Financial constraints, Technology Transfer and Organizational Form *

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Abstract

In developing countries, transfer and assimilation of technologies developed in more industrialized countries constitute a major source of productivity growth. In this paper, we develop a simple model to show that financial constraints may have an impact on technological knowledge that is transferred from a global buyer to a local supplier. The model predicts that, when capital markets are perfect, high technology transfers are inferred while the supplier is more likely to operate as an independent firm. When the supplier has limited access to credit, technology transfers are reduced and vertical integration may be the preferred organizational form. Empirically, we test whether stronger credit constraints and lower financial development are associated with lower technology transfers, using firm-level data across 17 countries.

*We thank Thierry Verdier for helpful comments and suggestions. Contacts: juan.carluccio@ens.fr and fally@ens.fr

1 Introduction

International transmission of technology constitutes a major source of productivity growth for developing economies. In searching for the determinants of flows of international flows of technology, empirical evidence has stressed the role of firm-specific relationships. In particular, local suppliers of a developing country may learn from global buyers using advanced technologies and desiring to source specific inputs at lower cost. Technology spillovers may also be observed within the boundaries of firms, when the local supplier is integrated by the foreign corporation. As some knowledge may flow unintentionally, technology transfers are often the result of voluntary decisions of global buyers in order to boost the productivity of their respective suppliers. Indeed, Teece (1977) shows that transfer costs are sizeable and range from 2% to 59% of total costs when a downstream firm transfers the capacity to manufacture a good to a local firm, which can be a subsidiary, a joint venture, or a licensee.

The literature has emphasized the role of intellectual patent protection, property rights, and the risk of expropriation as institutional determinants of technology transfers, as well as human capital and investment in R&D at the firm level. In this paper we focus on the impact of credit constraints affecting the local supplier. By doing so, we suggest that local financial development constitutes an economically important institutional determinant of technology transfers and organizational structure.

In our model, a multinational firm seeking to source inputs from a low wage location enters in negotiations with a local upstream firm. In order to obtain an intermediate that fits its advanced technological requirements, the foreign firm has to transfer knowledge to the local partner. The process of technology transmission is assumed to entail costs in terms of real resources to both parties; the foreign firm has a cost of "teaching" the production process, whereas the local supplier faces costs of technology assimilation. The institutional features defining interactions between these two firms are characterized by two main assumptions. One is an incomplete contract setting. When firms actions cannot be enforced by contracts, the division of the surplus is made by ex post bargaining. Following Grossman and Hart (1986) and Hart and Moore (1990), we assume that bargaining positions are affected by ownership of residual rights over the use of the assets. Second, local capital markets function imperfectly, and this results in a limited level of initial liquidity for the supplier. Available funds are thus constrained by her initial capital and whatever funds she can obtain from external sources, which are limited by imperfect enforcement of financial contracts. Constraints on liquidity play a central role in the model since it is assumed that relationship-specific efforts are "hard" and need to be financed with upfront advances of capital.

Such a setting is used to study the interaction between access to finance, technology transfers and organizational form. We find that outsourcing and large technology transfers are more likely if financial markets are frictionless. Because the supplier is assigned residual rights, her incentives to invest in assimilating the technology are maximized. When access to finance is not an issue,

the supplier can undertake the level of desired investments, maximizing total surplus. When, however, access to finance is reduced due to low initial funds or frictions in the financial system, the model predicts a lower degree of technology transfer, and, eventually, the decision to integrate the supplier on the part of the multinational.

Our model delivers predictions that are susceptible to be tested against data. In the empirical section, we use cross-country firm-level data of 2372 manufacturing firms on 17 low- and low-middle income countries to corroborate the empirical validity of our theoretical intuitions. We provide evidence of a positive correlation between measures of financial constraints (both at the country as at the individual firm level), and the likelihood of receiving technology transfers. In order to account for simultaneity biases, we employ a difference-in-difference approach based on the indicator of an industry's external finance dependence developed by Rajan and Zingales (1998). This measure is country invariant and allows identification by exploiting cross-country variation in financial development. We find support to the idea that financial development has a differential impact on technology transfers for firms in relatively financially dependent industries.

As it stands, our work relates to different strands of current literature. On the one hand, it attempts at providing microfoundations on the institutional determinants of the often observed technological transfers and spillovers from multinationals. From a theoretical standpoint, there are some models that relate technology transfer decisions to the institutional environment, mainly focusing on the enforcement of intellectual property rights and technology expropriation. Ethier and Markusen (1996) analyze dynamic choice of technology transfers when intellectual property rights are not perfectly enforceable. Lin and Saggi (2007), Mattoo, Olarreaga and Saggi (2004) consider the strategic implications of technology transfers with limited competition. Grover (2007) seems to be a rare case in which technology transfers affect bargaining positions. However, to the best of our knowledge, theoretical attention has not to date but put into the local financial system. Another branch of literature to which our paper is susceptible of contributing is a group of paper relating local institutions to the organizational decisions of firms. In particular, Antras and Helpman (2008) derive predictions on the impact of contractual friction on the relative importance of outsourcing versus integration. Closer to our paper, Acemoglu, Antras and Helpman (2006) analyze the role of contractual frictions in determining the degree of technological complexity and the number of tasks outsourced by the downstream producer. Finally, Acemoglu, Aghion, Griffith and Zilibotti (2005) show how technology interacts with the structure of ownership.

On the empirical side, there is a large literature on spillovers from multinational firms (see Blomstrom and Kokko 1996, for a survey). More specifically, Teece (1977) analyzes the cost of technology transfers. A recent literature investigates the link between financial development and FDI. In particular, Antras, Desai and Foley (2007) look at financial development as a determinant of vertical integration versus outsourcing according to the R&D intensity of the multinational firms. Alfaro et al (2004 and *forthcoming*) show that FDI has a stronger

and more positive impact on productivity growth when the recipient country is better financially developed, but there is no detailed microeconomic analysis of the underlying mechanism.

The rest of the paper is organized as follows. Section 2 develops and solves a theoretical model in which the level of technology transfer and the chosen mode of organization by a multinational firm is endogeneized and linked the financial constraints affecting the local supplier. Section 3 presents the database and provides econometric evidence in line with the main prediction of the theoretical model. Section 4 concludes.

2 Model

2.1 Setup

Production

Consider the interactions between a multinational firm -henceforth M -, and the manager of a local upstream firm - a "supplier", labeled S -.

The multinational firm needs one unit of an input in order to produce one unit of a final good. The production of the intermediate requires the undertaking of a continuum of tasks. We assume that the technology of production is represented by a CES function where tasks are imperfect substitutes. This specification has the property that the surplus is increasing with the range of tasks that are effectively undertaken. A higher range of tasks can be interpreted as a higher "complexity" of the intermediate, thus yielding increased productivity and a positive relationship between the range of tasks and the value of the good[1].

The technological knowledge required to carry out the tasks is assumed to be entirely owned by the multinational firm. For each of these, M has to decide whether to transfer the know-how to the supplier. Tasks for which no knowledge is transferred are therefore left out of the production process. We denote by θ the range of tasks for which technology is transferred (to be derived endogenously). We assume that the process of transferring technology is costly [2]. Moreover, we let tasks differ in the difficulty that the multinational faces when communicating knowledge to the supplier, with some requiring less resources than others. Given that all tasks are assumed to be equally important for production, this implies

[1] See Ethier (1982) and Acemoglu et al (2007) for a related approach to production technology.

[2] The notion that transferring technology requires the transferee to devote nonnegligible amounts of resources have been documented by Teece (1977), who estimated that these can range from 2% to 59% per cent of total project costs. Arrow (1969), on the other hand, has argued that communication costs of technological knowledge are key in understanding international inequalities in productivity. He sustained that difficulties in both verbal and nonverbal forms of communication of information can be exacerbated in foreign trade, due to differences in language and culture. He advanced a comparison with the educational system: "In the complicated interplay of messages between teacher and student, the unreliabilities of communication can lead to extreme inefficiencies" (p 34).

that less expensive tasks are transferred first. Under this specification, the cost of technology transfer can be summarized by a convex function. For simplicity, we assume it to be quadratic and equal to $\frac{\theta^2}{2\gamma}$ where γ is an index of the efficiency of the multinational firm.

Another important ingredient in the production of the input is a specific effort on the part of the supplier, which involves technology assimilation efforts. These investments increase her productivity in the range θ of tasks for which technology has been transferred. Formally, if we denote by e_i the specific effort undertaken by the agent in task $i \in [0, \theta]$, the production function writes as

$$Q = \left(\int_0^\theta e_i^\beta di \right)^{\frac{1}{\beta}}$$

where $\frac{1}{1-\beta} > 1$ represents the elasticity of substitution between tasks. When efforts are similar across tasks, the production function simplifies into $Q = \theta^{\frac{1}{\beta}} e$. The cost of efforts by the supplier for each task is represented by a linear function $c(e) = \frac{e}{\phi}$, where ϕ is an index of the productivity of the supplier (e.g. absorptive capacity). Hence, if effort e is implemented for all tasks, the total cost of efforts equals $\frac{\theta e}{\phi}$.

