T,\alpha)$ through the change in $T^T(\alpha)$ is positive. Whether or not this indirect effect dominates the direct effect of a spillover on $q^T(T,\alpha)$ is a priori not clear. We show that the effects of an increase in the potential spillover on the incentive to transfer technology and on both parties' payoffs depend on the efficiency of the spillover. In particular, in case of an efficient spillover MNE is induced to increase its technology transfer which results in a positive effect on the parties' payoffs. The effects of an increase in the potential spillover on the optimal tax rate, on the optimal investment, on both parties' payoffs, and on total surplus are summarized in the following result:

Proposition 1 *Increasing S has the following effects on the optimal tax rate $T^T(\alpha)$, on the optimal investment in technology transfer $q^T(T,\alpha)$, on both parties' payoffs, and on the efficiency of the project:*

(i) $\beta = 1$: $\frac{dT^T}{dS} < 0$, $\frac{dq^T}{dS} = 0$, $\frac{dU^T_{MNE}}{dS} = 0$, $\frac{dU^T_{HC}}{dS} = 0$, $\frac{d(U^T_{MNE}+U^T_{HC})}{dS} = 0$.

(ii) $\beta < 1$: $\frac{dT^T}{dS} < 0$, $\frac{dq^T}{dS} > 0$, $\frac{dU^T_{MNE}}{dS} > 0$, $\frac{dU^T_{HC}}{dS} > 0$, $\frac{d(U^T_{MNE}+U^T_{HC})}{dS} > 0$.

(iii) $\beta > 1$: $\frac{dT^T}{dS} < 0$, $\frac{dq^T}{dS} < 0$, $\frac{dU^T_{MNE}}{dS} < 0$, $\frac{dU^T_{HC}}{dS} < 0$, $\frac{d(U^T_{MNE}+U^T_{HC})}{dS} < 0$.

Proof: See Appendix.

As a special case emerges the situation of a symmetric spillover, $\beta = 1$. In this case the optimal tax rate is exactly adjusted for the spillover such that the optimal investment remains unchanged compared to the case without a spillover, i.e. $q^T(T, \alpha) = q^*(T)$. To be more precise, the taxation will be lowered such that in the aggregate the sum of tax rate and spillover is equal to the taxation when there is no spillover, i.e. $T^T(\alpha) = T^*(\alpha) - \frac{1-\alpha}{\alpha}S$.[16] Hence, for $\beta = 1$ taxation and spillover are perfect substitutes from HC's point of view.

If the spillover is not symmetric, $\beta \neq 1$, it is not a perfect substitute for taxation. Therefore, it has an effect on all variables, on the payoffs of both parties and on efficiency. The indirect effect of an efficient spillover dominates the direct effect on $q^T(\alpha)$ and vice versa for an inefficient spillover. Therefore, the investment $q^T(\alpha)$ increases (decreases) if the spillover is efficient (inefficient). Intuitively we can argue that an efficient spillover, $\beta < 1$, does not harm MNE too much but it fully benefits HC. The opposite is true for an inefficient spillover. As a result of these effects the parties' payoffs and the efficiency of the project also depend on the magnitude of the spillover for $\beta \neq 1$. To be more precise, both parties' payoffs, and therefore the efficiency of the project, increase (decrease) in S for $\beta < 1$ ($\beta > 1$). We can summarize that in contrast to widespread opinions a potential spillover need not in general reduce the incentive to transfer technology or the efficiency of a joint venture.

How are the incentives of both parties affected by a change in the ownership structure? Intuitively, it could be expected that decreasing the multinational's ownership share α reduces the incentive to transfer technology. On the other hand, the incentive for HC to choose an excessive taxation is also reduced. Both effects should be more pronounced in the presence of a

[16] $T^*(\alpha)$ and $q^*(T)$ characterize the optimal choices for $S = 0$.

potential spillover. Which of these effects dominates is a priori not clear. Obviously, since the parties' incentives are affected by a potential spillover the effects of a change in the ownership division should also depend on the spillover. The following proposition summarizes the effects of a decrease in the multinational's share α on optimal taxation, on both parties' payoffs and on the efficiency of the project:

Proposition 2 *Suppose $S > 0$. A decrease of MNE's share, α, of net profits reduces the optimal tax rate $T^T(\alpha)$. The effect on MNE's payoff is ambiguous. For large values of α, there exist cases where MNE benefits from giving up some share of the project to HC. The effects on HC's payoff and on the efficiency of the project depend on the efficiency of the spillover:*

(i) $\beta = 1$: HC's payoff and the efficiency of the project are strictly increasing as α decreases. The effects are exactly the same as for $S = 0$.

(ii) $\beta < 1$: HC's payoff and the efficiency of the project are strictly increasing as α decreases.

(iii) $\beta > 1$: There exist cases where HC's payoff and the efficiency of the project increase as α increases. Moreover, there exist cases where HC's payoff and the efficiency of the project are maximized if ownership of the project is <u>not</u> shared.

<u>Proof:</u> See Appendix.

$T^T(\alpha)$ is strictly decreasing as α decreases. Intuitively, the lower α is, the higher is the share of profits which goes directly to HC. In order to increase the expected profits of the joint venture HC will restrict the imposed tax.

Proposition 2 shows that there are circumstances where a joint venture agreement is mutually beneficial even in the presence of a spillover. For large values of α MNE can sometimes benefit from giving away some share of the profit to HC without being directly compensated for it. By sharing ownership HC is induced to impose lower taxes thereby increasing overall efficiency and MNE's payoff. A joint venture may hence be used to mitigate the problem of creeping expropriation. This result can be obtained independently of the efficiency of a spillover

even though it could be argued that an inefficient spillover should reduce the incentive for MNE to share ownership.

We have already shown that a symmetric spillover only has an effect on the optimal tax rate $T^T(\alpha)$. Consequently, it is very intuitive that compared to a situation without spillovers the effects of a change in α differ only with respect to the effect on $T^T(\alpha)$. Because of the spillover a decrease in α reduces the optimal tax rate more than it would without a spillover. The other effects remain unchanged in their magnitude: A decrease in α increases the efficiency of the project and has a strictly positive effect on HC's payoff.

