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April 2006 No. 4

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Herausgeber:
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Asset tangibility and capital allocation within multinational corporations[1]

Abstract

We investigate capital allocation across a firm's divisions that differ with respect to the degree of asset tangibility. We adopt an incomplete contracting approach where the outcome of potential debt renegotiations depends on the liquidation value of assets. However, with diversity in terms of asset tangibility, liquidation proceeds depend on how funds have been allocated across divisions. As diversity can be traced back to institutional differences between countries, we provide a rationale for multidivisional decision-making in an international context. A main finding is that multinationals may be bound to go to certain countries when financiers cannot control the capital allocation.

Keywords: Internal capital markets, multinational corporations, incomplete contracts, asset tangibility.

JEL Classification: G31, F23, D82

Zusammenfassung

Gegenstand dieser Untersuchung ist die Kapitalallokation bei multidivisionalen Unternehmen, deren Divisionen sich durch eine unterschiedliche Verwertbarkeit der mit ihnen verbundenen Vermögensgegenständen auszeichnen. Ausgangspunkt ist ein Modell unvollständiger Verträge, wobei das Ergebnis von Kreditnachverhandlungen vom Liquidationswert des Unternehmens abhängen. Aufgrund der Diversität bezüglich der Verwertbarkeit sind die Liquidationserlöse davon abhängig, wie das Kapital auf die Divisionen verteilt sind. Da Diversität auf institutionelle Unterschiede zwischen Ländern zurückführbar ist, werden somit Entscheidungen in multidivisionalen Unternehmen in einem internationalen Kontext dargestellt. Ein Ergebnis ist, dass multinationale Unternehmen nicht frei in ihrer Auswahl von Gastländern sind, wenn Gläubiger die Kapitalallokation nicht steuern können.

Schlagworte: Interne Kapitalmärkte, multinationale Unternehmen, unvollständige Verträge, asset tangibility.

1 This paper was partly written while the author was visiting the University of Illinois at Urbana-Champaign. Financial support from Fritz Thyssen Stiftung is gratefully acknowledged.

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1 Introduction

Asset tangibility has been found to be an important determinant of a company's ability to finance investments externally (Almeida and Campello, 2006). The basic reasoning is that the tangibility of assets determines the external financiers' valuation of a firm's transferable assets in case of default. As financiers rely to some extent on the liquidation of a company's assets in order to cope with opportunistic behavior or asymmetric information issues, the degree of the overall asset tangibility finally establishes an upper bound on a firm's total debt capacity.

But what happens when a firm has several lines of business that differ with respect to the degree of asset tangibility? How does *diversity* in terms of asset tangibility affect the firm's investment behavior? In this paper we take up this problem, which can be given a concrete motivation. During the last decades the world economy has integrated at a rapid pace. This process has taken place to a significant degree on the firm level, which refers to the economic activities of multinational corporations (henceforth MNCs). Diversity in terms of asset tangibility has then almost naturally become an issue since MNCs virtually always operate in countries that differ with respect to jurisdiction, regulations and other country-specific institutional factors that affect asset tangibility.[2] For example, when assets are to be liquidated in a certain country, lacking property rights and unpredictable legal decisions may require additional costly safeguarding measures to enforce the claims specified in an asset sale contract. Other problems may arise when labor market regulations form an obstacle for a potential buyer to redeploy assets properly by adjusting employment. Furthermore, in a country with an inadequately developed financial system potential purchasers of assets may be credit constrained. In either case, opportunities to collect much by means of liquidation may be limited for institutional reasons.

Yet, knowledge about how diversity in terms of asset tangibility affects the firm-internal allocation of funds and thereby the borrowing capacity is still vague. This is remarkable, the more so as MNCs nowadays account for a significant share of capital expenditure, employment, and value added around the globe. For example, in 2003 the value added of majority-owned nonbank foreign affiliates in the U.S. accounted for 5.8 percent of total value added in U.S. private industries. The value added of nonbank U.S. parents accounted for an additional 24 percent. Hence, U.S. GDP can be traced back, for a large part, to the operations of multinational corporations.[3]

Against this background, this paper provides a rationale for multidivisional decision-making in an international context by examining the role of diversity in terms of asset tan-

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2 It is widely recognized that country-specific institutions determine how external financiers assure themselves of getting a return on their investment (*Shleifer and Vishny*, 1997).

3 These figuers are calculated from *Zeile* (2005) and *Mataloni* (2005). Similar figures can be obtained for the EU (discussion in *Hanson and Slaughter*, 2004).

gibility for external financing constraints and for the firm-internal allocation of funds. We adopt a contracting approach where headquarters has an incentive to default strategically in order to renegotiate the terms of a debt contract. External financiers thus restrict the face value of debt to the proceeds of liquidating assets. How they cope with diversity in terms of asset tangibility crucially depends on whether they are able to control the allocation of funds across subsidiaries. When the MNC's investment policy is transparent, a financial contract governs the use of funds (as in the case of a tight lending relationship with a bank), and headquarters can commit to favoring subsidiaries in countries where assets are highly tangible. When, however, applicable disclosure rules and accounting standards are not reliable, not even the use of funds by headquarters is verifiable and financiers are thus not able to control the internal allocation of funds. The MNC is then referred to as being opaque and headquarters is inclined to improve its relative bargaining position for renegotiations by investing funds strategically biased, i.e. in a way which restrains financiers to some extent from liquidating assets in case the firm defaults.

One important question that can be addressed is whether MNCs are in some way bound to go to certain countries. The argument in this paper suggests that firms, which have to finance their investments to a large extent externally but cannot commit to a specific investment policy, are generally better off by choosing a relatively low degree of diversity. Transparent firms, however, can pledge their highly tangible assets to obtain external finance for investments in countries where institutions are less developed. The reason is that the pooling of projects, which are diverse in terms of tangibility, is only worthwhile when the firm does not become too opaque. To put it differently, the benefit of integrating projects that differ with respect to the degree of asset tangibility is that projects with severely limited liquidation values may obtain external finance, which they would not if they were stand-alones. On the other hand, the dark side of integration is that diversity may come along with opacity, which creates additional disincentives on the part of headquarters. MNCs headquartered in, e.g., emerging markets may thus be bound to favor other emerging countries in order to keep diversity within a narrow range.