Firms are assumed to operate in a monopolistic competition setup. This gives revenues as a function of Q:

$$Y = A^{1-\beta'} Q^{\beta'}$$

where A represents the level of industry demand and $\frac{1}{1-\beta'} > 1$ is the elasticity of substitution between final goods. For simplicity of exposition, we normalize A to unity and assume that the elasticity of substitution between final goods equals the elasticity between tasks in the production function (that is $\beta = \beta'$)[3]. The value of the production is thus linear in the level of technology transfer:

$$Y = \theta e^\beta$$

Given these features, total economic surplus, that is, production net of costs of technology transmission and investments by the supplier, is given by the following expression,

$$V = \theta e^\beta - \frac{\theta e}{\phi} - \frac{\theta^2}{2\gamma}.$$

Incomplete Contracting

We assume that firms operate in an environment where contracts are incomplete. This contract incompleteness comes from the inability to contract on the level

[3]This assumption is non essential and it is made for expositional reasons. In a more general specification, the level of efforts would depend on the level of technology transfers, and this would prevent us from obtaining simple analytical expressions. The model would be tractable and all our main results would remain qualitatively similar.

of investment e, as well as from the impossibility to contract over the quality of the input, which are assumed to be unverifiable for third parties.

We make on the other hand the assumption that the range of tasks over which technology is transferred can be specify in the initial contract, and perfectly verified by third parties[4].

This inability to write enforceable contracts for the quality of the traded good results in ex post bilateral bargaining over the surplus. We model this using the Nash bargaining solution with symmetric bargaining shares. In this bargaining game, when negotiations are through, each party obtains half of the quasi-rents generated by the partnership plus its outside option, represented by the value of the better alternative available in the event of no agreement.

Outside options in our context are assumed to be contingent on the prevailing organizational structure, following the property rights theory of the firm. We consider two forms of organizational structure. Under a nonintegration, or "outsourcing" arrangement, it is the supplier who is given residual rights. Therefore, in case that no agreement is reached in the bargaining stage, she walks away from the negotiations table with the input in hand. We assume that the input can be sold in the market at a value given by αY, with $\alpha < 1$. This parameter indexes the extent to which the input has been produced for the specific needs of the multinational, and how compatible it is for use by other final producers. Outside options for M in an outsourcing structure are assumed to be nil.

The alternative organizational arrangement is that of (backward) Vertical Integration, in which M incorporates S as an internal unit (affiliate), hires the manager as the head of this unit and retains ownership of the input in the eventual case of no agreement. If such is the case, the multinational can fire the manager and replace it with someone else, which constitutes its threat point in the ex post negotiation. We assume that this would come at a cost of losing part of her investment in intangible assets; specifically, the value of final output is decreased by a fraction δ, where $\delta < 1$. The outside option for the supplier is zero under Vertical Integration.

Analytically, outside options contingent on ownership structure are given by:

$$\begin{aligned} \mathcal{O}_S^O &= \alpha Y \\ \mathcal{O}_M^O &= 0 \end{aligned}$$

$$\begin{aligned} \mathcal{O}_S^I &= 0 \\ \mathcal{O}_M^I &= (1-\delta)Y \end{aligned}$$

with $\{O, I\}$ indexing outsourcing and vertical integration respectively.

[4]If this assumption does not hold, the sequentiality of technology transfers and effort of assimilation would allow some sort of commitment strategy for the multinational firm. In the same vein, we can think that payments and technology transfers are made step by step in order to prevent any deviation. Otherwise, if technology transfers are not enforcable at all, financial constraint would impact on the level technology transfers only through its negative effects on efforts.

Financial constraints

Finally, an important feature or our model is the fact that local capital markets are assumed to work only imperfectly. This implies that the local supplier is financially constrained at the moment of starting business with the multinational firm. The multinational firm, on the other hand, is assumed to have access to both foreign or internal financial markets and thus not face liquidity constraints at all.

Financial constraints prevent the supplier from raising enough cash, even in the presence of profitable projects. This lack of finance affects interactions between the two firms through two main channels. On the one hand, lack of liquidity imposes a bound on the level of any ex ante (upfront) transfers the supplier might be asked to make to the multinational. These transfers can represent royalties payments, or the cost of a licensing fee for the use of the technology, or may be interpreted simply as a participation fee. The important point is that they will be directly restrained by the level of liquidity held by the supplier at the beginning of the game. On the other hand, limited available funds reduce the ability of the supplier to make specific investments, in cases where these are in the form of physical investments that require monetary dispenses (e.g. building up production facilities that are in line with the technology's requirements, or making specialized machines for production of the input).

We assume that the level of initial liquidity in the hands of the supplier is made up by two elements. One is initial holdings of cash, which are summarized by a parameter W. This parameter is exogenous in the model and might be representative of cumulated cash flows from past entrepreneurial activities, or simply by inherited wealth. In addition, the supplier can raise debt in the local banking system[5].

The level of local financial development is indexed by a parameter $\kappa \in [0,1]$. Specifically, a project with expected returns equal to R is assumed to raise at most an amount κR from local banks. Thus, a value of $\kappa = 1$ indicates perfect capital markets, whereas $\kappa = 0$ indicates no capital markets. Between these two extreme values, κ provides an index of financial development. Such a relationship can be obtained when κ is interpreted as non-pecuniary costs of diverting the funds and not repaying the debt. Imagine that the cost the supplier faces from such an action is proportional to the level of profits, i.e. κR. Thus, total returns from diversion would write $(1-\kappa)R$, which are zero for $\kappa = 1$ and maximal at $\kappa = 0$. On the other hand, normalizing the interest rate to zero, returns from good behavior are $R - L$, where L indicates the amount of the loan. Thus, the amount on the debt that banks will be willing to issue in light of the moral hazard problem would be subject to the constraint $L \leq \kappa R$. See Schneider and Tornell (2004) and Aghion, Banerjee and Piketty (1997) for a similar approach to modeling financial development.

[5]For simplicity, we assume that local entrepreneurs do not have access to foreign financial markets. This assumption seems reasonable enough. The key is that local suppliers are credit constrained so, as long as access to foreign credit is not perfect, the assumption is harmless.

Before continuing on to the the solution of the model, we present the timing of events:

1. The multinational offers the supplier a tuple (Z, T, θ) where Z is the organizational form, T an upfront monetary transfer from S to M, and θ the level of technology transfers. The upfront payment T is restricted by the initial level of liquidity of the supplier.
2. The upfront payment T and the technology transfer take place for the range θ of tasks.
3. The supplier decides its level of effort e and produces the input at no extra costs (the total cost may not exceed available liquidity).
4. Nash bargaining on the value of joint production Y, and repayment of the external debt, if any, take place.

2.2 Solution of the model

In this section we solve for the equilibrium of the model. We proceed in the following way. First, we describe the problem faced by the multinational firm under each of both possible organizational arrangements. Note that, given ownership structure, the decision of the multinational amounts to choosing a range of tasks over which technology is transferred and a level of ex ante monetary payments. These decisions are taken by perfectly anticipating optimal behavior by the supplier and taking into account her liquidity constraints. Second, we describe optimal choices as a function of financial frictions, starting from the benchmark case of no financial constraints. Next, we analyze the choices of investments and technology transfer under outsourcing when financial constraints bind. Finally, we analyze the case of integration and derive the condition determining the optimal organizational form.

Maximization program under outsourcing

In this organizational structure, the supplier is given residual rights over the assets. This means that she can make use of the assets and technology in case of disagreement in the bargaining stage, and thus has positive outside options. These define ex post bargaining threat points and thus the ex post sharing of the value created by the partnership. In formal terms, under an outsourcing arrangement, M chooses the pair (θ, T) that solves the following constrained maximization problem:

$$\max_{\theta,T} \quad \Pi = \left(1 - \tfrac{1+\alpha}{2}\right)\theta e^{\beta} - \tfrac{\theta^2}{2\gamma} + T$$

$$\begin{aligned}
\text{s.t.} \quad & T \leq \left(\tfrac{1+\alpha}{2}\right)\theta e^{\beta} - \tfrac{\theta e}{\phi} && \text{(Participation constraint)} \\
& T \leq W + L - \tfrac{\theta e}{\phi} && \text{(Liquidity constraint)} \\
& L \leq \kappa\left(\tfrac{1+\alpha}{2}\right)\theta e^{\beta} && \text{(Financial constraint)} \\
& e = \text{argmax}_{e \leq (W+L-T)\frac{\phi}{\theta}} \left\{\left(\tfrac{1+\alpha}{2}\right)\theta e^{\beta} - \tfrac{\theta e}{\phi}\right\} && \text{(Incitation constraint)}
\end{aligned}$$

The objective function of the multinational has three components. The first term is the payoff resulting from the ex post bargaining of the surplus, which is easily computable from the definition of total surplus and of the outside options. The second term represents total costs of transferring the technical knowledge and the third one is the ex ante transfer that it receives from the supplier.

The level of ex ante transfers that the multinational can demand is subject to two constraints. The participation constraint imposes nonnegative total payoffs to the supplier. The financial constraint is made up by two separate features of the model. The first of these is the fact that the supplier has limited financial capacity (debt and initial capital), which puts an upper bound on the amount that the foreign firm can ask her to pay upfront. The second is the liquidity that is required for supplier investments, in particular R&D and adoption costs that are necessary to assimilate the technology. Therefore, M can, at most, extract ex ante from S the liquidity that exceeds the costs of financing its specific investments. The third constraint puts an upper bound to the debt that S can raise, which cannot exceed the cost of default (proportional to the index of financial development κ). Finally, the last constraint shows how the supplier optimally determines its level of efforts, given her available funds.