An efficient spillover extends the scope for voluntary joint venture agreements. The reason for this is that the spillover benefits HC more than it reduces MNE's profit. In this case MNE is given a stronger incentive to share ownership since thereby taxation is reduced more, while the loss due to the spillover is comparably small. HC has always an incentive to share ownership and therefore to enjoy a share of the project's net profits and to get access to the effective spillover.

Surprisingly, however, we find that for $\beta > 1$, there are cases where HC benefits and the efficiency of the project increases if α increases. Moreover, it is sometimes not in the interest of HC nor efficient at all to share ownership. What is the reason for this result? Increasing α reduces HC's share of the net profit and induces HC to increase total taxation. Increasing taxation has an indirect negative effect on the technology transfer by MNE and therefore on the probability of a successful project. On the other hand, increasing α has a positive direct effect on investment q since the loss due to the spillover for MNE is reduced. For sufficiently large values of β the latter effect may become very large and outweigh the effect on the profit share. This result gives a rationale why full ownership of the project by MNE can sometimes be in the interest of HC even though only shared ownership gives rise to a spillover. The finding is particularly interesting for countries in transition or Eastern European countries where sometimes multinationals are restricted to shared ownership arrangements. As we show, the negative effects associated with shared ownership, i.e. the reduced incentive for MNE to further invest, can become very strong. And thus, it can be optimal for HC to restrict its own

share of the project or even not to share ownership at all, but rather to enjoy a large expected tax revenue.

4 Spillovers and Investment by the Host Country

Now we ask how both parties' incentives are affected by a potential spillover if HC does not impose a tax on the project but instead has the option to undertake some investment, M, in order to increase the return of the project. Again, we first consider MNE's decision on how much to invest in the second stage of the project. MNE maximizes (3). The optimal level of investment q is characterized by the following first order condition:

$$K'(q^M) = R + M - \frac{1-\alpha}{\alpha}\beta S. \tag{7}$$

Note that $q^M(M, \alpha)$ is a strictly increasing function of M for all $M > 0$. Note further, that it depends directly on α because of the existence of a spillover.

When HC decides on the level of investment, M, it takes into account the effect on $q^M(M, \alpha)$ and thus on its own share of profits. HC maximizes (4). In the Appendix we prove under which conditions HC's payoff is maximized at $M^M(\alpha) \in (\underline{M}, \infty)$, where $\underline{M} = \max\{0, \frac{1-\alpha}{\alpha}\beta S - R\}$.[17] Hence, the optimal investment $M^M(\alpha)$ satisfies the following first order condition:

$$\frac{dq^M(M)}{dM}\left[(1-\alpha)\frac{\beta - \alpha\beta + \alpha}{\alpha}S\right] + q^M(M)(1-\alpha) - C'(M) = 0. \tag{8}$$

Note that, if $\alpha = 1$, HC will choose $M^M(1) = 0$. Thus, the host country has an incentive to invest in local infrastructure only if ownership of the project is shared.

How are the incentives to transfer technology and to invest in local infrastructure affected by the potential spillover S? Intuitively, it could be argued that a potential spillover reduces the incentive to transfer technology because it directly reduces MNE's payoff. On the other hand, HC is given a stronger incentive to invest in local infrastructure. Since the parties' decisions are interdependent a change in S has a direct effect on $M^M(\alpha)$ and $q^M(M, \alpha)$ and an indirect

[17] See Lemma 2 in the Appendix.

effect through the change in the other variable. As expected, the potential spillover S has a direct negative effect on the technology transfer $q^M(M, \alpha)$ and a direct positive effect on the investment $M^M(\alpha)$. The overall effect on the investment of HC is positive. Thus, the indirect effect on $q^M(M, \alpha)$ is positive and may therefore compensate for the direct negative effect of S. Which of the effects on the optimal transfer of technology dominates is a priori not clear. The effects of an increase in the potential spillover on both parties' profits and on the efficiency of the project are also ambiguous too as the following proposition states:

Proposition 3 *Increasing S strictly increases the optimal investment $M^M(\alpha)$. The effects on the optimal investment in technology transfer $q^M(M, \alpha)$, on both parties' payoffs and on the efficiency of the project are ambiguous:*

$$\frac{dM^M}{dS} > 0, \frac{dq^M}{dS} \gtreqless 0, \frac{dU^M_{MNE}}{dS} \gtreqless 0, \frac{dU^M_{HC}}{dS} \gtreqless 0, \frac{d(U^M_{MNE} + U^M_{HC})}{dS} \gtreqless 0.$$

Proof: See Appendix.

In general, a spillover has, independently of its efficiency β, an effect on all variables and therefore on both parties' payoffs and on the efficiency of the project. Again, as in scenario 1 with taxation by HC, the presence of a potential spillover need not in general reduce the incentive to transfer technology.

Contrary to the result in the first scenario, a spillover can affect both parties' payoffs and efficiency even if it is symmetric, $\beta = 1$. The reason for this result is that $M^M(\alpha)$ reacts differently than $T^T(\alpha)$ in case of a symmetric spillover. The investment does not in general perfectly compensate for the spillover and adjust the choice of $q^M(M, \alpha)$. This is caused by the fact that HC has to bear the investment cost $C(M)$ alone and independently of the project's success or failure, while the benefit of this investment can only be enjoyed in case of success.

More surprisingly, however, a spillover can have a negative effect on both parties' payoffs and on the efficiency of the project if the spillover is efficient, $\beta < 1$, or a positive effect if it is inefficient, $\beta > 1$. This is also in contrast to the results in scenario 1, where an efficient spillover always has a positive effect on payoffs and vice versa for an inefficient spillover. In

scenario 2, whether the spillover has a positive or negative effect depends on its impact on the incentive to invest for HC. Whenever a potential spillover leads to a strong incentive to invest in infrastructure the multinational is given a stronger investment incentive as well. This results in a positive effect on payoffs. Obviously, the host country's incentive to invest depends on the nature of the investment costs for local infrastructure. We can conclude that the cheaper the cost to invest in local infrastructure, or the more efficient the spillover, the more likely a potential spillover has a positive impact on both parties' payoffs.