The arguments in this paper add to the theoretical literature on the allocation mechanisms inside a multidivisional firm.[4] A common basic assumption in this literature is that headquarters exerts control rights over the resources pooled in a multidivisional firm (Gertner, Scharfstein and Stein, 1994), and as long as it is not contrary to existing law or enforceable contractual agreements, these rights allow headquarters to pursue its own interests while deciding on the allocation of funds. The main motive driving its decision is to channel resources to the most productive projects or, to put it differently, to

4 See *Hellwig, Laux and Müller* (2002) and *Stein* (2003) for comprehensive surveys on this literature.

pick up winners (Stein, 1997).[5] Albeit this strategy aims at improving the efficiency of capital allocation, it also generates additional adverse incentives. On the divisional level, incentives to exert effort (Brusco and Panunzi, 2005) or to gather and process information (Stein, 2002) may be weak. Moreover, internal power struggles among division managers may hamper efficient capital allocation (Rajan, Servaes and Zingales, 2000). Concerning disincentives for headquarters, it may not be willing to provide necessary incentives for division managers by paying them higher wages but by assigning higher capital budgets (Scharfstein and Stein, 2000). In addition, integrating projects may allow headquarters to turn its back on external financiers once the pooling of internally generated cashflows suffices in order to ensure follow-up finances for at least some of its projects, thereby lowering headquarters' incentive to meet its obligations vis-a-vis financiers (Inderst and Müller, 2003).[6]

Investment-financing relationships for multinational firms have been addressed by some empirical research. Stevens and Lipsey (1992), e.g., show for a sample of seven U.S. multinationals that capital expenditures in different countries are interrelated by means of firm-wide borrowing constraints. Desai and Foley (2004) add to this evidence. Their study, which is based on almost comprehensive data on U.S. multinationals' activities provided by the Bureau of Economic Analysis, confirms that rates of returns and investment rates of the operations of U.S. multinational firms comove, primarily as a result of firm-wide borrowing constraints. In addition, Desai, Foley and Forbes (2004) show that affiliates of U.S. MNCs in emerging markets – as opposed to local firms – are able to use cross-border internal capital markets to capitalize on the competitiveness benefits of large currency depreciations. However, although perhaps beneficial in some times of financial distress, internal capital markets of multinational firms seem far from being frictionless. Denis, Denis and Yost (2002), e.g., document that global diversification contributes to similarly large inefficiencies as industrial diversification does and leads, on average, to valuation discounts. However, Fauver, Houston and Naranjo (2004) find that international diversification has no effect on the value of multinationals headquartered in Germany, which suggests that the value of international diversification may depend on institutions that exist where the company is headquartered.

The remainder of the paper is organized as follows. In section 2, we introduce a simple model of debt renegotiations. Section 3 deals with a transparent MNC, while section 4

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5 Channeling resources should be understood broadly. It may concern cashflows (as in *Stein*, 1997) as well as real assets that are already in place (as in *Gertner et al.*, 1994) or – as in this paper – even funds raised externally.

6 In summary, evidence for dysfunctional internal capital markets in the context of multidivisional firms is provided by *Berger and Ofek* (1995), *Lamont* (1997), *Shin and Stulz* (1998) and *Rajan et al.* (2000), among others. In addition, *Lins and Servaes* (1999) and *Fauver, Houston and Naranjo* (2003) seem to support the view that institutions matter regarding (in-)efficiencies in internal capital markets of multidivisional firms.

focuses on an opaque MNC. The implications of the analysis are subsequently presented in section 5. The final section consists of some concluding remarks.

2 The basic structure of the model

The model is a contracting model with long-term investments where pledgeability of cashflows is limited. It is, therefore, related to papers such as those of Bolton and Scharfstein (1990), Hart and Moore (1998) and Campello (2005), but particularly to Hart and Moore (1994) from whom we adopt the main assumption that an entrepreneur can quit at some date before the returns are due and withdraw his human capital from the project. This potential behavior puts an upper bound on total indebtness if the entrepreneur cannot be costlessly replaced by the financiers. For the same reason as in Hart and Moore (1994) the optimal contract is a debt contract where the entrepreneur owes a repayment, which is constant across states, and where financiers assume control over the project's assets when the entrepreneur does not meet his obligations.

At date $T = 0$ the entrepreneur has two investment opportunities (projects) in different countries. Let I_n denote capital investment in country $n = 1, 2$ and suppose that each project yields a nonverifiable but safe return $R(I_n)$ at date $T = 2$ if the entrepreneur contributes his specific knowledge at some intermediate date $T = 1$. The production function R applies to both projects, it is twice continuously differentiable with $R(0) = 0$ and satisfies the Inada conditions.

If the entrepreneur does not provide his human capital, the physical assets can generate returns only by means of liquidation. The proceeds of liquidation depend on the respective tangibility of assets. From the perspective of multinational investments, the MNC's assets will exhibit a low degree of tangibility when they are primarily bound to a subsidiary located in a country where appropriate institutions are lacking and financiers have thus to encounter particular difficulties in finding a potent and reliable buyer for the assets. Against this background, we assume that liquidation will yield βI_1 or $\mu\beta I_2$, respectively. Through this, tangibility of assets in country 1 is reflected by β while the relation of the degrees of tangibility of both countries is captured by $\mu \in [0,1]$. We further assume that $\beta < \gamma$ with $\gamma > 1$ being the marginal gross return on an alternative investment.

First-best investment I_n^{fb} in country n is implicitly defined by $R'(I_n^{fb}) = \gamma$. When internal funds W of the entrepreneur do not suffice to finance these first-best investments, i.e. when $I_1^{fb} + I_2^{fb} > W$, the entrepreneur may raise a loan from external financiers to fill this gap. The financial contract may be unenforceable, however, as the entrepreneur cannot commit himself at $T = 0$ to contribute his specific human capital to the project at $T = 1$. Hence, even though at $T = 0$ funds are invested and repayments payable to the financiers at $T = 2$ are agreed upon, the entrepreneur might initiate renegotiations at

$T = 1$ to beat down repayments by threatening to withdraw his specific skills. Assuming that the entrepreneur has all the bargaining power he can offer a new payment equal to the liquidation value of assets and the financiers can do nothing better but accept. The entrepreneur, therefore, has an incentive to renege on the repayments to financiers when the promised repayment H exceeds the liquidation value of assets. Put differently, actual repayments P are bounded above by the total liquidation proceeds $\beta I_1 + \mu\beta I_2$:

$$P = \min\{H, \beta I_1 + \mu\beta I_2\}. \tag{1}$$

To complete the model setup, we need to pin down two further restrictions generally known as the participation constraints. First, financiers are willing to supply funds only if P satisfies

$$P \geq \max\{\gamma(I_1 + I_2 - W), 0\}, \tag{2}$$

which means that, if internal funds W do not suffice to cover the sum of investments $I_1 + I_2$ and the MNC thus raises a loan L of size $I_1 + I_2 - W$, financiers are willing to meet the demands of the MNC only if P is at least as large as the respective opportunity costs of external funds. Assuming that financiers are competitively organized, condition (2) holds with equality.

Second, the entrepreneur will accept a contract when the sum of the projects' returns net of repayments to financiers cover at least the opportunity costs of internal funds, which could also be invested in the alternative investment yielding a marginal return γ:

$$R(I_1) + R(I_2) - P + \max\{\gamma(W - I_1 - I_2), 0\} \geq \gamma W. \tag{3}$$

However, since there are no other costs than I for projects to be carried out, participation constraint (3) will not be binding in equilibrium and we henceforth neglect it in our formal analysis.