Maximization program under integration

In this case the multinational is given property rights over the assets in the event that negotiations break down. The problem now amounts to choosing (θ, T) to maximize:

$$\begin{array}{lll} \max\limits_{\theta,T} & \Pi = \left(1-\frac{\delta}{2}\right)\theta e^{\beta} - \frac{\theta^2}{2\gamma} + T & \\ \text{s.t.} & T \leq \left(\frac{\delta}{2}\right)\theta e^{\beta} - \frac{\theta e}{\phi} & \text{(Participation constraint)} \\ & T \leq W - \frac{\theta e}{\phi} & \text{(Liquidity constraint)} \\ & e = \text{argmax}_{e \leq (W-T)\frac{\phi}{\theta}} \left\{ (\frac{\delta}{2})\theta e^{\beta} - \frac{\theta e}{\phi} \right\} & \text{(Incitation constraint)} \end{array}$$

There are two fundamental differences with the previous case. First, ex post payoffs to both parties change according to the new allocation of residual property rights. Second, bank debt does not play any relevant role. Under integration, the supplier becomes the manager of the affiliate, and it is not help responsible for the debt in the case of disagreement. Thus, if any level of debt L is raised, it is equivalent to a reduced ex ante payment $T - L$, given that the debt would be entitled to the multinational.

No Financial Constraints

When W is large or capital markets are frictionless, and irrespective of organizational form, both the financial and the liquidity constraints are slack, and it is only the participation constraint that binds. In this case, profits of the

multinational, for organizational form $z \in [O, I]$, are equal to:

$$\Pi_z = \max_{\theta} \left\{ \theta e_z^{\beta} - \frac{\theta e_z}{\phi} - \frac{\theta^2}{2\gamma} \right\}$$

This expression also represents the total value of the project, since the MNE can extract the whole surplus generated in the partnership through ex ante payments, without constraining the investment of the supplier. The key difference lies in the effort implemented by the supplier. In both cases, first-best efforts cannot be implemented due to the incomplete nature of contracts. As efforts are not contractible, they are determined by the decision of the supplier, which is uncoordinated with the multinational firm. Ex post bargaining implies that the supplier can only recover a portion of the marginal benefits of her investments; therefore she prefers a suboptimal degree of effort that maximizes ex post surplus. Since this is higher in the case that she is allocated residual rights (given that $\frac{1+\alpha}{2} > \frac{1}{2} > \frac{\delta}{2}$), efforts, and total surplus, are higher in outsourcing.

Solving for equilibrium levels of relationship-specific investments in each organization we obtain:

$$e_O = (\beta\phi)^{\frac{1}{1-\beta}} \left(\frac{1+\alpha}{2} \right)^{\frac{1}{1-\beta}}$$

and

$$e_I = (\beta\phi)^{\frac{1}{1-\beta}} \left(\frac{\delta}{2} \right)^{\frac{1}{1-\beta}}$$

with clearly $e_I < e_0$. Inserting these in expression X above, we see that, in the case of no financial constraints, property rights are always given to the supplier[6]. When there are no constraints to transfers of surplus and to making the desired levels of investment, outsourcing is preferred to integration because it delivers stronger incentives to the supplier while the whole surplus is extracted by the MNE through ex ante payments. Given that we know that outsourcing is chosen, we can now derive the first order condition that determines technology transfers that maximize profits for the multinational. Inserting the equilibrium level of efforts and deriving total profits with respect to θ gives:

$$\theta = \gamma(1 - \beta\frac{1+\alpha}{2}) \left(\beta\phi\frac{1+\alpha}{2} \right)^{\frac{\beta}{1-\beta}}$$

In this benchmark case, both efforts and technology transfers increase with the outside option of the supplier: the higher this is, the higher are efforts, and thus the higher the gains from technology transfers. Moreover, they are also increasing in ϕ, the productivity of the supplier. Technology transfers also increase with the efficiency of the multinational firm γ, but, in this particular case

[6]The definitions of the upper and lower bounds of financial constraints are given in the following sections

where gains from technology transfers are linear (the elasticity of substitution between tasks equals the elasticity of substitution between final goods), γ has no impact on the level of efforts. Obviously, none of these depend either on initial capital W or financial development κ in the case of slack financial constraints.

Binding Financial Constraints under Outsourcing

In order to investigate on the relationship between financial constraints and technology transfers, in this section we treat in more detail the case of outsourcing when financial constraints bind. Note that, as already mention, in our model the impact of financial development on integrated pairs is much simpler. We go back to it when we discuss the implications of our theory with regards to the optimal choice of organization.

Note that, from the maximization problem of the outsourcing case displayed above, the second are third constraints can be merged into one single condition summarizing the two aspects determining liquidity constraints: wealth and debt. This gives the following,

$$\begin{array}{lll} \max\limits_{\theta,T} & \Pi = \left(1-\frac{1+\alpha}{2}\right)\theta e^{\beta} - \frac{\theta^2}{2\gamma} + T & \\ \text{s.t.} & T \leq \left(\frac{1+\alpha}{2}\right)\theta e^{\beta} - \frac{\theta e}{\phi} & \text{(Participation constraint)} \\ & T \leq W + \kappa\left(\frac{1+\alpha}{2}\right)\theta e^{\beta} - \frac{\theta e}{\phi} & \text{(Liquidity constraint)} \\ & e = \text{argmax}_{e \leq (W+L-T)\frac{\phi}{\theta}} \left\{\left(\frac{1+\alpha}{2}\right)\theta e^{\beta} - \frac{\theta e}{\phi}\right\} & \text{(Incitation constraint)} \end{array}$$

As already mentioned, when financial constraints are not binding, the ex ante payment is determined by the condition imposing nonnegative ex ante profits for the supplier. Therefore, to know in which cases will financial constraints bind, we need to equate the first two constraints. This gives:

$$(1) \quad W = (1-\kappa)\left(\frac{1+\alpha}{2}\right)\theta e^{\beta}$$

Plugging in equilibrium efforts and technology transfers as defined in case without financial constraints, we obtain the lower bound on W for which the financial constraint binds:

$$\overline{W} \equiv \gamma(1-\kappa)(1-\beta\frac{1+\alpha}{2})\left(\beta\phi\right)^{\frac{2\beta}{1-\beta}}\left(\frac{1+\alpha}{2}\right)^{\frac{1+\beta}{1-\beta}}$$

Three points are worth commenting. First, there is a negative relationship between the minimum level of wealth determining liquidity constraints and the level of financial development: the higher the possibility of raising external funds, the less tightening the level of individual wealth. Second, the financial constraint is more likely to bind when outside options of the supplier are larger ($\overline{W}$ increases with α): the higher is the bargaining power of the supplier, the higher is the ex ante payment required to extract S' ex post payoff.

Third, an interesting relationship between supplier's productivity and financial constraints arises: *for a given level of initial capital*, financial constraints are more likely to bind when supplier productivity is higher. The reason is that higher productivity increases supplier's ex post profits and the upfront payment that the multinational would like to receive. However, if we assume that initial capital and productivity are positively correlated (if W is interpreted as the cumulation of past profits, and productivity is assumed to be non decreasing over time), we might obtain that financial constraints are less likely to bind for higher productivity.

At this point we should note that, if the financial constraint binds, it does not imply the participation constraint is slack. Both constraints will bind as long as equality (1) holds: it can be verified even though $W < \overline{W}$, if efforts or technology transfers are lower than in the case without financial constraint.

A Lagrangian approach

The problem described above is one of an objective function subject to two constraints on the same variable, T. It can be reformulated through a lagrangian approach. To do so, let us denote by $\mu \geq 0$ the lagrangian multiplier related to the financial constraint. Optimality for the ex ante payment T imposes that the lagrangian multiplier of the participation constraint needs to be equal to $1 - \mu \geq 0$. It follows that $\mu \in [0, 1]$ and that we can organize the discussion around one single parameter defining the weight of the financial constraint. Clearly, when $\mu = 0$, the financial constraint is slack and only the participation constraint binds, and this has been treated in the previous subsection. At the other extreme, when $\mu = 1$, it is only the participation constraint that is tight. Finally, in cases where $0 < \mu < 1$ both constraints are binding (which implies that condition (1) is satisfied).

Let us now re-express the problem faced by the multinational in its lagrangian form:

$$\begin{array}{l} \Pi_o = \max_\theta \Lambda\theta e^\beta - \frac{\theta e}{\phi} - \frac{\theta^2}{2\gamma} + \mu W \\ \text{s.t.} \\ e = \text{argmax}_{e \leq (W+L-T)\frac{\phi}{\theta}} \left\{ \left(\frac{1+\alpha}{2}\right) \theta e^\beta - \frac{\theta e}{\phi} \right\} \quad \text{(Incitation constraint)} \end{array}$$

where $\Lambda \equiv 1 - \mu(1-\kappa)\frac{1+\alpha}{2} \leq 1$.