How are the incentives of both parties affected by a change in the ownership structure? Intuitively, it could be expected that decreasing the multinational's ownership share α reduces its incentive to transfer technology. On the other hand, the incentive for HC to invest in local infrastructure should increase which in turn has a positive effect on the incentive for MNE. Whether or not one of the effects dominates is ambiguous. Since the parties' incentives are affected by a potential spillover the effects of a change in the ownership structure should also depend on the spillover. The following proposition summarizes the effects of a decrease in the multinational's share α on both parties' payoffs and on the efficiency of the project with or without the existence of a potential spillover:

Proposition 4 *A decrease of MNE's share, α, of net profits increases the optimal investment $M^M(\alpha)$. The effect on MNE's payoff is ambiguous. For large values of α, there exist cases where MNE benefits from giving up some share of the project to HC. The effects on HC's payoff and on the efficiency of the project depend on the existence of a spillover:*

(i) $S = 0$*: HC's payoff and the efficiency of the project increase as α decreases.*

(ii) $S > 0$*: There exist cases where HC's payoff and the efficiency of the project increase as α increases.*

Proof: See Appendix.

$M^M(\alpha)$ is strictly increasing as α decreases. Intuitively, the lower α the higher the share of profits which goes directly to HC and also the higher the share of the return on the investment

$M^M(\alpha)$. In order to increase the expected profits of the joint venture HC will extend its investment.

Proposition 4 shows that in the absence of a potential spillover, $S = 0$, a joint venture can be efficiency improving and beneficial for the multinational enterprise. Thus, also in this scenario with an investment by HC instead of taxation there are circumstances where MNE voluntarily gives away a share of the project without direct monetary compensation.[18] HC has always an incentive to share ownership since it only then enjoys a share of the project's return and is given an incentive to invest in local infrastructure. Consequently, the overall efficiency also increases with a decreasing ownership share of MNE.

For $S > 0$ there are again cases where a joint venture agreement is mutually beneficial and hence the multinational would voluntarily agree to it. HC has an incentive to share ownership and is thereby given the incentive to invest. Surprisingly, however, the results divert from those in scenario 1 in different aspects. We find that it is sometimes in the interest of HC and efficient to restrict its ownership share to a small fraction. And moreover, this result is independent of the efficiency of the spillover. In other words, even if the spillover is very efficient, $\beta < 1$, there are cases where HC is not interested in holding too large a share of the project. What is the reason for this counterintuitive result? Whether or not HC would like to hold a share of the project depends on the exact nature of the investment cost which HC has to bear independently of success or failure of the project. If investment in infrastructure is too expensive relative to the return on investment, HC has only little incentive to invest. This in turn results in only a small positive effect on the incentive to transfer technology by MNE. Moreover, there exist cases where for a given ownership division both parties have no incentive to invest. Therefore, in this scenario our theoretical analysis gives a rationale against a general restriction of ownership to a specified minimum share of the domestic partner. However, if HC's share of the project, $1 - \alpha$, can be chosen sufficiently small, both parties have an incentive to invest and the efficiency of

[18] Asiedu and Esfahani [2001] find evidence that any host country characteristic that increases productivity of local assets in the project tends to lower the foreign equity share. This might be in the interest of the foreign investor because it provides an incentive for the host country to improve its infrastructure and thereby enhance productivity.

the project can be maximized. The reason for this is that the smaller HC's share $1 - \alpha$ is, the smaller is the spillover and hence the smaller is the investment M needed to compensate for the spillover. Thus, in principle, HC always has an interest to hold at least a small share of the project.

5 Empirical Implications

With respect to the influence of a potential spillover, the model produces results which can be straightforwardly interpreted as regards to their empirical implications. In scenario 1, we have shown theoretically that a potential spillover has a very clearcut and intuitive influence on the parties' strategic decisions. Regarding the influence of the host country's taxation policy on the incentive for MNE to transfer technology and the influence of a potential spillover on the taxation policy itself we can formulate the following hypotheses:

Hypothesis 1 *The larger the political risk of the host country, the smaller the incentive to transfer technology.*

Hypothesis 2 *The larger the potential for a spillover, the smaller the risk of excessive taxation.*

As the model's results show, the influence of the spillover on the investment incentive for MNE depends on the efficiency of the spillover:

Hypothesis 3 *The potential for a spillover should have (a) a positive effect on the incentive to transfer technology if the effective spillover is efficient or (b) a negative effect if the effective spillover is inefficient.*

In scenario 2 we have shown that the results for the impact on the incentive to invest are less straightforward. Regarding the influence of the investment in local infrastructure by the host country on the incentive to transfer technology and the effect of a potential spillover on the investment incentive we can state the following hypotheses:

Hypothesis 4 *The larger the investment in local infrastructure by the host country, the larger the incentive to transfer technology.*

Hypothesis 5 *The larger the potential for a spillover, the larger the incentive to invest in infrastructure.*

Concerning the influence of a potential spillover we cannot formulate an unambiguous hypothesis but rather emphasize a tendency with respect to the efficiency of the effective spillover.

Hypothesis 6 *The potential for a spillover should tend to have (a) a positive effect on the incentive to transfer technology if the effective spillover is efficient or (b) a negative effect if the effective spillover is inefficient.*

6 Discussion and Conclusions

As previous studies have suggested and often argued, foreign direct investment is a source for the diffusion of knowledge and technology. It is well recognized that sharing ownership with a local partner can reveal a multinational's proprietary knowledge and in that way give rise to technology spillovers. The extent of such technology spillovers certainly depends on the nature of the transferred technology and on the ownership structure in the joint venture. We contribute to the literature by providing a simple model of an international joint venture between a multinational enterprise and a host country firm. In particular, we analyzed the effects of the potential for a spillover on the transfer of technology and on the host country's policy. Concerning the host country policy we considered two different scenarios: Taxation or investment in infrastructure.