3 Transparency and commitment

Having set up the general structure of the model, we proceed with an MNC that is always transparent irrespective of how diverse (in terms of asset tangibility) it is. This is the case when the MNC is headquartered in a country with a highly developed banking system and maintains a close lending relationship with a bank. The main characteristic of such a lending relationship is that a banker not only supplies funds but is also engaged in monitoring activities that allow her to gather insider information about the firm. Based on this knowledge she can thus directly exert influence on the internal capital allocation. The model setup, therefore, corresponds in principle to that in Diamond and Rajan (2001) – with the extension that a banker can squeeze more than anyone else out of a company's assets because she is someone who actively controls how funds are used by the entrepreneur, and in so doing she may increase the total liquidation value of assets.[7]

The contracting problem can be seen as a situation where the entrepreneur and the banker jointly maximize total surplus with respect to the investment profile (I_1, I_2) taking (1) and (2) simultaneously into account. Combining these two restrictions yields

$$\beta I_1 + \mu\beta I_2 \geq \max\{\gamma(I_1 + I_2 - W), 0\}, \tag{4}$$

and the optimization problem thus reads as

$$\begin{aligned} &\max_{I_1, I_2} R(I_1) + R(I_2) - \gamma(I_1 + I_2) \\ &\qquad s.t. \\ &\beta I_1 + \mu\beta I_2 \geq \max\{\gamma(I_1 + I_2 - W), 0\}. \end{aligned} \tag{5}$$

In what follows the upper index C denotes commitment. Accordingly, I_n^C is the investment in country n of a transparent firm. We conclude

7 In this sense, the difference between a banker and an unprotected external financier regarding the achievable liquidation proceeds is endogenous in our approach.

Proposition 1 *Define a critical value of internal funds*

$$W_{crit}^{C} := \left(2 - \frac{\beta(1+\mu)}{\gamma}\right) I^{fb}. \tag{6}$$

The optimum investment is then characterized by:

- *If* $W \geq W_{crit}^{C}$*, there are first-best investments in both projects, i.e.* $I_1^C = I_2^C = I^{fb}$.
- *If* $W < W_{crit}^{C}$ *and* $\mu < 1$*, there is underinvestment in both projects with underinvestment being more severe in country 2 where tangibility of assets is worse, i.e.* $I_2^C < I_1^C < I^{fb}$.

Proof. See Appendix.

Firstly, as projects have hard-to-pledge returns the MNC is subject to a borrowing constraint and needs to fill in the resulting financial gap with internal funds. If there are, however, plenty of them the borrowing constraint does not restrain the MNC from first-best investments (part 1 of proposition 1). Secondly, since assets in country 2 are less valuable to a banker ($\mu < 1$) her willingness to grant a loan is even more restricted when the entrepreneur uses funds for investment in country 2. The results of proposition 1, part 2, are thus driven by the entrepreneur's need to trade off not only the marginal returns on investments but also to take into account the different effects these investments have on the strength of the borrowing constraint. Therefore, when the financial constraint is binding, i.e. when $W < W_{crit}^{C}$, an entrepreneur is willing to forgo investment returns in country 2 in favor of financial easing.

4 Opacity and strategic allocation

The financial contract derived in the previous section requires that the entrepreneur can credibly commit himself to the investment profile (I_1^C, I_2^C), i.e. once the contract is concluded the entrepreneur is not able to use funds (including the loan) in any way different from what is stated in the contract. Financiers may, however, not be able to control the internal allocation of resources when this allocation is not verifiable – a situation, which refers to what is meant by opacity.

When projects differ regarding the degree of asset tangibility, this deficiency generates an additional problem at the entrepreneurial level since, in principle, the entrepreneur can henceforth allocate funds strategically. By strategic allocation we mean that the investment strategy aims at a weakening of the bargaining position of financiers in renegotiations. In what follows now, we will consider the entrepreneur's investment decision for a given amount of funds available at first. Subsequently we endogenise the loan size and ask what the optimum loan contract will look like when the firm is opaque.

4.1 Investment decision

The entrepreneur decides on capital investment when loan L has already been granted. He knows that the allocation of funds may affect what he has to pay back to financiers because liquidation proceeds depend on capital allocation, and any promised payments higher than the liquidation proceeds can, in principal, be renegotiated later on. While renegotiation-proof payments $P = \min\{H, \beta I_1 + \mu\beta I_2\}$ look identical to those in the case of a transparent corporation, their implications are fairly different now. The reason for this is that the entrepreneur is subject to a time-inconsistency problem as the allocation of funds is not verifiable.

For the time being we also assume that the MNC does not invest in the alternative investment (which yields γ); it will become clear that this restriction will not be binding in the optimum. Moreover, owing to the budget constraint it suffices to consider investment in only one country. Let the upper index S denote strategic investment. The incentive constraint of an opaque MNC then reads as

$$I_1^S \in \arg\max_{I_1}\left[R(I_1) + R(L+W-I_1) - \min\{H, \beta I_1 + \mu\beta(L+W-I_1)\}\right], \tag{7}$$

which leads to:

Lemma 1 *An investment*

$$\hat{I}_1^S \;:\; R'(\hat{I}_1^S) = R'(L+W-\hat{I}_1^S)$$

is called symmetric as the entrepreneur does not care about asset tangibility, i.e. $\hat{I}_1^S = \frac{1}{2}(L+W)$*, whereas an investment*

$$\overline{I}_1^S \;:\; R'(\overline{I}_1^S) = R'(L+W-\overline{I}_1^S) + \beta(1-\mu)$$

is called strategically biased as the entrepreneur places more weight on that project with assets that are less tangible and a lessen weight on the other, i.e. $\overline{I}_1^S < \frac{1}{2}(L+W)$.

Define H^* *as the largest promised repayment for which it does not pay to invest strategically biased and to renegotiate. Then* H^* *and the optimum investment* I_1^S *simultaneously fulfill the following conditions*

$$\begin{aligned} H^* = &\left[R(\hat{I}_1^S) + R(L+W-\hat{I}_1^S) \right] \\ &-\left[R(\overline{I}_1^S) + R(L+W-\overline{I}_1^S) \right] \\ &+\left[\beta\overline{I}_1^S + \mu\beta(L+W-\overline{I}_1^S) \right], \end{aligned} \tag{8}$$

$$I_1^S = \begin{cases} \overline{I}_1^S & \text{if} \quad H > H^*, \\ \hat{I}_1^S & \text{if} \quad H \le H^*, \end{cases} \tag{9}$$

where $\beta\overline{I}_1^S + \mu\beta(L+W-\overline{I}_1^S) < H^* < \beta\hat{I}_1^S + \mu\beta(L+W-\hat{I}_1^S)$.

Proof. See Appendix.

Lemma 1 is a reformulation of the incentive constraint (7). It reflects that the entrepreneur is in principle inclined to allocate funds strategically biased unless either the projects have identical liquidation values ($\mu = 1$) or promised repayments do not exceed some critical value H^*. This critical value depends on the investment profiles in the two regimes and lies in the open interval between the respective liquidation proceeds.

Intuitively, with H being small it never pays for the entrepreneur to renege on promised repayments because the liquidation value of assets is higher than what he promised to repay, irrespective of the capital allocation. With repayments being independent from the investment policy, the entrepreneur always invests symmetrically (i.e. marginal returns are balanced) as this implies maximum total returns. However, when repayment obligations are very high, the entrepreneur always prefers to renege on H, and for this he improves his relative bargaining position for renegotiations by investing strategically

biased. Yet he will not invest solely in low-tangible assets because this would imply a forgoing of too much of the total returns. Finally, for intermediate values of promised repayments the entrepreneur takes into account that investing strategically biased has not only a benefit (as repayments can thereby be beaten down). Its downside is that it also implies a deviation from a return maximizing investment policy. Investing symmetrically and observing the contract is, therefore, still advantageous as long as the profits of doing so are not lower than investing strategically biased and entering into renegotiations afterwards. But there is a critical repayment obligation H^*, for which profits of investing symmetrically and complying with the contract's promises are exactly equal to the profits of investing strategically biased and breaking the contract. For any $H > H^*$ it does not pay to observe the contract and the entrepreneur is better off with a policy where investment is higher in that project where assets are less tangible.