We can now look into how the weight of the financial constraint distorts decisions on the part of the multinational firm. It is straightforward to note that for $0 < \mu < 1$, the level of effort that maximizes MNE's ex ante profits might be different from the value of e that would be chosen individually by the supplier. Two cases arise. When financial constraints are moderate, the multinational is better off by letting the supplier exert it preferred level of efforts e_o. Thus, it maximizes profits by setting an ex ante ante payments that leaves the supplier just enough liquidity to undertake them. We refer to this situation as the case of "unconstrained efforts". A different situation arises when liquidity

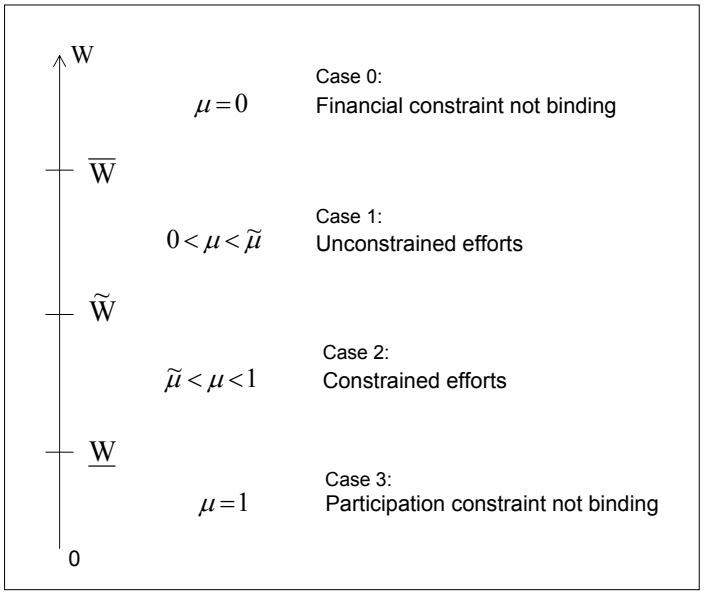

Figure 1: Initial capital, financial constraints and efforts

becomes scarcer. In such a case, the level of investments that maximizes profits of the multinational is lower than what the supplier chooses. This is due to the fact that, when financial constraints are strong, the multinational needs to advance more cash to the supplier (in the form of a lower ex ante payment) for her to undertake the required specific investments. The more constrained the supplier is, the more "expensive" these efforts are to M. When the level of liquidity in the hands of the supplier becomes low enough, the multinational is better off restricting these investments by not alleviating the financial situation of the upstream firm. Given that efforts are limited by financial capacity, the multinational can influence them through T. We refer to this situation as the case of "constrained efforts". Finally, when $\mu = 0$, only the financial constraint in binding.

We define $\tilde{\mu} \equiv \frac{1}{1-\kappa}\frac{1-\alpha}{1+\alpha}$. In what follows, we discuss these cases in more detail (figure 1).

Case 1: Unconstrained efforts

When $0 < \mu \leq \tilde{\mu}$, which implies $\Lambda \geq \frac{1+\alpha}{2}$, efforts are chosen by the supplier:

$$e_o = \left(\beta\phi\frac{1+\alpha}{2}\right)^{\frac{1}{1-\beta}}$$

By replacing e_o into (1), it is straightforward to derive the level of technology transfers that maximizes profits for the multinational. At the optimum, θ is given by:

$$\theta = \gamma \left[1 - \beta\frac{1+\alpha}{2} - \mu(1-\kappa)\frac{1+\alpha}{2}\right]\left(\beta\phi\frac{1+\alpha}{2}\right)^{\frac{\beta}{1-\beta}}$$

which is smaller than the case without credit constraints.

Note that the above expression gives technology transfers as a function of the shadow cost of financial constraints, μ. In this case of unconstrained efforts, efforts do not depend on μ. Thus, from the equality between the participation and the financial constraints, we can directly determine the level of technology transfers as a function of W and other parameters[7]. We find:

$$W = (1-\kappa)\left(\frac{1+\alpha}{2}\right)\theta e^{\beta}$$

and plugging in e_o and rearranging

$$\theta = \frac{W}{(1-\kappa)\left(\frac{1+\alpha}{2}\right)^{\frac{1}{1-\beta}}(\beta\phi)^{\frac{\beta}{1-\beta}}}$$

This condition is informative of an important effect of credit constraints. For a given level of initial capital W, efforts and technology transfers are substitutes. In particular, the higher the productivity of the supplier ϕ, the higher the level of efforts e, but the lower the technology transfers θ. Similarly, outside options α have a positive effect on efforts but negative effect on technology transfers. This situation contrasts with the case of perfect capital markets, where efforts and technology transfers are complementary: productivity and outside options have a positive effect on technology transfers.

Profits are determined by efforts and technology transfers. Using expression above for θ, we obtain total profits for the multinational:

$$(2)\quad \Pi_o = \frac{W\left(1-\beta\frac{1+\alpha}{2}\right)}{(1-\kappa)\left(\frac{1+\alpha}{2}\right)} - \frac{1}{2\gamma}\left(\frac{W}{(1-\kappa)\left(\frac{1+\alpha}{2}\right)^{\frac{1}{1-\beta}}(\beta\phi)^{\frac{\beta}{1-\beta}}}\right)^2$$

Where it can be seen that profits are increasing with W. In opposition with technology transfers, total profits increase with the productivity of the supplier. They also increase with the level of financial development. Finally, outside options has a inverted U-shape effect on total profits (see section 2.3 for a detailed analysis of this last aspect).

Case 2: Constrained efforts

[7] Note that μ is a function of the model's parameters, especially of those indexing affecting the liquidity level of the supplier, W and κ. An explicit expression for it can be obtained by plugging in the expression for θ into expression (1).

When $\tilde{\mu} \leq \mu < 1$, implying $\Lambda < \frac{1+\alpha}{2}$, effort is chosen by the MNE by shortening the liquidity of the supplier[8]. As mentioned before, when the cost of financial constraints is high, the level of efforts is determined by the maximization of expression multinational's profits which yields:

$$e = (\beta\phi\Lambda)^{\frac{1}{1-\beta}}$$

where $\Lambda \equiv 1 - \mu(1-\kappa)\frac{1+\alpha}{2}$.

Similarly, technology transfers are determined by the maximization of total profits. We obtain the following expression:

$$\theta = \gamma(1-\beta)\,(\beta\phi)^{\frac{\beta}{1-\beta}}\,(\Lambda)^{\frac{1}{1-\beta}}$$

Proceeding as before, we use equality X to solve for μ and replace e and θ for their equilibrium values we obtain:

$$(3)\quad \Lambda^{\frac{1}{1-\beta}} \equiv \left[1 - \mu(1-\kappa)\tfrac{1+\alpha}{2}\right]^{\frac{1}{1-\beta}} = (\beta\phi)^{-\frac{1}{1-\beta}} \left[\frac{\beta\phi}{\gamma(1-\beta)} \frac{W}{(1-\kappa)(\frac{1+\alpha}{2})}\right]^{\frac{1}{\beta+1}}$$

In words, the cost of the financial constraint is decreasing with the initial capital of the supplier and the level of financial development, but increasing with outside options α and the productivity of the supplier.
Reincorporating the value of Λ into the expression of e and θ, we find:

$$(4)\quad e = \left[\frac{\beta\phi}{\gamma(1-\beta)} \frac{W}{(1-\kappa)(\frac{1+\alpha}{2})}\right]^{\frac{1}{\beta+1}}$$

and:

$$(5)\quad \theta = \left[\frac{\beta\phi}{\gamma(1-\beta)}\right]^{-\frac{\beta}{\beta+1}} \left[\frac{W}{(1-\kappa)(\frac{1+\alpha}{2})}\right]^{\frac{1}{\beta+1}}$$

Again, it follows that efforts and technology transfers are substitutes under financial constraints. Efforts e are increasing with ϕ but technology transfers θ are decreasing with ϕ. In addition, we find that both efforts and technology transfers decrease with α because, in this case, α does not have positive effects on specific investments. Finally, we want to determine the threshold for initial capital below which the regime of constrained efforts appears. It is determined by the equality between Λ and $\frac{1+\alpha}{2}$. Using the expression for Λ above, we find the threshold $\widetilde{W}$ between case 1 and case 2:

$$\widetilde{W} \equiv \gamma(1-\kappa)(1-\beta)\,(\beta\phi)^{\frac{2\beta}{1-\beta}} \left(\tfrac{1+\alpha}{2}\right)^{\frac{2}{1-\beta}}$$

(naturally, we verify that $\widetilde{W} < \overline{W}$).

[8]It might be noted that this case cannot arise when financial development is high; more precisely when $\frac{1}{1-\kappa}\frac{1-\alpha}{1+\alpha}$ is larger than one. For the sake of simplicity, we that the value of κ is such that this is never the case.

Case 3: Strong Financial Constraints

Finally, when $\mu = 1$, financial constraints are so strong that the participation constraint becomes slack. This means that T is determined by the financial constraint only. Profits of the multinational equal:

$$\Pi_o = \max_{\theta} \left[1 - (1-\kappa)\frac{1+\alpha}{2}\right] \theta e^{\beta} - \frac{\theta e}{\phi} - \frac{\theta^2}{2\gamma} + W$$

In words, the multinational firm does not take into account the part of supplier ex post profit that is not pledgable. Moreover, we can note that an additional unit of initial capital translates into an additional unit of ex ante payment and an additional unit of profits for the multinational: efforts and technological choices do not depend on W. In this case, as long as financial development is not too high[9], efforts are chosen by the MNE. Their equilibrium values are given by expressions (4) a,d (5) from case 2 by setting $\mu = 1$. Again, these results show that, when financial constraints are strong, efforts are increasing with the productivity of the supplier ϕ, but technology transfers tend to decrease with ϕ. Moreover, both efforts and technology transfers decrease with α. In addition, efforts and technology transfers do not depend on the level of initial capital in this case, but they both increase with the level of financial development κ.