In contrast to existing arguments we showed that the potential for a spillover does not necessarily have a negative effect on the incentive to transfer technology. There rather exist cases in both scenarios where a potential spillover has a positive effect on the transfer of technology and on the efficiency of the project. In the first scenario this depends crucially on the efficiency of the spillover. Surprisingly, however, we found that in the second scenario an efficient spillover can also have a negative effect on both parties' profits and vice versa for an inefficient spillover. However, besides these differing results we can still argue that a more efficient spillover generally has a positive effect on the incentive to transfer technology and thus

on the efficiency of the project and the other way round for an inefficient spillover.

Moreover, we examined how the incentives of both parties can be controlled through the determination of the ownership structure in an international joint venture. We showed that there are circumstances where a joint venture is mutually beneficial and thus the MNE voluntarily agrees to it. Interestingly, however, we found that it can be efficient for the host country to restrict its ownership share in the joint venture. Furthermore, there are circumstances where it is not in the interest of the host country nor efficient at all to share ownership. Hence, even though a spillover occurs in our model only if the host country holds a share of the project, a joint venture is sometimes not the optimal arrangement for the host country. This result is particularly interesting to countries in Central and Eastern Europe and transition countries, where sharing of ownership is often required by host country governments. The reasoning for these requirements is that in this way the diffusion of knowledge is facilitated and economic growth is spurred. But we show that exactly the opposite can be true, namely that the negative effects on the incentive to transfer technology dominate or the cost of investment in infrastructure is too expensive relative to its return. In these cases the host country should actually prefer not to foster a joint venture.

The present analysis throws some light on the question of whether or not the extent of local participation with multinationals has an impact on the extent of spillovers. As our model suggests, the extent of the effective spillover depends not only on the ownership structure but also on the incentive to transfer technology and on the host country's policy. Theses factors, on the other hand, depend on country specific as well as industry specific determinants. Whether or not a larger ownership share of the host country firm in turn leads to stronger spillovers is a priori not clear and can differ across countries and industries. This observation may help to explain why the empirical evidence on this issue is mixed. While Blomström and Sjöholm [1999] found no effect, Dimelis and Louri [2001] found evidence that the degree of domestic ownership matters with respect to the magnitude of spillovers.

Possible extensions of the model could include more sophisticated specifications of the bargaining game or the examination of the influence of other market characteristics such as

competition in the product market. It was not the aim of this model to determine the optimal ownership structure in an international joint venture. Despite these arguments we feel confident that our model helps to explain determining factors for the distribution of ownership in international joint ventures. A sounder theoretical approach to this issue and empirical tests of the proposed hypotheses are left for future research.

Appendix

Lemma 1 *For any $\alpha \in (0,1)$, HC's maximization problem has a unique interior solution $T^T(\alpha) \in \left(-(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S, R - \frac{1-\alpha}{\alpha}\beta S\right)$.*

Proof:

We first show that HC's profit function is strictly concave in T. By the implicit function theorem, $\frac{dq^T(T)}{dT} = -\frac{1}{K''(q^T)} < 0$. Differentiating U^T_{HC} with respect to T we get

$$\begin{aligned}
\frac{dU^T_{HC}}{dT} &= \frac{dq^T(T)}{dT}\left[(1-\alpha)[\underbrace{R-T-K'(q^T)}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by } (5)}+S]+T\right] + \alpha q^T(T) \\
&= -\frac{1}{K''(q^T)}\left[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S+T\right] + \alpha q^T(T).
\end{aligned}$$

$$\frac{d^2U^T_{HC}}{dT^2} = -\frac{1}{K''}\left[\frac{K'''}{[K'']^2}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S+T]+1+\alpha\right] < 0.$$

Hence, the optimal $T^T(\alpha)$ must be unique. Furthermore, it is never optimal to choose $T \geq R - \frac{1-\alpha}{\alpha}\beta S$, because this would imply $q^T(T,\alpha) = 0$ and $U^T_{HC} = 0$, while a strictly positive payoff can be obtained by choosing $T < R - \frac{1-\alpha}{\alpha}\beta S$. Finally, it cannot be optimal to choose $T = \underline{T} \equiv -(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S$. To see this note that at $T = \underline{T}$ we have $q^T(T,\alpha) > 0$.Thus,

$$\frac{dU^T_{HC}}{dT}|_{T=\underline{T}} = \alpha q^T(T,\alpha) > 0.$$

Hence, if $\alpha > 0$, a strictly higher payoff can be obtained by choosing $T > \underline{T}$.

Q.E.D.

Proof of Proposition 1:

By the implicit function theorem we can show that

$$\frac{dq^T}{dS} = -\frac{1}{K''}\left[\frac{1-\alpha}{\alpha}\beta + \frac{dT^T}{dS}\right].$$

Using again the implicit function theorem and taking account of the direct effect of an increase in S on q, i.e. $-\frac{1}{K''}\frac{1-\alpha}{\alpha}\beta$, we find that

$$\begin{aligned}
\frac{dT^T}{dS} &= -\frac{\frac{K'''}{[K'']^2}\frac{dq^T}{dS}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S+T^T]+\frac{dq^T}{dT}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}+\alpha\frac{dq^T}{dS}}{\frac{K'''}{[K'']^2}\frac{dq^T}{dT}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S+T^T]+\frac{dq^T}{dT}+\alpha\frac{dq^T}{dT}} \\
&= -\left(\frac{1-\alpha}{\alpha}\beta\right)\underbrace{\frac{\frac{K'''}{[K'']^2}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S+T^T]+1+\frac{\alpha}{\beta}}{\frac{K'''}{[K'']^2}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S+T^T]+1+\alpha}}_{=A>0} \\
&= -\left(\frac{1-\alpha}{\alpha}\beta\right)A<0, \qquad \text{with } A \gtreqless 1 \text{ if } \beta \lesseqgtr 1.
\end{aligned}$$