This behavior implies that repayments are a concave (non-monotonic) function of the promised repayment (figure 1). As raising the promised repayments does not impair the incentives for symmetric investment as long as they remain below H^*, actual repayments P increase one-to-one in H. However, if the entrepreneur promises to repay more than H^* he certainly will do both, invest strategically biased and renege on the promised repayments afterwards. A marginal increase in H above H^* therefore implies that the amount actually paid by the entrepreneur will drop once and for all, and will not change anymore if H increases further.

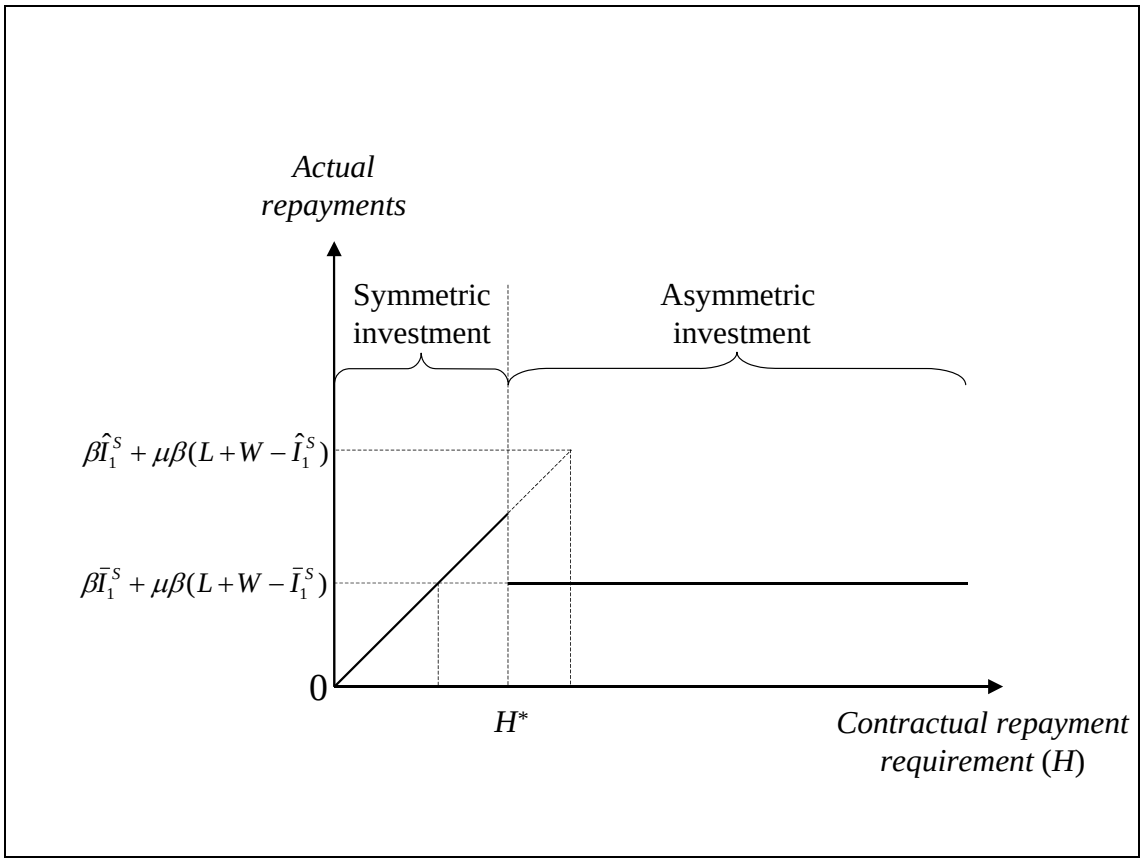
Given the entrepreneur's investment behavior we can then conclude:

Proposition 2 *For an opaque MNC that has total funds amounting to $L+W$ available the maximum enforceable repayments to financiers P^* are given by H^* according to lemma* 1. *With $H \leq H^*$ investment will always be symmetric.*

Proof. The proof follows directly from lemma 1.

One important implication of proposition 2 is that even if a repayment $H \leq H^*$ is promised the investment profile differs from optimum investment under commitment. As already shown in section 3, symmetric investment is – given the holdup problem and $\mu < 1$ – efficient only if the financial constraint is not binding. However, with an entrepreneur who has an opportunity to invest strategically biased there will always be symmetric investment irrespective of whether the borrowing constraint is binding or not. When compared to a transparent MNC, there is thus a tendency to invest more in assets that are less tangible (however, compared to the first best allocation there is no such bias but only underinvestment). This is due to the entrepreneur's lack of ability to commit, and from his perspective it is best to split funds so that marginal returns are counterbalanced.

Figure 1:
Repayments and repayment obligation



4.2 The optimum loan contract

Having analyzed the entrepreneur's investment policy for an exogenously given amount of funds, let us turn to the question of how many funds can be borrowed by the entrepreneur when the capital allocation is not verifiable. Assume that the entrepreneur is to make a take-it-or-leave-it offer to financiers at $T = 0$ and proposes both a loan size L^S and a repayment H^S. But, which combination of L^S and H^S does maximize the entrepreneurs profits? When answering this question one has to recognize that financiers anticipate what the entrepreneur will do with the funds and that they will only agree upon a loan contract when the proposed size of the loan and the offered repayments ensure that they are not worse off than investing in the alternative asset.

From our analysis so far, we are able to specify the incentive-compatible relationship between the size of the loan L and the maximum enforceable repayment P^*:

Lemma 2 *For $W > 0$ the maximum the entrepreneur can commit to paying (P^*) is a continuous and monotonously increasing function of the loan size L satisfying*

$$\frac{\partial P^*}{\partial L} \in (\mu\beta, \beta) \quad \text{if} \quad \mu < 1,$$

$$\frac{\partial P^*}{\partial L} = \beta \quad \text{if} \quad \mu = 1, \tag{10}$$

$$P^* > 0 \quad \text{if} \quad L = 0.$$

Proof. See Appendix.

Intuitively, as an increase in the loan size allows the entrepreneur to accumulate more assets, and since assets' returns can only be pledged up to their liquidation value, any additional dollar lent to the entrepreneur increases the maximum enforceable repayment by the projects' marginal liquidation value. This value is at most as large as the marginal liquidation value β of the most tangible assets but higher than that of the least tangible assets $\mu\beta$. Moreover, with $W > 0$ the maximum enforceable repayment is strictly positive since any investment has a positive liquidation value to be pledged even if investments are financed solely by internal funds.