Discussion

These results establish a causal relationship running from initial capital and financial development (measured as the strength of the financial constraint) to technology transfers and profit levels for the the multinational (see figure 2).

Given the production technology, by increasing the range of tasks over which it transfers technology to the supplier, the multinational increases the value of the ex post joint surplus. When capital markets are well functioning, M is able to extract all surplus ex ante by setting an adequate transfer T, which is only limited by the nonnegativity condition on the profits of the supplier. Therefore, it chooses θ by equating total marginal costs to total marginal benefits.

The possibility of ex ante rent extraction vanishes as financial constraints become tighter. The effect of financial constraints, as determined by the supplier's endowment of liquidity W, is to directly affect the extent to which the multinational is able to capture ex ante the value of rents accruing to the supplier ex post. This reduced possibility of rent appropriation lowers incentives by the multinational to transfer technological knowledge, given that the transmission of such knowledge is costly. Note that gains from technology transfer are divided according to the ex post Nash bargaining rule, whereas communication costs are unilaterally born by the multinational. Thus, the higher is W, the higher is the value of technology transmission costs that the multinational is able to recover through ex ante payments. Hence, the wider the range of

[9] i.e. $(1-\kappa) > \frac{1-\alpha}{1+\alpha}$ holds

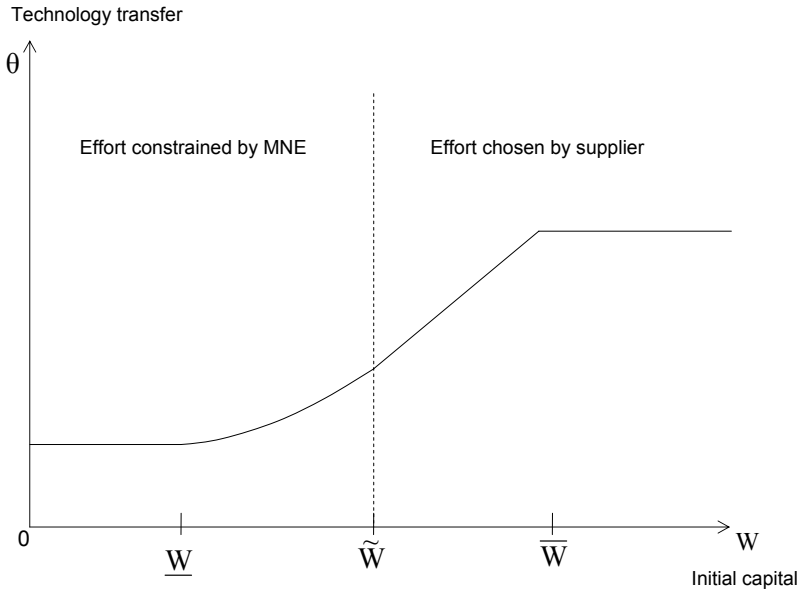

Figure 2: Technology transfers and initial capital

tasks for which resources are devoted to teaching the agent. As a result, when the local agent's wealth lies in an intermediate range - given by case 2 above -, equilibrium technology transfers (and thus productive efficiency and profits) are a function of W.

The initial level of liquidity of the supplier plays another fundamental role in the model, since liquidity is needed to finance relationship-specific investments. Thus, financial constraints may also affect the relationship between technology transfers and supplier efforts. Absent liquidity constraints, specific investments and technology transfers are complementary since higher investments in "absorptive capacity" (technology assimilation) increase the profitability of technology transfers. On the contrary, under financial constraints specific investments and technology transfers become substitutes: the higher efforts are, the lower the amount of ex ante payment that can be paid to the multinational, which discourages the transfer of technology, since the ability of the multinational to extract surplus is reduced. As financial constraints become even tighter, the level of efforts may be constrained and decided by the multinational firm by setting adequate ex ante transfers.

As presented in figure 1, we classify these different cases according to the value of the initial capital of the supplier W. Financial constraint do not bind as long as W is larger than $\overline{W}$. When W is lower than $\overline{W}$ but larger than $\tilde{W}$, the financial constraint is binding but does not affect the choice of specific

investments which are still determined by the supplier. When W is lower than $\tilde{W}$, the level of specific investments by the supplier is determined by her financial capacity once the ex ante transfer T is paid. As W drops below $\underline{W}$, the participation does not bind. Technology transfers are minimal and do not depend on W (this minimal value is however increasing with the level of financial development κ).

Choice between Outsourcing and integration

We now use our setup to shed some light into the decision of organizational mode in the presence of liquidity constraints. Note that, when the multinational firm integrates the supplier, it retains residual rights over the assets. The outside option for the supplier are nil. As already discussed, in cases when the supplier faces no liquidity problems, integration is never an optimal strategy, since it discourages investment by the former and thus lowers the value of production. Integration, however, becomes interesting when financial constraints are strong: in such a case, initial payments are low and the option of integrating the supplier and retaining higher ex post bargaining power to capture larger portions of the ex post value becomes more attractive. Further, financial constrains are less likely to bind under integration for the same reason.[10]

Thus, in our model, a trade-off between outsourcing and vertical integration arises for moderate and strong levels of financial constraints. We thus here concentrate in case 2 above: "constrained efforts"[11]. The ratio of profits in outsourcing to profits in integration as a function of financial constraints is given by:

$$\frac{\Pi_O}{\Pi_I} = \frac{2(1-\Lambda^{\frac{\beta+1}{2}})(1-\beta)\Lambda^{\frac{1+\beta}{1-\beta}}}{(1-\frac{\delta}{2}\beta)^2(\frac{\delta}{2})^{\frac{2\beta}{1-\beta}}}$$

From this expression, we can characterize the threshold for financial constraints above which integration is preferred. It is implicitly given by the following condition

$$\frac{\Pi_O}{\Pi_I} < 1 \Longleftrightarrow \Lambda < i(\tfrac{\delta}{2})$$

where $i(\frac{\delta}{2})$ is an implicit function that cannot be solved for analytically in the general case. However, it is possible to show that i is increasing with $\frac{\delta}{2}$ and lies strictly between $\frac{\delta}{2}$ and 1. This condition shows that high values of μ (henceforth low value of Λ) encourage integration[12].

The value of Λ is given by equation (3). Since Λ decreases with the productivity of the supplier ϕ, her outside options α, the ease to transfer technology γ

[10] For very low initial capital, financial constraints might also arise under integration. The case of vertical integration is however more simple than outsourcing: we can show that liquidity constraints never impact on the level of efforts chosen by the supplier.

[11] Comparing integration to case 1 or 3 yields qualitatively the same results.

[12] Note: we can show that when δ is small enough, credit constraints do not bind under integration, around the threshold between outsourcing and integration.

and increases with the initial capital of the supplier W and the level of financial development κ, we can deduce that integration is more likely in less financially developed economies, when the supplier is more productive, less wealthy, has more outside options or when technology transfer costs are lower.

2.3 Endogenous Specificity of Technology Transfers

In this final section we propose an extension of the model in which the level of specificity of the technology that is transferred is endogeneized, as an strategic variable of the multinational. Starting with the work of Coase (1937) and Williamson (1985), specificity has been thought of as playing a fundamental role in the study of the economics of organizations. The transaction costs theory of the firm proposes a mapping from specificity to organizational forms. This approach has been taken further by the Grossman-Hart-Moore property rights theory, that we take that as a base for our theoretical framework. Nevertheless, an understanding of specificity as an endogenous variable and of its relation to financial development have not yet been carefully formalized.

In our model, α is an inverse measure of specificity; the outside option of the supplier is increasing in this parameter. From our previous analysis, it can be seen that the effect of specificity in multinational profits depends on the strength of the financial constraint. In the case without financial constraints ($W \geq \overline{W}(\alpha)$), both technology transfers and efforts, as well as profits, are increasing in α. Therefore, there is an incentive to raise α either until its maximal value, or until the financial constraint binds. This is so since high α gives more incentives to the supplier, and that whenever finance is not a problem, this increase in surplus can be expropriated by the foreign firm. Nevertheless, a higher α increases the amount to be transferred ex ante and this makes the financial constraint more likely to bind.

On the other hand, in the case with strong financial constraints ($W \leq \widetilde{W}(\alpha)$), both technology transfers and efforts are decreasing with α. Profits, thus, also decrease with α. In this case, there is an incentive to lower α, to minimal values, or until efforts cease to lie in the constrained regime.

We denote by $\hat{\alpha}$ the optimal value of α chosen by the multinational firm. At optimum, we can deduce that either: 1) the financial constraint does not bind and $\hat{\alpha}$ equals its maximum value; 2) the financial constraint binds, efforts are constraints and $\hat{\alpha}$ equals its minimal value; 3) the financial constraint binds and efforts are set by the supplier (*case 2* above).