Thus, it follows

$$\frac{dq^T}{dS} = \frac{1}{K''}\frac{1-\alpha}{\alpha}\beta[A-1].$$

Differentiating U^T_{MNE} and U^T_{HC} with respect to S and re-arranging we get:

$$\begin{aligned}
\frac{dU^T_{MNE}}{dS} &= -\,q^T\alpha\frac{dT^T}{dS}-q^T(1-\alpha)\beta \\
&\quad \underbrace{+\frac{dq^T}{dS}\alpha\underbrace{\left[R-T^T-K'(q)\right]}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by (5)}}-\frac{dq^T}{dS}(1-\alpha)\beta S}_{=0} \\
&= q^T(1-\alpha)\beta[A-1].
\end{aligned}$$

$$\frac{dU^T_{HC}}{dS} = \frac{dq^T}{dS}\left[(1-\alpha)[\underbrace{R-T^T-K'(q)}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by (5)}}+S]+T^T\right]+q^T\left[(1-\alpha)+\alpha\frac{dT^T}{dS}\right]$$

$$= \frac{dq^T}{dS}\left[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S+T^T\right]+q^T(1-\alpha)[1-\beta A].$$

Summarizing the effects:

(i) $\beta=1 \Rightarrow A=1 \Rightarrow \frac{dT^T}{dS}<0, \frac{dq^T}{dS}, \frac{dU^T_{MNE}}{dS}, \frac{dU^T_{HC}}{dS}=0, \Rightarrow \frac{d(U^T_{MNE}+U^T_{HC})}{dS}=0$

(ii) $\beta<1 \Rightarrow A>1 \Rightarrow \frac{dT^T}{dS}<0, \frac{dq^T}{dS}, \frac{dU^T_{MNE}}{dS}, \frac{dU^T_{HC}}{dS}>0, \Rightarrow \frac{d(U^T_{MNE}+U^T_{HC})}{dS}>0$

(iii) $\beta>1 \Rightarrow A<1 \Rightarrow \frac{dT^T}{dS}<0, \frac{dq^T}{dS}, \frac{dU^T_{MNE}}{dS}, \frac{dU^T_{HC}}{dS}<0, \Rightarrow \frac{d(U^T_{MNE}+U^T_{HC})}{dS}<0$

For $\beta = 1$ we have $\frac{dq^T}{dS} = 0$. Thus, it follows from (5) that for $\beta = 1$ we must have $T^T(\alpha) = T^* - \frac{1-\alpha}{\alpha}S$, where T^* characterizes the optimal choice of T for $S = 0$.

Q.E.D.

Proof of Proposition 2:

By the implicit function theorem, it is straightforward to show that

$$\frac{dq^T}{d\alpha} = -\frac{1}{K''}\left[\frac{dT^T}{d\alpha} - \frac{1}{\alpha^2}\beta S\right].$$

Using again the implicit function theorem and taking account of the direct effect of an increase in α on $q^T(T,\alpha)$, i.e. $\frac{1}{K''}\frac{1}{\alpha^2}\beta S$, we can show that

$$\begin{aligned}
\frac{dT^T}{d\alpha} &= \frac{1}{\alpha^2}\beta S \underbrace{\frac{\frac{K'''}{[K'']^2}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + T^T] + 1 - \alpha^2 + \frac{\alpha^2}{\beta} + \alpha}{\frac{K'''}{[K'']^2}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + T^T] + 1 + \alpha}}_{=B>0} \\
&\quad + \underbrace{\frac{q^S(T)}{\frac{K'''}{[K'']^3}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + T^T] + (1+\alpha)\frac{1}{K''}}}_{=D>0} \\
&= \frac{1}{\alpha^2}\beta S B + D > 0, \text{ with} B \gtreqless 1 \text{ for } \beta \lesseqgtr 1.
\end{aligned}$$

Differentiating U^T_{HC} with respect to α and re-arranging we get:

$$\begin{aligned}
\frac{dU^T_{HC}}{d\alpha} &= \frac{dq^T}{d\alpha}\left[(1-\alpha)[\underbrace{R - T^T - K'(q^T)}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by (5)}} + S] + T^T\right] + \alpha q^T \frac{dT^T}{d\alpha} \\
&\quad + K(q^T) - q^T[R - T^T + S] \\
&= -\frac{1}{K''}\left[\frac{dT^T}{d\alpha} - \frac{1}{\alpha^2}\beta S\right]\left[\underbrace{(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + T^T}_{=K''\alpha q^T \text{ by (6)}}\right] + \alpha q^T \frac{dT^T}{d\alpha} \\
&\quad + K(q^T) - q^T[R - T^T + S] \\
&= \underbrace{K(q^T) - q^T\left[R - T^T + S\right]}_{<0} + \underbrace{q^T\frac{1}{\alpha}\beta S}_{>0}. \qquad (9)
\end{aligned}$$

A marginal increase of α reduces HC's share of total surplus, $q^T[R - T^T] - K(q^T)$, and reduces

the received spillover, $q^T S$. On the other hand, a marginal increase of α induces HC to increase total taxation by $\frac{dT^T}{d\alpha}$ and it induces MNE to change investment by $\frac{dq^T}{d\alpha}$. Both effects sum up to $q^T \frac{1}{\alpha}\beta S$, which is basically the direct effect of an increase in α on the investment q^T. This effect may dominate and thus HC may prefer to increase α, if β is sufficiently large. Note that (9) can be positive only if $\beta > 1$. To see this, note further that MNE will choose $q^T > 0$ only if $U^T_{MNE} > 0$, i.e.

$$q^T \alpha[R - T^T] - q^T(1-\alpha)\beta S - \alpha K(q^T) - I > 0.$$

Condition (9) is positive if, after re-arranging, we have

$$q^T \alpha \left[R - T^T\right] - q^T \beta S + \alpha q^T S - \alpha K(q^T) < 0.$$

Both conditions can be fulfilled simultaneously only if $\beta > 1$.