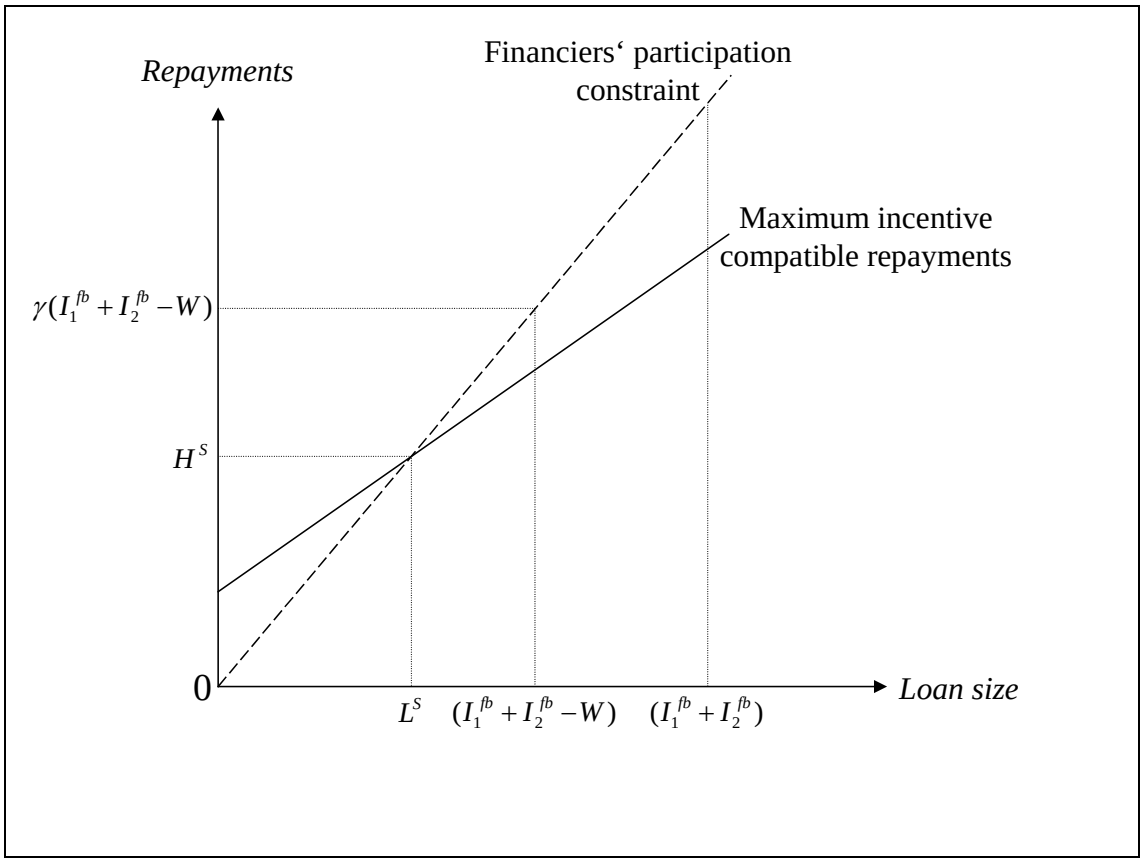
Besides, the financiers' participation constraint defines another relationship between P^* and L that has to be taken into account:

Lemma 3 *According to (2) financiers are willing to extend lending by γ^{-1} when the enforceable repayments P^* increase by one dollar.*

Proof. Omitted.

Figure 2 illustrates the interplay between these two relationships assuming $\mu < 1$. The dashed line represents the financiers' participation constraint. It depicts the maximum size of the loan, which is dependent on what financiers can extract from the entrepreneur given that they are marginally willing to accept the contract. Its intercept is zero and its slope in the (L, P^*)-space is γ. The solid line represents the maximum the entrepreneur can credibly commit to pay as a function of the loan size. It has a positive intercept and its slope is positive but smaller β and hence also smaller γ.

Figure 2:
The optimum loan contract



The intersection point of the two relationships represents the combination of the maximum loan size L^S and a promised repayment H^S such that the associated maximum enforceable repayments make financiers marginally willing to accept the contract. Any loan larger than L^S is not feasible since this calls for higher repayments to financiers than the entrepreneur is able to commit himself to pay. Hence, when external funds required for first-best investments ($I_1^{fb} + I_2^{fb} - W$) exceed the maximum loan size L^S (as it is in figure 2), the borrowing constraint is binding. Consequently, a financially constrained entrepreneur raises a loan L^S and offers a repayment H^S, and he will invest symmetrically and will not renege on H^S afterwards.[8] On the other hand, when $I_1^{fb} + I_2^{fb} - W$ is smaller than L^S, the borrowing constraint is not binding and the entrepreneur raises a loan just to fill his financial gap $I_1^{fb} + I_2^{fb} - W$. We summarize:

8 Note, raising a loan that is smaller than L^S is not efficient here. This is because the entrepreneur then forgoes net investment returns since marginal returns on investment are higher than γ due to general underinvestment as a result of a binding borrowing constraint.

Proposition 3 *For* $W < I_1^{fb} + I_2^{fb}$ *there is a unique optimum loan contract given by a pair* (L^S, H^S) *such that*

$$L^S = \min\left\{L^*, I_1^{fb} + I_2^{fb} - W\right\} \tag{11}$$

and

$$H^S = \gamma L^S, \tag{12}$$

with L^* *being the loan size, for which the associated maximum enforceable repayments (according to the entrepreneur's incentive constraint (7)) cover exactly its opportunity costs (according to the financiers' participation constraint (2)). The implied investments are then given by*

$$I_n^S = \frac{1}{2}(L^S + W) \quad \text{for all } n = 1, 2. \tag{13}$$

Proof. The proof follows from lemmata 1 to 3 and proposition 2.

Before turning to some implications of the model, it should be noted that it is indeed not crucial to assume that the MNC will not use loans for the alternative investment. Since there is underinvestment, the marginal return on either project is never lower than the marginal return on the alternative investment. Hence it is never worthwhile to use scarce funds for that purpose.

5 Implications

Diversity and opacity have several implications for the investment behavior of multinational corporations. The most important ones, however, are those related to the strength of the borrowing constraint. To fully understand how the incentives for the entrepreneur affect international capital allocation, it is useful to distinguish clearly between changes in diversity and changes in the overall tangibility of assets. To do so we redefine the marginal liquidation value in country 1 as $\beta := \beta_0/(1+\mu)$, such that variations in μ reflect changes in the degree of diversity, while changes in the average liquidation proceeds are captured by variations in β_0 – given that the MNC allocates funds across subsidiaries symmetrically.

The first implication refers to the minimum internal funds, which are required for a first-best investment policy:

Implication 1 *Internal funds required for first-best investments do not depend on the degree of diversity when the MNC is transparent, while they do increase according to the degree of diversity when the MNC is opaque.*

Proof. See Appendix.

A transparent MNC that is able to pursue first-best investments can do so irrespective of how diverse it is. The reason for this can be traced back to the financiers' ability to control the internal allocation of funds as this implies that the only thing that matters here is the average liquidation value β_0, which by definition does not change with diversity. However, when the capital allocation is not verifiable, a higher degree of diversity creates additional incentives for the entrepreneur to invest strategically biased, which implies that the maximum enforceable repayments decrease. To encounter this, financiers curtail credit. Consequently the MNC needs more internal funds in order to invest first-best optimally when diversity becomes more of an issue.