In the later case, multinational profits are given by expression (2) as a function of W and α. By differentiating with respect to α, it is straightforward to find $\hat{\alpha}$ as a function of W and other parameters[13]:

$$\frac{1+\hat{\alpha}}{2} = \left(\frac{W}{\gamma(1-\kappa)(1-\beta)(\beta\phi)^{\frac{2\beta}{1-\beta}}} \right)^{\frac{1-\beta}{1+\beta}}$$

[13]Note that we can verify that $\overline{W}(\hat{\alpha}) < W < \widetilde{W}(\hat{\alpha})$ strictly holds as long as $\hat{\alpha}$ is an interior solution.

as long as $\hat{\alpha}$ is an interior solution.

Note that $\hat{\alpha}$ (inversely related to the specificity of technology transfers) increases with the initial capital of the supplier and the level of financial development but decreases with the productivity of the supplier and the multinational (ϕ and γ). When the supplier is more productif or when the technology is easily transferable, it is more profitable to extract a larger share of the surplus and increase technology transfers.

We can now calculate optimal technology transfers in the case of endogenous α. Replacing the value of $\hat{\alpha}$ into the expression for θ, we find:

$$\theta = (\gamma(1-\beta))^{\frac{1}{1+\beta}} (\beta\phi)^{\frac{\beta}{1+\beta}} \left(\frac{W}{1-\kappa}\right)^{\frac{\beta}{1+\beta}}$$

Two differences with respect to the main framework are to notice. First, the elasticity of θ according to the level of initial capital is lower; W has a lower impact on optimal technology transfers. Second, and more importantly, we now find a positive impact of supplier's productivity on technology transfers, even in the case of binding financial constraints. This can be explained by the fact that higher productivity permits to increase the specificity of technology transfers and reduce the bargaining power of the supplier, which in turn increases the returns from technology transfers.

Finally, we can also find the expression of MNE profits with endogenous α:

$$\Pi = (\beta\phi)^{\frac{2\beta}{1+\beta}} \left(\frac{W}{1-\kappa}\right)^{\frac{2\beta}{1+\beta}} (\gamma(1-\beta))^{\frac{1-\beta}{1+\beta}} \left(\frac{1+\beta}{2}\right) - \beta\left(\frac{W}{1-\kappa}\right)$$

We can show that the elasticity of total profits according to the productivity of the supplier is higher than in the case of exogenous and fixed specificity. This finding has several consequences. For example, in a framework with endogenous specificity, outsourcing is more likely than integration when the productivity of the supplier is higher. It contrasts with the result of the previous section and points out the important role of the specificity of technology transfers in organizational choices.

2.4 Some testable predictions

Before passing on to the empirical section of the paper, we summarize some testable predictions that can be obtained from the theoretical section:

- Prediction 1: lower initial capital and stronger credit constraints are associated, *else equal*, with lower levels of technology transfers at the firm-level.
- Prediction 1': higher levels of financial development are associated, *else equal*, with higher levels of technology transfers.
- Prediction 2: the correlation between technology transfers and supplier productivity is stronger in financially developed countries.

- Prediction 3: the correlation between technology transfers and product specificity is positive in financially developed countries and negative when financial institutions are poor.

- Prediction 4: Outsourcing is more likely when financial development is high, integration is more likely when financial development is low.

In what follows of this preliminary version of the paper, we provide and discuss some preliminary evidence concerning these predictions.

3 Empirical analysis

3.1 Data description

The empirical analysis in this section relies on cross-country, firm-level data extracted from the World Bank Enterprize Surveys conducted between 2001 and 2005. These data are constructed with surveys to firms with more than 10 employees. The sampling strategy and survey instruments were developed to ensure comparability across countries [14]. For the purpose of our analysis, we use only data on manufacturing firms.

Our model formalizes interactions between local suppliers and multinational firms, with special regards to how financial development and financial constraints impact on technology transfers. Therefore, in the empirical analysis, we restrict ourselves to firms that we identify as having foreign customers. We are able to do so given that firms in our data are asked to provide information regarding the number of foreign customers in their main product line. Unfortunately, our database does not provide such information for all countries. Out of the 57 countries surveyed, 23 countries provide this variable, all of which are low- or lower-middle- income following the World Bank classification. Of the 7397 firms surveyed in these countries, 3135 fall in this category, and we label them as "MNE suppliers".

One interesting aspect of this dataset is that it includes a series of questions regarding technology acquisition by firms and, among these, questions specifically related to whether technology was explicitly transferred by foreign firms. This allows us to construct a "technology transfer" variable that indicates whether the firm incorporated technology that was transferred from foreign sources, and that we take as the central variable of the empirical analysis that follows. More specifically, the questionnaire includes a section in which firms are asked the most important sources of technology acquisition during the two years previous to the survey. Using this question, we define a firm as a beneficiary of technology transfers (or transferee) whenever at least one of the following alternatives is mentioned as being its main source of technology acquisition: "Licensing or turnkey operations from international sources", "Transferred from parent company", and "Developed in cooperation with client firms". Similarly

[14] More information as well as the full dataset can be found at www.entreprisesurveys.org

to our previously defined variable, the question regarding technology transfers is not available for all countries. Keeping only countries for which this question was included in the survey leaves us with a database composed of observations for 17 countries. Within this set of countries, the average response rate to this variable is of 86%.

This leaves us with a final database used for estimations that is composed of 17 low- and lower-middle-income countries, with 2373 manufacturing firms. Table 1 gives the list of countries and provides some basic summary statistics.

INSERT TABLE 1

In our regressions, we will use two types of measures of financial constraints facing firms. One of these is given by macro variables describing the development of the financial system in which they operate. Following the literature, our main variable defining the level of financial development of a country is the ratio of private credit to GDP. This variable is taken from Beck, Demirg-Kunt and Levine (2000, updated 2006). Since private credit over GDP may be endogenously correlated with other variables having a positive impact on the productivity of the economy and thus affecting technology transfers, we instrument this measure of financial development by legal origin (see Djankov, McLiesh and Shleifer 2007).

On the other hand, our data also provide us with subjective measures of the perceived impact of financial underdevelopment as an impediment to business growth. Managers of the firms in our sample are asked to judge, among other things, the severity of access to finance as an obstacle to the operation and growth of their business. This results in a categorical variable taking five values ranging from zero, indicating "No obstacle", to four, meaning "Very severe obstacle". There are concerns to be taken when using subjective data in rigorous economic analysis, that sustain a general skepticism the economic profession (e.g. Easterly 2002). It has been argued, for example, that measurement errors might be correlated with the explanatory variables (Bertrand and Mullaihathan 2001), and there might be endogeneity problems given that some individual characteristics (such as productivity in the case of firm-level data) affect the tendency to report encountered obstacles. A recent paper by Carlin, Schaffer and Seabright (2007) proposes an alternative interpretation and usage of these subjective variables and apply their methodology on the same data source as our paper. Using a Lagrangian approach, they argue that managers' perceptions of institutional constraints are to be understood as the shadow cost of institutional failure (in terms of foregone profits when evaluated at the individual level; of foregone economic value when evaluated at the aggregated level). As such, it is thus plausible to believe that these shadow values differ across firms and depend on individual (sometimes observable) characteristics. We take these potential problems into account and instrument this variable with other objective measures of financial health at the firm level.

INSERT TABLE 2

We will also include macro- and microeconomic controls that are of standard usage in the literature. Our macroeconomic variables include market size (log population of the country), the share of investment in total GDP, the price level and openness (source: PWT 6.2). Moreover, we control for the (- log) number of days to enforce a contract (source: Doing Business), which permits to assess that financial development and contract enforcement have separate effects. Our microeconomic controls (variables from the survey) include the firm size (log number of employees), labor productivity (log value added in US dollars by employee), the educational level of the manager (indexed between 1: "did not complete secondary school" and 6: "post graduate degree") and a dummy for the presence of foreign capital (equals 1 if the share of foreign capital in the firm is strictly positive).

Before going into the details for the econometric strategy, Table 3 provides simple descriptive statistics regarding the proportion of firms that receive technology transfers according to the level of financial development and the size of the firm. It shows that technology transfers seem to be more frequent in financially developed countries. However, firms in our sample are large in financially developed countries (column 2). Thus, we also provide these statistics for small or large firms only, in countries above or below the median of private credit.

INSERT TABLE 3

3.2 Econometric strategy

We now use our database to test the empirical validity of the following assertions: 1) higher levels of financial development are associated, else equal, with higher levels of technology transfers flowing into the country; 2) credit constraints are associated with lower levels of technology transfers at the firm-level. In later regressions, we would like to test whether: 3) the correlation between technology transfers and supplier productivity is stronger in financially developed countries; 4) the correlation between technology transfers and product specificity is positive in financially developed countries and negative when financial institutions are poor.

We first look at some evidence from "naive" OLS regressions[15] of technology transfers on the level of financial development. The dependent variable TT_ij is a dummy variable taking the value of one if the firm i in country j falls under the category of "transferee" defined above, and zero otherwise. Thus, we first estimate the following equation:

[15]Probit regressions would be more appropriate given the nature of the dependent variable. In this preliminary work, we focus on simple OLS for simplicity reasons: coefficients are easier to interpret. Note however, that all OLS regressions presented here yield significant coefficients for credit in (non reported) probit regressions. Finally, regressions with interactions terms require the bias correction proposed by Ai and Norton (2003) which will be achieved in future work.