Differentiating U^T_{MNE} with respect to α and re-arranging we get:

$$\begin{aligned}
\frac{dU^T_{MNE}}{d\alpha} &= q^T[R - T^T + \beta S] - K(q^T) - q^T \alpha \frac{dT^T}{d\alpha} \\
&\quad \underbrace{+ \frac{dq^T}{d\alpha}\alpha \underbrace{\left[R - T^T - K'(q^T)\right]}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by } (5)} - \frac{dq^T}{d\alpha}(1-\alpha)\beta S}_{=0} \\
&= \underbrace{q^T[R - T^T + \beta S] - K(q^T)}_{>0} - \underbrace{\alpha q^T \frac{dT^T}{d\alpha}}_{>0}. \qquad (10)
\end{aligned}$$

Thus, the impact of α on MNE's payoff may be ambiguous. A marginal increase of α increases MNE's share of the total net payoff, $q^T[R - T^T] - K(q^T)$, and reduces the loss due to the spillover, $q^T \beta S$. On the other hand, a marginal increase of α induces HC to increase total taxes by $\frac{dT^T}{d\alpha}$, of which MNE has to pay the share α in case of a successful project, which happens with probability q^T. If α is close enough to 0, the second effect vanishes and MNE always prefers to increase α. However, if α is sufficiently large, the second effect may dominate. The effect of a change of α on total surplus is given by

$$\frac{d(U^T_{MNE} + U^T_{HC})}{d\alpha} = q^T \frac{1}{\alpha}\beta S - q^T \alpha \frac{dT^T}{d\alpha} + q^T(\beta - 1)S$$

$$= \underbrace{q^T \frac{1}{\alpha} \beta S[1-B]}_{\gtreqless 0 \text{ for } \beta \gtreqless 1} - \underbrace{\alpha q^T D}_{>0} + \underbrace{q^T(\beta-1)S}_{\gtreqless 0 \text{ for } \beta \gtreqless 1}. \tag{11}$$

By proof of Proposition 1 we know that for $\beta = 1$, $T^T(\alpha) = T^* - \frac{1-\alpha}{\alpha} S$ and thus $q^T(\alpha) = q^*(\alpha)$, where $q^*(\alpha)$ and $T^*(\alpha)$ characterize the optimal choices for $S = 0$. Hence, equations (9), (10), and (11), and therefore the effects of a decrease in α are the same for $\beta = 1$ and for $S = 0$.

Summarizing the effects:

(i) $\beta = 1 \Rightarrow \frac{dT^T}{d\alpha} > 0, \frac{dq^T}{d\alpha} < 0, \frac{dU^T_{MNE}}{d\alpha} \gtreqless 0, \frac{dU^T_{HC}}{d\alpha} < 0, \frac{d(U^T_{MNE}+U^T_{HC})}{d\alpha} < 0.$

(ii) $\beta < 1 \Rightarrow \frac{dT^T}{d\alpha} > 0, \frac{dq^T}{d\alpha} < 0, \frac{dU^T_{MNE}}{d\alpha} \gtreqless 0, \frac{dU^T_{HC}}{d\alpha} < 0, \frac{d(U^T_{MNE}+U^T_{HC})}{d\alpha} < 0.$

(iii) $\beta > 1 \Rightarrow \frac{dT^T}{d\alpha} > 0, \frac{dq^T}{d\alpha} \gtreqless 0, \frac{dU^T_{MNE}}{d\alpha} \gtreqless 0, \frac{dU^T_{HC}}{d\alpha} \gtreqless 0, \frac{d(U^T_{MNE}+U^T_{HC})}{d\alpha} \gtreqless 0.$

We prove by example that there indeed exist cases with the properties described in the proposition. Consider the following cost function:

$$K(q) = \frac{1}{1-q} - q.$$

For $\alpha = 0.98$, $R = 40$, and $S = 3$ the following results are obtained for different values of β:

	$\frac{dU^T_{MNE}}{d\alpha}$	$\frac{dU^T_{HC}}{d\alpha}$	$\frac{d(U^T_{MNE}+U^T_{HC})}{d\alpha}$	q^S	T^S	U^T_{MNE}	U^T_{HC}
$\beta = 0.3$	**-0.25**	-4.11	-4.36	0.65866	32.40	2.669	21.434
$\beta = 1$	**-0.07**	-2.72	-2.79	0.65855	32.36	2.665	21.406
$\beta = 1.2$	**-0.02**	-2.32	-2.34	0.65852	32.35	2.664	21.398
$\beta = 3$	0.43	**1.23**	**1.67**	0.65823	32.25	2.655	21.327

Thus, for large values of α, there exist cases where MNE's payoff increases as α decreases. This result can be obtained independently of the efficiency of a spillover β. For $\beta > 1$ there exist cases where HC's payoff and the efficiency of the project increase as α increases. This is the case for $\beta = 3$ in the example. However, for $\alpha = 1$ and $R = 40$ we get:

	$\frac{dU^T_{MNE}}{d\alpha}$	$\frac{dU^T_{HC}}{d\alpha}$	$\frac{d(U^T_{MNE}+U^T_{HC})}{d\alpha}$	q^S	T^S	U^T_{MNE}	U^T_{HC}
$\alpha = 1$	-	-	-	0.65838	32.51	24.921	21.352

Hence, in some cases HC benefits and the efficiency of the project is maximized if ownership is not shared.

Q.E.D.

Lemma 2 *For any $\alpha \in (0,1)$, HC's payoff is maximized at $M^M(\alpha)$, with*

(a) $M^M(\alpha) \in (0,\infty)$, if $R > \frac{1-\alpha}{\alpha}\beta S$ and $\frac{d^2U^M_{HC}}{dM^2}|_{M=M^M} < 0$, or

(b) $M^M(\alpha) \in (\frac{1-\alpha}{\alpha}\beta S - R, \infty)$, if $R \leq \frac{1-\alpha}{\alpha}\beta S$, $\frac{d^2U^M_{HC}}{dM^2}|_{M=M^M} < 0$, and $U^M_{HC}(M^M) > 0$, or

(c) $M^M = 0$, if $R \leq \frac{1-\alpha}{\alpha}\beta S$ otherwise.