Implication 1 also means that, for a given degree of diversity, internal funds required for first-best investments are higher when opacity forms an additional obstacle for financiers to collect loans: Recall, when the entrepreneur possesses own funds amounting to W_{crit}^{C} (as defined in proposition 1) he would be able to raise a loan of $I_1^{fb} + I_2^{fb} - W_{crit}^{C}$ if the allocation were verifiable. But with total funds of $I_1^{fb} + I_2^{fb}$ available, an entrepreneur whose investment policy is not verifiable will invest symmetrically only if promised repayments do not exceed an H^* that is associated with these funds. Otherwise the entrepreneur aims at renegotiations, for which a strategically biased investment policy is advantageous. From lemma 1, however, we already know that H^* is strictly smaller than the liquidation value of a symmetric investment. Hence, since investing first-best

optimally is a special case of a symmetric investment policy, a promised repayment of $0.5\beta_0(I_1^{fb} + I_2^{fb})$, which just about suffices to make financiers accept the contract when the capital allocation would be contractible, is higher than the associated critical H^*. Accordingly, the entrepreneur has an incentive to invest strategically biased. But when investing relatively more funds into that country with a lower asset tangibility, financiers would not be able to extract sufficiently high repayments from the entrepreneur during the course of renegotiations. Consequently, they are ex ante not willing to provide enough funds required for first-best investments when the entrepreneur contributes own funds equal to W_{crit}^C. Put differently, an opaque MNC needs more internal funds for first-best investments. Along the same line of arguments, we can also draw the more general conclusion that for a given degree of diversity the borrowing constraint is tighter when financiers suffer from opacity.

Next we will consider how the described disincentives affect the *relative* capital allocation when diversity in terms of tangibility becomes more severe.

Implication 2 *An increasing degree of diversity implies that*

1. *when the MNC is financially constrained and opaque, the share of* I_2^S *in total investment does not change but total investment falls;*
2. *when the MNC is financially constrained and transparent, investment in the country with highly tangible assets* I_1^C *as well as total investment increases, whereas the response of investment in the other country is indeterminate.*

Proof. See Appendix.

When the capital allocation cannot be governed by a contract, i.e. opacity is severe, any (changes in the) differences in the tangibility of assets are irrelevant regarding the *relative* distribution of funds among different projects. This follows from proposition 3, according to which the entrepreneur always invests symmetrically irrespective of the degree of diversity. However, the strength of the borrowing constraint and, therefore, total investment heavily depends on diversity since a decrease in μ provides an additional incentive for the entrepreneur to invest strategically biased and the financiers' propensity to grant a loan dwindles.

The results are, however, completely different when opacity does not hamper financial contracting. In this case, the banker requires the entrepreneur to shift funds in favor of that country where assets are highly tangible. As the entrepreneur can comply with those demands due to his ability to commit, the banker is willing to extend lending. Accordingly, total investment increases when diversity becomes more severe, and as the entrepreneur can back investments in low tangible assets to an increasing degree with its highly tangible assets, even the project with a lower degree of tangibility may bene-

fit. This suggests that, e.g., German multinationals can effectively make use of tangible assets at home to pledge them for international investments.

Another, related aspect refers to the effects of variations in internal funds on the *relative* capital allocation, which also differ depending on whether the entrepreneur is able to pursue a commitment policy or not:

Implication 3 *Declining internal funds imply that*

1. *when the MNC is financially constrained and opaque, the share of* I_2^S *in total investment does not change;*
2. *when the MNC is financially constrained and transparent, the share of* I_2^C *in total investment is likely to decrease particularly if*
   a. *diversity is high (*μ *is low),*
   b. *average tangibility (*β_0*) is high, and*
   c. *marginal opportunity costs of funds (*γ*) are low.*

Proof. See Appendix.

According to the first part of implication 3, changes in internal funds have no effects on the relative capital allocation when the entrepreneur cannot commit to any investment policy. Again, as we already know from proposition 3, contracts will in this case always be designed so that the entrepreneur invests symmetrically. Therefore, variations in internal funds do not affect the relative distribution of funds at all but only total investment spending.

The second part has the following intuitive rationale: Note first that a high average tangibility in combination with a high degree of diversity and relatively low marginal opportunity costs of funds implies that the banker does not forfeit much when the entrepreneur enters into renegotiations given that he has invested most of his funds in highly tangible assets. On the flip side, potential losses to the banker are severe when funds have been invested in the country where asset tangibility causes much concern. Hence, an entrepreneur who reduces investment in that country where asset tangibility is worst will therefore be honored by the banker who substantially eases the financial constraint. As this absorbs most of the initial impact of a tightening of the borrowing constraint the entrepreneur's optimum response to declining internal funds is to reduce the share of investment in less tangible assets in the total investment. Note this strategy is, to some extent, irrespective of its opportunity costs, which may come from additional differences in the marginal returns on investment.

Altogether, the model implies that multinationals from emerging countries may be bound to go to countries with similarly developed institutions, while those from, say Germany, are almost free to go anywhere. If MNCs from emerging economies would apply for a loan to invest where assets are significantly more tangible, financiers would be rightly anxious about the firm not deviating from what it promised to invest there. Headquarters may instead divert money for spending it on investments at home (or in other emerging markets). Anticipating this disincentive, financiers are rather unwilling to provide funds. Therefore, investments into countries associated with a higher degree of tangibility is, for those firms, worthwhile only if there are plenty of internal funds available. On the other hand, when the MNC is tied to a banker who makes it fairly impossible for headquarters to deviate, it can pledge its highly tangible assets to obtain external funds for investments into countries where institutions are less developed.

6 Summary and concluding remarks

This paper has developed a theory of multinational investments. As multinationality refers to differences in the development of institutions that, e.g. provide for the enforceability of contracts and laws on a country level, it is associated with differences in the tangibility of assets across subsidiaries. The flip side of multinationality is that it may also be associated with opacity. Firms that are headquartered in countries with weak creditor protection can conceal how they allocate funds internally. When, in addition, subsidiaries differ with respect to tangibility, headquarters has an incentive to favor subsidiaries in those countries where the degree of tangibility is lowest. On the other hand, firms tightly bound to banks are transparent concerning the internal capital allocation. These firms are able to commit to investing predominantly in countries where financiers will yield higher liquidation proceeds.

In either case, limited pledgeability may cause a borrowing constraint and with regards to the strength of the borrowing constraint, we derive the following implications: Firstly, only if the firm is opaque, does the need for internal funds required for first-best investments rise when diversity increases. In other words, for a given degree of diversity the borrowing constraint is tighter when financiers suffer from opacity. Secondly, a higher degree of diversity may destroy potential benefits of integration when opacity prevails. Thirdly, when the entrepreneur's investment policy is transparent and diversity is pronounced, a fall in internal funds affects the project with the lowest liquidation value the most. When, on the other hand, the firm is opaque, both projects are identically affected by decreasing internal funds.

It is necessary to make a few remarks on the causes of potential differences in the tangibility of assets. Diversity in terms of tangibility may not only result from multinationality. Assets in some lines of business may also be more tangible than in other industries, even in the same country. Yet, operating in different industries implies that the respective production functions can also be expected to differ across divisions. The assumption, however, that the same production technology applies to different subsidiaries means that diversity in terms of asset tangibility can only be traced to institutional differences, which can be predominantly associated with multinationality. Thus, when diversity in tangibility arises for reasons other than multinationality, the model may be applied to ordinary multidivisional firms as well, while at the same time other models of internal capital markets cannot be associated with multinationality.