(6) $TT_{ij} = privo_j + controls_j + controls_{ij}$

In this first specification, where the main variable varies only across countries, we estimate clustered (robust) standard errors by country. In order to account for factors that might be associated with the local level of financial development and at the same time with technology transfers, we successively test a specification without controls, with macroeconomic controls only (contract enforcement, market size, price level, openness, investments), and with all controls (industry dummies and firm controls: firm size, human capital, productivity, foreign capital).

In a second specification, we analyze the impact of credit constraints at the firm-level. Our main variable is a subjective index from 1 to 4 where 4 index strong credit constraints:

(7) $TT_{ij} = creditconstraints_{ij} + controls_j + controls_{ij}$

In order to avoid some of the caveats associated with the use of subjective variables, we instrument by three variables on the financial health of the firm: the ratio of debt to total asset, the ratio of long-term debt to short term debt (less than one year) and a dummy equal to one if the firm is regularly subject to financial audits.

The above specifications can provide evidence of correlations between technology transfers and the level of financial development of the country in which firms operate. They are not, however, very much informative of the direction of causality. One can plausibly think that the presence of foreign firms and technology transfers has a positive impact on investment opportunities and increases the size of the banking sector (endogeneity bias). One can also think that there are variables that affect the likelihood that a firm will receive technology transfers and at the same time affect financial development (for example, variables affecting the efficiency of the economy may in the same time increase the size of the banking sector and increase technology transfers). There might be problems associated with the interpretation of the results derived from simple OLS regressions due to possible biases associated with both endogenous and omitted variables.

A first attempt to solve the endogeneity bias is to instrument private credit by legal origin as suggested by Djankov, McLiesh Shleifer (2007) and Aghion, Howitt and Mayer (2004) for example. In our sample, half of the firms are located in countries with French origin and half with English origin. However, this method does not completely solve the problem of omitted variables: legal origin may also have impacts on different policy instruments that are not directly related to finance, besides contract enforcement (e.g. labor regulations).

To overcome these problems, we next run a set of regressions in which we employ a difference-in-difference strategy. This approach consists in identifying an industry-specific factor that affects the way the level of financial development impacts on the decision of firms to transfer technology to their local suppliers. Following the work by Rajan and Zingales (1998), we identify an industry's

need for external finance, as defined by the difference between investments and cash generated from operations, using data for firms in the US manufacturing industry. Under the assumption that US capital markets are frictionless (or, at least, one can safely assume they are less plagued with frictions than markets in the rest of the world), this index provides a measure of "technological" dependence on outside funds for firms in a given industry. Interacting this variable, which is industry-specific and does not vary across countries, with a measure of financial development defined at the country level allows us to investigate whether financial development affects technology transfers relatively more in industries that rely more on external finance. As we will be exploiting within country differences between industry cells, we can also include country and industry controls in our regressions to minimize problems of omitted variable bias and other misspecifications. We therefore run the following regression on our sample of firms:

$$(8) \quad TT_{ij} = privo_j * findep_i + FE_j + FE_s + controls_{ij}$$

where we include controls for firm characteristics which might benefit technology transfers and which are not correlated to the country dummies: firm size, human capital, productivity and foreign capital.

Finally, our model suggests that, when financial constraints are tightening, we should observe a weaker relationship between the productivity of the supplier and the level of technology transfers. We propose to test this prediction by regressing technology transfers on an interaction term between productivity (or alternatively human capital) and financial development. The model predicts a positive coefficient: higher financial development should increase the correlation between productivity (human capital) and technology transfers. Precisely, we run the following regressions:

$$(9a) \quad TT_{ij} = privo_j * productivity_{ij} + FE_s + FE_i + controls_{ij}$$

$$(9b) \quad TT_{ij} = privo_j * humancapital_{ij} + FE_s + FE_i + controls_{ij}$$

where the controls include firm size, human capital, productivity and foreign capital.

3.3 Results

Table 4 shows the results obtained from estimating equations (6) and (7). In the first column, we regress technology transfers on the index of financial development, private credit over GDP. The correlation is strong and positive. Given a standard deviation of 0.32, the effect of one standard deviation increase in private credit boosts the probability of technology transfers by 7%, which corresponds to over one third of the average. When controls at the country level are included, the coefficient drops but it is still positive, significant and large.

INSERT TABLE 4

As can be seen there, the coefficient on the financial development measure (which represents the constant average marginal effect) has the expected sign, and it is significant at the 1% level. In the second column, industry dummies are included; the coefficient in this specification is lowered but still significant with the same level of confidence. The coefficient for contract enforcement is positive but not significant (as in Nunn 2007), which enlightens a distinct effect of financial development. Market size seems to positively affect technology transfers, while the economy-wide price level seems to have a negative impact. Openness has a positive sign but only marginally significant, whereas the share of investments in host country GDP does not seem to impact on technology transfers. Note that these two columns report very simple correlations that does not involve controls at the firm-level. Alternatively, we can regress the probability of technology transfer by country on country variables: we also obtain a positive and significant coefficient for private credit.

In column (3), we include more detailed controls obtanied from the enterprize survey: firm size, human capital, productivity and foreign capital. We also include industry dummies to control for industry specific level of demand for technology transfers. The resulting coefficient for private credit is still large and significant. Controls at the country level remains stable: contract enforcement has no significant effect, market size has a positive effect and the price level has a negative effect. Openness is not significant any longer and becomes even negative. Among firm-level controls, the coefficient for the presence of foreign capital has a positive, large and significant coefficient. For other controls, coefficients are not statistically significant according to usual criteria. We should note however that, in a regression without country variables (not shown), all firm-level controls excepting manager's education have significant (at 5% level) and positive coefficients.[16]

In column (4), private credit is instrumented by legal origin (2SLS). It attempts to control for possible endogenous biases affecting the coefficient for private credit, as mentioned previously. Surprisingly, the coefficient is even stronger than in simple OLS regressions: technology transfers are more intense in English legal origin countries compared to those with a French origin.

In column (5), we regress technology transfers on the subjective index of credit constraints that we instrument using a dummy for financial audit, the ratio of debt over total asset, and the ratio of long-term debt over short-term debt. Without controls, we obtain a positive and significant coefficient. However, if we add the complete set of controls (see column 6), this coefficient is just slightly significant. Moreover, from the whole set of controls, only contract enforcement and the presence of foreign capital have significant coefficients, with expected sign: contract enforcement and foreign capitals increase the probability of technology transfers.

[16] Firm productivity and human capital enhance the "absorptive capacity", which favors the assimilation of transferred technologies.

INSERT TABLE 5

In table 5, we follow the difference in difference approach (equation 8) pioneered by Rajan and Zingales (1998) which consists in testing whether financial development has a stronger impact on industries that rely more heavily on external finance. This method allows to including industry dummies as well as country dummies. A first estimation without firm-level controls yields a positive and significant coefficient. Quantitatively, if we move from one standard deviation from private credit and one standard deviation in financial dependence, the effect seems to have nearly half of the value estimated in column (1) of table 4. While including the whole set of controls, the estimated coefficient for the interaction terms actually increases and remains significant. As in Aghion, Fally, Scarpetta (2007), we might want to test whether the estimated interaction term is stronger for small firms which generally experience stronger financial constraints. In column (3) we find indeed that small firms exhibit a larger coefficient whereas, in column (4), the coefficient is not significant for large firms.

INSERT TABLE 6

Finally, our model predicts alternative interaction effects. More precisely, we want to test whether technology transfers are more correlated with productivity or absorptive capacity with higher financial development. First, column (1) of table 6 exhibits a positive and significant interaction term between financial development and productivity. This coefficient however does not remain significant if other firm-level controls are included, as shown in column (2). The interaction term between financial development and human capital (here proxied by the education of the manager) seems to be more robust (column 3).

In column (4) and (5), we try to analyze the impact of specificity. We assume that the number of customers is negatively associated to the specificity of the firm's products. The results show that the number of foreign customers has no effect on technology transfers on average and, interestingly, that it has a more positive impact in countries with higher level of financial development (but these results hold only for firms that have relatively small number of customers).

3.4 Evidence on outsourcing versus integration

Using data on US affiliates of multinational firms, Antras, Desai and Foley (2007) provide evidence that integration is less likely when host countries are financially developed. In particular, this effect is stronger when multinational firm activities are intensive in terms of research and development. It suggests that, when multinational firms are potentially important sources of technology transfers, financial development may have a strong impact on the choice between integration and outsourcing.

They develop a model in order to rationalize this finding, based on the idea that foreign direct investment is a commitment to monitor the supplier when

the technology is specific to the multinational firm. Our model provides also a rationale for this empirical result, based on very different mechanisms where technology transfers between the multinational firm and the supplier are key to the understanding of the choice of organization. Future research using data on French multinational firms aims at testing more precise predictions of our model on the choice of outsourcing versus integration according to technological characteristics.

4 Conclusion

(to be added)

References

[1] Acemoglu, D., Aghion, A., Griffith, R. and Zilibotti, F. (2005) "Vertical Integration and Technology: Theory and Evidence", mimeo, Harvard University.