<u>Proof:</u>

By the implicit function theorem, $\frac{dq^M(M)}{dM} = \frac{1}{K''(q^M)} > 0$. Differentiating U^M_{HC} with respect to M we get

$$\begin{aligned}\frac{dU^M_{HC}}{dM} &= \frac{dq^M}{dM}(1-\alpha)\left[\underbrace{R+M-K'(q^M)}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by (7)}}+S\right] + q^M(1-\alpha) - C'(M) \\ &= \frac{1}{K''(q^M)}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + q^M(M)(1-\alpha) - C'(M).\end{aligned}$$

$$\frac{d^2U^M_{HC}}{dM^2} = -\frac{1}{K''}\left[\frac{K'''}{[K'']^2}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S - (1-\alpha)\right] - C''(M).$$

Hence, HC's payoff is maximized at $M^M(\alpha)$, if $\frac{d^2U^M_{HC}}{dM^2}|_{M=M^M} < 0$ and if moreover $U^M_{HC}(M^M) > 0$. Given the assumptions on $C(M)$ there must exist an upper bound for M^M.

If $\alpha < 1$ and $R > \frac{1-\alpha}{\alpha}\beta S$, it is never optimal to choose $M = 0$. To see this note that in this case $q^M > 0$ and thus

$$\left.\frac{dU^M_{HC}}{dM}\right|_{M=0} = \frac{1}{K''(q^M)}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + q^M(M)(1-\alpha) > 0.$$

Hence, if $\alpha \in (0,1)$, a strictly higher payoff can be obtained by choosing $M > 0$.

If $\alpha < 1$ and $R \leq \frac{1-\alpha}{\alpha}\beta S$, it follows from (7) that $q = 0$ for all $M \leq \frac{1-\alpha}{\alpha}\beta S - R$. Hence, HC chooses $M^M \in (\frac{1-\alpha}{\alpha}\beta S - R, \infty)$ if $U^M_{HC}(M^M) > 0$ and $M^M = 0$ otherwise.

Q.E.D.

Proof of Proposition 3:

By the implicit function theorem we can show that

$$\frac{dq^M}{dS} = -\frac{1}{K''}\left[\frac{1-\alpha}{\alpha}\beta - \frac{dM^M}{dS}\right].$$

Using again the implicit function theorem and taking account of the direct effect of an increase in S on $q^M(M,\alpha)$, i.e. $-\frac{1}{K''}\frac{1-\alpha}{\alpha}\beta S$, we find that

$$\begin{aligned}
\frac{dM^M}{dS} &= -\frac{-\frac{K'''}{[K'']^2}\frac{dq^M}{dS}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + \frac{dq^M}{dM}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha} + \frac{dq^M}{dS}(1-\alpha)}{-\frac{K'''}{[K'']^2}\frac{dq^M}{dM}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + \frac{dq^M}{dM}(1-\alpha) - C''} \\
&= \frac{1-\alpha}{\alpha}\beta\,\underbrace{\frac{\frac{K'''}{[K'']^2}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + \frac{\alpha}{\beta}}{\frac{K'''}{[K'']^2}(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S - (1-\alpha) + K''C''}}_{=E>0} > 0.
\end{aligned}$$

The last inequality follows from the fact that the denominator has to be positive by Lemma 2 if HC's payoff is maximized at $M^M(\alpha)$. And it follows

$$\frac{dq^M}{dS} = \frac{1}{K''}\frac{1-\alpha}{\alpha}\beta[E-1] \gtreqless 0.$$

Differentiating U^M_{MNE} and U^M_{HC} with respect to S and re-arranging we get:

$$\begin{aligned}
\frac{dU^M_{MNE}}{dS} &= \underbrace{\frac{dq^M}{dS}\alpha\underbrace{[R+M-K'(q^M)]}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by (7)}} - \frac{dq^M}{dS}(1-\alpha)\beta S}_{=0} \\
&\quad + q^M\alpha\frac{dM^M}{dS} - q^M(1-\alpha)\beta \\
&= q^M(1-\alpha)\beta[E-1] \gtreqless 0.
\end{aligned}$$

$$\begin{aligned}
\frac{dU^M_{HC}}{dS} &= \frac{dq^M}{dS}(1-\alpha)\left[\underbrace{R+M-K'(q^M)}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by (7)}} + S\right] + q^M(1-\alpha)\frac{dM^M}{dS} \\
&\quad + q^M(1-\alpha) - C'(M)\frac{dM^M}{dS} \\
&= -\frac{1}{K''}\left[\frac{1-\alpha}{\alpha}\beta - \frac{dM^M}{dS}\right](1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S + q^M(1-\alpha)\frac{dM^M}{dS}
\end{aligned}$$

$$
\begin{aligned}
& + q^M(1-\alpha) - C'(M)\frac{dM^M}{dS} \\
= & -\frac{1}{K''}\frac{(1-\alpha)^2}{\alpha}\left(\frac{\beta-\alpha\beta+\alpha}{\alpha}\right)\beta S + q^M(1-\alpha) \gtreqless 0.
\end{aligned}
$$

The effect of a change in S on total surplus is given by

$$
\begin{aligned}
\frac{d(U^M_{MNE}+U^M_{HC})}{dS} &= q^M(1-\alpha)\beta[E-1] - \frac{1}{K''}\frac{(1-\alpha)^2}{\alpha}\frac{\beta-\alpha\beta+\alpha}{\alpha}\beta S \\
& + q^M(1-\alpha) \gtreqless 0.
\end{aligned}
$$

Q.E.D.

<u>Proof of Proposition 4:</u>

By the implicit function theorem we can show that

$$
\frac{dq^M}{d\alpha} = \frac{1}{K''}\left[\frac{dM^M}{d\alpha} + \frac{1}{\alpha^2}\beta S\right].
$$

Using again the implicit function theorem and taking account of the direct effect of an increase in α on $q^M(M,\alpha)$, i.e. $\frac{1}{K''}\frac{1}{\alpha^2}\beta S$, we can show that

$$
\begin{aligned}
\frac{dM^M}{d\alpha} &= -\frac{1}{\alpha^2}\beta S\frac{\frac{K'''}{[K'']^2}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S] + \alpha - \alpha^2 + \frac{\alpha^2}{\beta}}{\frac{K'''}{[K'']^2}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S] - (1-\alpha) + K''C''} \\
& -\frac{q^M(M)}{\frac{K'''}{[K'']^3}[(1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S] - (1-\alpha)\frac{1}{K''} + C''} \qquad < 0.
\end{aligned}
$$