To conclude, our approach can in principle be applied to a broader set of question, e.g. what implications do diversity and opacity of MNCs have for macroeconomic issues such as the international transmission of business cycles, growth, and the effects of financial crisis. For example, in the 1990s the Japanese MNCs were not able to offset decreasing supply of bank loans at home by an increase of financing in the U.S., and they had thuse to reduce the number of foreign direct investment projects in the U.S. (Klein,

Peek and Rosengren, 2002). This observation is consistent with the argument developed in this paper. The Japanese banking crisis was associated with enormous collateral devaluations in Japan, hence the degree of diversity increased substantially. As it is reasonable to posit that U.S. investors judge Japanese MNCs as fairly opaque, they had to face the additional risk that funds provided to U.S. affiliates would then be shifted to Japan. Moreover, the willingness to provide external finance dwindled even further as internal funds generated by Japanese MNCs had also decreased during the course of the deep Japanese recession.[9] Although suggestive, a deeper analysis of these and related questions is arguably worthy of further research.

9 A similar reasoning can be given for the decline in lending activities of Japanese banks in the U.S. as observed by *Peek and Rosengren* (2000).

Appendix

Proof of Proposition 1

The FOCs associated with program (5) are given by

$$\frac{\gamma-\mu\beta}{\gamma-\beta}R'(I_1^C)-R'(I_2^C)-\frac{\gamma\beta(1-\mu)}{\gamma-\beta}=0, \tag{14}$$

$$\beta I_1^C+\mu\beta I_2^C-\gamma(I_1^C+I_2^C-W)\geq 0, \tag{15}$$

$$\lambda\geq 0, \tag{16}$$

$$\lambda\left(\beta I_1^C+\mu\beta I_2^C-\gamma(I_1^C+I_2^C-W)\right)=0, \tag{17}$$

with (14) being the marginal condition, (15) the borrowing constraint, and λ the Lagrangian multiplier.

The critical value of internal funds W_{crit}^C is obtained from (15) where it holds with equality for $I_n^C=I^{fb}$. When the entrepreneur invests first-best optimally in project n, i.e. $R'(I_n^{fb})=\gamma$, the marginal condition (14) requires for project $m\neq n$ that $R'(I_m^{fb})=\gamma$ also holds, i.e. first-best investment in project m is optimal too. When $W<W_{crit}^C$, the borrowing constraint is binding and from (14) we have $R'(I_1^C)<R'(I_2^C)$ so that $I_1^C>I_2^C$ for all $W<W_{crit}^C$.

Proof of Lemma 1

Reconsider (7)

$$I_1^S\in\arg\max_{I_1}\left[R(I_1)+R(L+W-I_1)-\min\left\{H,\beta I_1+\mu\beta(L+W-I_1)\right\}\right]$$

and assume that H is sufficiently large so that the entrepreneur always enters into renegotiation. He then chooses $I_1^S=\overline{I}_1^S$ according to the FOC

$$R'(\overline{I}_1^S)-R'(L+W-\overline{I}_1^S)-\beta(1-\mu)=0.$$

On the other hand, with H being very small renegotiations are never worthwhile and $I_1^S=\hat{I}_1^S$ according to

$$R'(\hat{I}_1^S) - R'(L+W-\hat{I}_1^S) = 0$$

is optimal. Furthermore, because of

$$R(\hat{I}_1^S) + R(L+W-\hat{I}_1^S) - H > R(\overline{I}_1^S) + R(L+W-\overline{I}_1^S) - H,$$

which holds for all H since total returns associated with $\overline{I}_1^S$ are strictly lower than those associated with $\hat{I}_1^S$, it is never worthwhile to invest strategically biased when the entrepreneur will certainly observe the contract and pay H. Accordingly, because of

$$\begin{aligned} &R(\hat{I}_1^S) + R(L+W-\hat{I}_1^S) - \beta\hat{I}_1^S - \mu\beta(L+W-\hat{I}_1^S) \\ &< R(\overline{I}_1^S) + R(L+W-\overline{I}_1^S) - \beta\overline{I}_1^S - \mu\beta(L+W-\overline{I}_1^S), \end{aligned}$$

which holds since $\overline{I}_1^S$ already maximizes profits given that renegotiations take place, it is never worthwhile to invest symmetrically when the entrepreneur will pay exactly the liquidation value of assets. Combining these two results yields that the entrepreneur will never invest strategically biased without entering into renegotiations and, at the same time, he will never invest symmetrically without observing the contract's rules.

To conclude, the entrepreneur will invest strategically biased ($\overline{I}_1^S$) and reneges on H if and only if the profits of doing so are strictly higher than those associated with investing symmetrically ($\hat{I}_1^S$) and observing the contact's rules:

$$R(\hat{I}_1^S) + R(L+W-\hat{I}_1^S) - H < R(\overline{I}_1^S) + R(L+W-\overline{I}_1^S) - \beta\overline{I}_1^S - \mu\beta(L+W-\overline{I}_1^S).$$

Hence there is a critical $H = H^*$ (given by (8)), for which the entrepreneur is indifferent and (9) follows immediately.

Finally, we have $H^* > \beta\overline{I}_1^S + \mu\beta(L+W-\overline{I}_1^S)$ because of (8) and because $R(\hat{I}_1^S) + R(L+W-\hat{I}_1^S) > R(I_1^S) + R(L+W-I_1^S)$ holds for all $I_1^S \neq \hat{I}_1^S$ as $\hat{I}_1^S$ already maximizes the sum of the projects' returns. Additionally, $H^* < \beta\hat{I}_1^S + \mu\beta(L+W-\hat{I}_1^S)$ holds, which can be proven by contradiction: Suppose the opposite to be true, i.e. $H^* > \beta\hat{I}_1^S + \mu\beta(L+W-\hat{I}_1^S)$. Then it would be also true that

$$\begin{aligned} &R(\hat{I}_1^S) + R(L+W-\hat{I}_1^S) - \left[\beta\hat{I}_1^S + \mu\beta(L+W-\hat{I}_1^S)\right] \\ &> R(\hat{I}_1^S) + R(L+W-\hat{I}_1^S) - H^* \\ &= R(\overline{I}_1^S) + R(L+W-\overline{I}_1^S) - \left[\beta\overline{I}_1^S + \mu\beta(L+W-\overline{I}_1^S)\right]. \end{aligned}$$

However, this is false since $\overline{I}_1^S$ already maximizes profits taking into account its effects on repayments.