[2] Aghion, P., Fally, T. and Scarpetta, S "Credit Constraints as a Barrier to the Entry and Post-Entry Growth of Firms: Lessons from Firm-Level Cross Country Panel", *Economic Policy*,

[3] Aghion, P., Howitt, P. and Mayer, D. "The Effect of Financial Development on Convergence: Theory and Evidence" mimeo, Hardvard University.

[4] Alfaro, L., Areendam, C., Kalemli-Ozcan, S. and Sayek, S. (2004) "FDI and Economic Growth: The Role of Local Financial Markets." *Journal of International Economics* 64 (1).

[5] Alfaro, L., Kalemli-Ozcan, S. and Sayek, S. (2004) "Foreign Direct Investment, Productivity, and Financial Development: An Empirical Analysis of Complementarities and Channels" *The World Economy* forthcoming.

[6] Antras, P., Desai, M. and Foley, F. (2007) "Multinational Firms, FDI Flows and Imperfect Capital Markets", mimeo, Harvard University.

[7] Antras, P. and Helpman, E. "Contractual Frictions and Global Sourcing", forthcoming in Helpman, E., D. Marin, and T. Verdier, The Organization of Firms in a Global Economy, Harvard University Press, 2008.

[8] Arrow, K (1969) "Classificatory Notes on the Production and Transmission of Technological Knowledge", *American Economic Review*, Papers and Proceedings, 59(2).

[9] Beck, T., A. Demirg-Kunt and R. Levine (2000) "A new database on financial development and structure", *World Bank Economic Review*, 14.

[10] Bertrand, M. and S. Mullainathan (2001) "Do People Mean What They Say? Implications for Subjective Survey Data" *American Economic Review* Papers and Proceedings, 91(2).

[11] Bolmstrom, M. and Kokko, A. (1997) "The Impact of Foreign Investment on Host Countries: A Review of the Empirical Evidence" *World Bank Policy Research Working Paper* No. 1745

[12] Carlin, W., Schaffer, M. and Seabright, P. "Where are the Real Bottlenecks? Evidence from 20,000 firms in 60 countries about the shadow costs of constraints to firm performance", IZA Discussion Paper No. 3059.

[13] Coase, R. (1937) "The Nature of the Firm", *Economica*, 4.

[14] Djankov, S., C. McLiesh and A. Shleifer (2007) "Private credit in 129 countries", *Journal of Financial Economics*.

[15] Ethier, W. (1982), "National and international returns to scale in the modern theory of international trade", *American Economic Review* 72(3).

[16] Ethier, W. and Markusen, J. (1996) "Multinationals, Technical Diffusion, and Trade" *Journal of International Economics* 41.

[17] Grossman, S. and Hart, O. (1986) "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration", *Journal of Political Economy* 94 (4).

[18] Grover, A. (2007) "The Role of Technological Complexity and Absorptive Capacity in Internalization Decision," Working papers 153, Centre for Development Economics, Delhi School of Economics.

[19] Hart, O. and Moore, J. (1990) "Property Rights and the Nature of Firms", *Journal of Political Economy* 98.

[20] Lin, P. and Saggi, K. (2007) "Multinational firms, exclusivity, and backward linkages," *Journal of International Economics*, 71(1).

[21] Mattoo, A., Olarreaga M. and K. Saggi (2004) "Mode of foreign entry, technology transfer, and FDI policy", *Journal of Development Economics* 75, 95-111.

[22] Rajan, R. and L. Zingales (1998) "Financial dependence and growth" *American Economic Review*, 88.

[23] Teece, D. J. (1997) "Technology transfer by multinational corporations: The resource cost of transferring technological know-how." , *Economic Journal*, Vol. 87.

[24] Williamson, O. (1985) "The Economic Institutions of Capitalism", New York, NY: Free Press

Table 1: Simple statistics

Country	Year	Income group (Worldbank)	Number of obs	% large firms (> 100 emp)	Technology transfers	Private Credit over GDP
Cambodia	2003	low	43	95,3	0,33	0,07
Ecuador	2003	low-middle	148	26,5	0,07	0,20
El Salvador	2003	low-middle	154	39,6	0,02	0,40
Ethiopia	2002	low	29	41,4	0,21	0,27
Guatemala	2003	low-middle	176	36,9	0,06	0,18
Honduras	2003	low-middle	149	38,3	0,05	0,39
Indonesia	2003	low-middle	197	82,1	0,28	0,19
Kenya	2003	low	65	43,5	0,22	0,26
Nicaragua	2003	low	148	15,5	0,04	0,22
Pakistan	2002	low	149	21,5	0,22	0,22
Philippines	2003	low-middle	189	59,5	0,20	0,35
South Africa	2003	low-middle	128	65,6	0,27	1,28
SriLanka	2004	low-middle	151	70,1	0,16	0,28
Tanzania	2003	low	29	35,7	0,00	0,07
Thailand	2004	low-middle	581	76,6	0,34	0,95
Uganda	2003	low	18	16,7	0,06	0,05
Zambia	2002	low	19	22,2	0,11	0,06

Table 2: By industry

Industry	Number of observations	% large firms (> 100 emp)	Technology transfers
Textiles	212	72,2	0,23
Leather	39	15,4	0,18
Garments	578	65,2	0,17
Food	330	57,7	0,15
Beverages	33	42,4	0,09
Metals and machinery	239	36,4	0,24
Electronics	195	75,0	0,46
Chemicals and pharmaceutics	160	39,0	0,16
Wood and furniture	206	36,8	0,07
Non-metallic and plastic materials	201	41,7	0,10
Paper	31	19,4	0,16
Sport goods	33	21,2	0,12
Other manufacturing	37	47,2	0,05
Auto and auto components	72	74,6	0,44
Other transport equipment	7	71,4	0,29

Table 3: Above and below median

Proportion with technology transfers	All firms	(Proportion large firms)	Only small firms	Only large firms
Below median of private credit	0,14	(40,9)	0,09	0,22
Above median of private credit	0,22	(62,6)	0,15	0,27

Table 4: Technology transfers and credit constraints

Dependent variable	Technology transfer					
	(1)	(2)	(3)	(4)	(5)	(6)
Private credit /GDP	0.214	0.108	0.209	0.336		
	[0.065]***	[0.024]***	[0.049]***	[0.085]***		
Credit constraint					-0.203	-0.147
					[0.036]***	[0.078]*
Contract enforcement		0.027	0.008	-0.004		0.115
		[0.032]	[0.040]	[0.041]		[0.069]*
Market size		0.060	0.027	0.019		0.006
		[0.007]***	[0.012]**	[0.012]		[0.023]
Price level		-0.049	-0.114	-0.143		-0.048
		[0.027]*	[0.040]**	[0.037]***		[0.050]
Openness		0.001	-0.001	-0.002		-0.001
		[0.001]*	[0.001]	[0.001]***		[0.001]
Investment level		-0.000	0.002	0.002		-0.000
		[0.002]	[0.003]	[0.003]		[0.005]
Firm size			-0.003	-0.004		-0.012
			[0.004]	[0.004]		[0.011]
Manager education			0.003	0.003		0.013
			[0.006]	[0.005]		[0.010]
Productivity			0.011	0.007		-0.012
			[0.008]	[0.006]		[0.014]
Foreign capital			0.158	0.161		0.108
			[0.059]**	[0.056]***		[0.040]***
Industry dummies	no	no	yes	yes	no	yes
Observations	2373	2373	1795	1795	1677	1394
R-squared	0.04	0.08	0.15	0.14	-0.12	0.13
1st stage F-test (P)				0.000	0.000	0.001
J-test (P)					0.855	0.645

Table 5: Dependence in external finance

Dependent variable	Technology transfer			
	(1)	(2)	(3)	(4)
Credit * FinDep	0.165	0.341	0.606	0.216
	[0.049]***	[0.120]**	[0.239]**	[0.313]
Firm size		-0.007	-0.034	-0.005
		[0.004]*	[0.018]*	[0.012]
Manager education		0.011	0.005	0.022
		[0.006]*	[0.006]	[0.015]
Productivity		0.012	0.026	-0.001
		[0.008]	[0.007]***	[0.013]
Foreign capital		0.163	0.172	0.168
		[0.058]**	[0.072]**	[0.058]**
Industry dummies	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes
Sample			small firms	large firms
Observations	2329	1753	795	958
R-squared	0.13	0.16	0.17	0.14

Table 6: Other interactions

Dependent variable	Technology transfer				
	(1)	(2)	(3)	(4)	(5)
Credit * Productivity	0.058	0.038			
	[0.026]**	[0.034]			
Credit * Human K			0.049		
			[0.012]***		
Nb foreign customers				0.030	-0.017
				[0.025]	[0.025]
Credit * Nb fgn cust					0.094
					[0.041]**
Productivity	-0.002	-0.005	0.011	0.012	0.011
	[0.013]	[0.012]	[0.008]	[0.009]	[0.009]
Firm size		-0.008	-0.007	-0.010	-0.010
		[0.004]*	[0.004]	[0.007]	[0.006]
Manager education		0.010	-0.012	-0.002	-0.001
		[0.006]	[0.010]	[0.010]	[0.010]
Foreign capital		0.159	0.162	0.149	0.150
		[0.060]**	[0.057]**	[0.047]***	[0.048]***
Industry dummies	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes
Sample				< 10 cust.	< 10 cust.
Observations	1872	1795	1795	1173	1173
R-squared	0.14	0.16	0.16	0.17	0.17