The last inequality follows from the fact that the denominator has to be positive by Lemma 2 if HC's payoff is maximized at $M^M(\alpha)$. Differentiating U^M_{HC} and U^M_{MNE} with respect to α and re-arranging we get:

$$
\begin{aligned}
\frac{dU^M_{HC}}{d\alpha} &= \frac{dq^M}{d\alpha}(1-\alpha)\left[\underbrace{R+M-K'(q^M)}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by (7)}} + S\right] + q^M(1-\alpha)\frac{dM^M}{d\alpha} \\
& - C'(M)\frac{dM^M}{d\alpha} + K(q^M) - q^M[R+M^M+S] \\
&= \frac{1}{K''}\left[\frac{dM^M}{d\alpha} + \frac{1}{\alpha^2}\beta S\right](1-\alpha)\frac{\beta-\alpha\beta+\alpha}{\alpha}S \\
& + \frac{dM^M}{d\alpha}\left[q^M(1-\alpha) - C'(M)\right] + K(q^M) - q^M[R+M^M+S]
\end{aligned}
$$

$$= \underbrace{K(q^M) - q^M[R + M^M + S]}_{<0} + \underbrace{\frac{1}{K''}(1-\alpha)\frac{\beta - \alpha\beta + \alpha}{\alpha^3}\beta S^2}_{>0}. \tag{12}$$

Thus, the impact of α on HC's payoff is, independently of the efficiency of the spillover β, ambiguous. A marginal increase of α reduces HC's share of total surplus, $K(q^M) - q^M[R + M^M]$ and reduces the received spillover $q^M S$. On the other hand, a marginal increase of α induces HC to reduce its investment in infrastructure by $\frac{dM^M}{d\alpha}$ and it induces MNE to change investment by $\frac{dq^M}{d\alpha}$. Both effects sum up to the second expression in (12). This effect may dominate depending on the exact nature of investment costs.

$$\begin{aligned}
\frac{dU^M_{MNE}}{d\alpha} &= q^M[R + M^M + \beta S] - K(q^M) + \alpha q^M \frac{dM^M}{d\alpha} \\
&\quad \underbrace{+ \frac{dq^M}{d\alpha}\alpha[\underbrace{R + M - K'(q^M)}_{=\frac{1-\alpha}{\alpha}\beta S \text{ by } (7)}] - \frac{dq^M}{d\alpha}(1-\alpha)\beta S}_{=0} \\
&= \underbrace{q^M[R + M^M + \beta S] - K(q^M)}_{>0} + \underbrace{\alpha q^M \frac{dM^M}{d\alpha}}_{<0}.
\end{aligned}$$

The impact of α on MNE's payoff may also be ambiguous. A marginal increase of α increases MNE's share of total net payoff, $q^M[R + M^M] - K(q^M)$ and reduces the loss due to the spillover by $q^M \beta S$. On the other hand, a marginal increase of α induces HC to reduce its investment in infrastructure by $\frac{dM^M}{d\alpha}$, of which MNE enjoys the share α in case of a successful project, which happens with probability q^M. If α is close to 0, the second effect vanishes and MNE always prefers to increase α. However, if α is sufficiently large, the second effect may dominate. The effect of a change in α on total surplus is given by

$$\frac{d(U^M_{MNE} + U^M_{HC})}{d\alpha} = \underbrace{q^M(\beta - 1)S}_{\gtreqless 0 \text{ for } \beta \gtreqless 1} + \underbrace{\frac{1}{K''}(1-\alpha)\frac{\beta - \alpha\beta + \alpha}{\alpha^3}\beta S^2}_{>0} + \underbrace{\alpha q^M \frac{dM^M}{d\alpha}}_{<0}.$$

Summarizing the effects:

(i) $S = 0 \Rightarrow \frac{dM^M}{d\alpha} < 0, \frac{dq^M}{d\alpha} < 0, \frac{dU^M_{MNE}}{d\alpha} \gtreqless 0, \frac{dU^M_{HC}}{d\alpha} < 0, \frac{d(U^M_{MNE} + U^M_{HC})}{d\alpha} < 0.$

(ii) $S > 0 \Rightarrow \frac{dM^M}{d\alpha} < 0, \frac{dq^M}{d\alpha} \gtreqless 0, \frac{dU^M_{MNE}}{d\alpha} \gtreqless 0, \frac{dU^M_{HC}}{d\alpha} \gtreqless 0, \frac{d(U^M_{MNE} + U^M_{HC})}{d\alpha} \gtreqless 0.$

We prove by example that there indeed exist cases with the properties described in the proposition. Consider the following cost functions:

$$K(q) = \frac{1}{3}q^3 \text{ and } C(M) = M^2.$$

For $\alpha = 0.98$, $R = 0.1$, and $S = 20$ the following results are obtained for different values of β:

	$\frac{dU^M_{MNE}}{d\alpha}$	$\frac{dU^M_{HC}}{d\alpha}$	$\frac{d(U^M_{MNE}+U^M_{HC})}{d\alpha}$	q^M	M^M	U^M_{MNE}	U^M_{HC}
$\beta = 0.4$	**-0.92**	-4.62	-5.54	0.423	0.242	0.05	0.11
$\beta = 0.8$	0.03	**4.32**	**4.35**	0.315	0.326	0.02	0.02
$\beta = 0.9$	-	-	-	**0**	**0**	0	0

Thus, for large values of α, there exist cases where MNE's payoff increases as α decreases. Moreover, there exist cases where HC's payoff and the efficiency of the project increase as α increases. As the example highlights this can be the case even for an efficient spillover. For $\beta = 0.9$ sharing of ownership with $\alpha = 0.98$ results in no investment by both parties. However, for $\alpha = 0.99$, $R = 0.1$, and $S = 20$ we get:

	$\frac{dU^M_{MNE}}{d\alpha}$	$\frac{dU^M_{HC}}{d\alpha}$	$\frac{d(U^M_{MNE}+U^M_{HC})}{d\alpha}$	q^M	M^M	U^M_{MNE}	U^M_{HC}
$\beta = 0.9$	0.19	0.18	0.37	0.298	0.171	0.02	0.03

Q.E.D.

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