Proof of Lemma 2

Taking into account that maximum enforceable repayments P^* are equal to H^* and reconsidering the investment choice of the entrepreneur (7) gives us:

$$\begin{aligned}
0 &= P^* - R(\hat{I}_1^S) - R(L+W-\hat{I}_1^S) \\
&\quad + R(\bar{I}_1^S) + R(L+W-\bar{I}_1^S) - (1-\mu)\beta\bar{I}_1^S - \mu\beta(L+W) \\
0 &= R'(\bar{I}_1^S) - R'(L+W-\bar{I}_1^S) - \beta(1-\mu) \\
0 &= R'(\hat{I}_1^S) - R'(L+W-\hat{I}_1^S).
\end{aligned}$$

Since the last condition implies $\hat{I}_1^S = \frac{1}{2}(L+W)$, this system of three equations is equivalent to

$$\begin{aligned}
0 &= P^* - 2R(\frac{1}{2}(L+W)) \\
&\quad + R(\bar{I}_1^S) + R(L+W-\bar{I}_1^S) - (1-\mu)\beta\bar{I}_1^S - \mu\beta(L+W),
\end{aligned} \tag{18}$$

$$0 = R'(\bar{I}_1^S) - R'(L+W-\bar{I}_1^S) - \beta(1-\mu). \tag{19}$$

This system of two equations and two endogenous variables P^* and $\bar{I}_1^S$ defines P^* as an implicit function of L according to

$$\begin{aligned}
\frac{\partial P^*}{\partial L} &= R'(\frac{1}{2}(L+W)) - R'(L+W-\bar{I}_1^S) + \mu\beta \\
&> \mu\beta.
\end{aligned} \tag{20}$$

The sign is positive since we know that $\hat{I}_1^S > \bar{I}_1^S$ implying $R'(\frac{1}{2}(L+W)) > R'(L+W-\bar{I}_1^S)$. But we also know from (18) that $R'(L+W-\bar{I}_1^S) = R'(\bar{I}_1^S) - \beta + \mu\beta$. Hence we can substitute $R'(\bar{I}_1^S) - \beta + \mu\beta$ for $R'(L+W-\bar{I}_1^S)$ in (20) yielding

$$\begin{aligned}
\frac{\partial P^*}{\partial L} &= R'(\frac{1}{2}(L+W)) - R'(\bar{I}_1^S) + \beta \\
&< \beta
\end{aligned}$$

if $\mu < 1$ and

$$\frac{\partial P^*}{\partial L} = \beta$$

if $\mu = 1$. Finally, from (8) it follows $P^*\big|_{L=0} > 0$ for $W > 0$ and any $\mu \in [0,1]$.

Proof of Implication 1

For $\beta := \frac{\beta_0}{1+\mu}$ the partial derivatives of W_{crit}^C with respect to μ is given by

$$\frac{dW_{crit}^C}{d\mu} = 0.$$

To show what happens to the amount of internal funds needed for first-best investments of an opaque MNC we take an indirect way. First, comparative statics to (18) and (19) yields that

$$\frac{dP^*}{d\mu} = \frac{\beta_0}{(1+\mu)^2}\left(L + W - 2\bar{I}_1^S\right),$$

which is positive because $\bar{I}_1^S < \frac{1}{2}(L+W)$. Hence an increase in diversity lowers the maximum enforceable payments P^*. Consequently, financiers' supply of external funds decrease and in order to maintain first-best investments, additional internal funds are required to fill the financial gap that arises when diversity increases. More internal funds ease the borrowing constraint in two ways. First, maximum enforceable repayments P^* increase and the need for external funds for first-best investments decreases.

Proof of Implication 2

Part 1 of implication 2 is a straightforward implication of proposition 3, whereby it is always optimal to invest symmetrically irrespective of how much internal funds are available.

Part 2 of implication 2 results from comparative statics. For investment in country 1 where asset tangibility is higher we obtain:

$$\frac{dI_1^C}{d\mu} = \frac{\Omega R''(I_2^C)\frac{\beta_0\left(I_2^C - I_1^C\right)}{(1+\mu)} + \Psi\left[\gamma\left(R'(I_2^C) - R'(I_1^C)\right) + \beta_0\left(R'(I_1^C) - \gamma\right)\right]}{\Psi^2 R''(I_1^C) + \Omega^2 R''(I_2^C)} < 0,$$

where

$$\Omega := \left(\gamma(1+\mu) - \beta_0\right) > 0$$

and

$$\Psi := \left(\gamma(1+\mu) - \mu\beta_0\right) > 0$$

i.e. when diversity becomes more pronounced, investment in highly tangible assets increase.

The response of investment in country 2 is however indeterminate as the comparative statics show

$$\frac{dI_2^C}{d\mu} = \frac{\Psi R''(I_1^C)\frac{\beta_0\left(I_2^C - I_1^C\right)}{(1+\mu)} + \Omega\left[\gamma\left[R'(I_1^C) - R'(I_2^C)\right] - \beta_0\left(R'(I_1^C) - \gamma\right)\right]}{\Psi^2 R''(I_1^C) + \Omega^2 R''(I_2^C)}.$$

But the total investment increases with diversity

$$\begin{aligned}\frac{dI_1^C}{d\mu} + \frac{dI_2^C}{d\mu} &= \frac{\beta_0\left(I_2^C - I_1^C\right)}{(1+\mu)}\frac{\Psi R''(I_1^C) + \Omega R''(I_2^C)}{\Psi^2 R''(I_1^C) + \Omega^2 R''(I_2^C)} \\ &\quad + (\Omega - \Psi)\frac{\gamma\left(R'(I_1^C) - R'(I_2^C)\right) - \beta_0\left(R'(I_1^C) - \gamma\right)}{\Psi^2 R''(I_1^C) + \Omega^2 R''(I_2^C)} \\ &< 0.\end{aligned}$$

Proof of Implication 3

Part 1 of implication 3 follows again from proposition 3, viz symmetric investment is always optimal.

Part 2 of implication 3 results from some comparative statics: By applying the general implicit function theorem to (15) and (14) for $W < W_{crit}^C$ it follows

$$\frac{\partial I_1^C}{\partial W} = \gamma(\gamma - \beta)\frac{R''(I_2^C)}{(\gamma - \beta)^2 R''(I_2^C) + (\gamma - \mu\beta)^2 R''(I_1^C)} > 0,$$

$$\frac{\partial I_2^C}{\partial W} = \gamma(\gamma - \beta)\frac{R''(I_1^C)}{(\gamma - \beta)^2 R''(I_2^C) + (\gamma - \mu\beta)^2 R''(I_1^C)}\frac{\gamma - \mu\beta}{\gamma - \beta} > 0,$$

where

$$\frac{\partial I_2^C}{\partial W} > \frac{\partial I_1^C}{\partial W} \Leftrightarrow \frac{\gamma - \mu\beta}{\gamma - \beta} > \frac{R''(I_2^C)}{R''(I_1^C)}.$$

With $\beta := \frac{\beta_0}{1+\mu}$ this condition is more likely to hold true for any $W < W_{crit}^C$ if μ and γ are small and if β_0 is large because

$$\frac{d}{d\mu}\left(\frac{\gamma-\mu\beta}{\gamma-\beta}\right)=-\beta_0\frac{2\gamma-\beta_0}{\left(\gamma+\mu\gamma-\beta_0\right)^2}<0,$$

$$\frac{d}{d\gamma}\left(\frac{\gamma-\mu\beta}{\gamma-\beta}\right)=-\beta_0\frac{1-\mu^2}{\left(\gamma+\mu\gamma-\beta_0\right)^2}<0,$$

$$\frac{d}{d\beta_0}\left(\frac{\gamma-\mu\beta}{\gamma-\beta}\right)=\gamma\frac{1-\mu^2}{\left(\gamma+\mu\gamma-\beta_0\right)^2}>0.$$

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