Informed Capital and Technological Conservatism

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Abstract

We examine an economy where informed lenders do not finance new technologies to preserve the value of their information on mature technologies. However, informed lenders can use their superior information to offer inexpensive financing for mature technologies. The choice of firms between informed and uninformed finance trades off freedom in technology adoption and low cost funding of mature technologies. Information as conservatism can explain why new technologies develop first in market-oriented financial systems and the importance of arm's length financial markets relative to intermediation increases with development.

Throughout modern history, technological progress appears positively associated with the importance of arm's length financial markets. Casual empiricism suggests that in the last two centuries many industries developed first in countries with a market-oriented financial structure (Allen and Gale, 2000). In the nineteenth century, railways developed first in the United Kingdom and were later exported to continental Europe with the financial support of the London Stock Exchange. In the twentieth century, the aircraft, consumer durable and biotechnology industries developed first in the United States. Only after these industries matured, countries with strong banking systems, like Germany and Japan, experienced their diffusion (Allen and Gale, 2000).

We propose a model that explains the historical association between arm's length finance and technological progress. The prior of the model is that intermediaries are better information collectors than arms' length investors (Diamond, 1984; Boyd and Prescott, 1986). We show that, while their high quality information makes intermediaries efficient financiers of mature technologies, their information can make them "conservative" in the financing of new technologies. The aspect of information that generates conservatism

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is its *specificity*. A lender not only collects information on the management of a firm, regardless of the technology adopted, but also specific information on the production process and on the productive assets of the firm. Because of this specificity, the lender's information on mature technologies loses value when new technologies are adopted. Therefore, the lender can hinder the adoption of new technologies to preserve the value of her information.[1]

We characterize intermediaries and their information gathering in accordance with previous studies. As in Diamond and Rajan (2001), we assume that a lender collects information on the second best use of the tangible assets of her borrower. This information allows the lender to recover value when her borrower defaults and the assets are redeployed outside the firm, making her funding of mature technologies inexpensive. However, since this information is specific to the traditional use of the assets, the lender expects that this information will go wasted if a new technology is adopted. In principle, the firm could compensate the lender for the depreciation in the value of her information by sharing the high returns of the new technology. However, in the presence of limited output verifiability, pledging the high returns of a new technology to the lender is not credible and an informed lender vetoes its adoption.

When lenders' information becomes conservatism, the choice of a firm between direct and intermediated finance trades off the freedom in adopting new technologies guaranteed by arm's length investors with the inexpensive funding of mature technologies offered by intermediaries. We show that the choice of the firm depends on several factors, including the value of its pledgeable assets, the probability that it has access to new technologies and the productivity gap between new and mature technologies.

We believe that the model lends itself to several applications. In the paper, we explore one, showing that the above explanation for the correlation between arm's length finance and technological progress can account for the evolution of the financial structure. It is argued that a positive correlation exists between development and the importance of the arm's length markets for debt and equity relative to the banking system (Gurley and Shaw, 1967). Since Adam Smith, economists also claim that development is associated with the adoption of increasingly productive and specialized (less flexible) technologies, with the flexibility of a technology being captured by the reusability of its assets in the production of a different good (Piore and Sabel, 1984; Saint Paul, 1992). In the paper (section II), we argue that, as technologies become increasingly specialized and the reusability of productive assets in new technologies declines, the specificity of banks' information on mature technologies increases. Using this argument in our model, we show that in developed economies banks have lower incentives to allow the adoption of new technologies. In order to escape this "technological sclerosis", firms can increase their reliance on transactional forms of finance, such as direct debt and equity, at the expense of more informed ones, such as banks.

Building on the results of the microeconomic analysis of financial intermediation (Diamond, 1984; Boyd and Prescott, 1986), the literature has generally stressed the positive role of informed finance in growth and innovation.[2] Greenwood and Jovanovic (1990) show that, by holding large portfolios of projects, intermediaries achieve better information on projects and fund highly productive ones. In turn, capital accumulation allows sustaining the fixed costs of intermediation. De la Fuente and Marin (1996) analyze the role of intermediaries as monitors in a growth model à la Grossman and Helpman (1991). In a context in which the development of new product varieties is affected by moral hazard, monitoring reduces the risk of entrepreneurs' moral hazard, spurring innovation and growth. In turn, by reducing the relative cost of capital, capital accumulation reduces the cost of monitoring relative to the cost of incentive contracts, promoting financial development.[3]

Among the theoretical studies that have analyzed the limits that informed finance imposes to technological progress, Allen and Gale (1999) propose a model in which investors "agree to disagree" on the prospects of projects. As in Diamond (1984), investors save on monitoring costs by delegating intermediaries to monitor projects. However, by so doing, they also risk seeing their funds invested in projects that they would have not funded if they had monitored projects on their own. Allen and Gale argue that this risk is higher when the probability that investors have different opinions on projects is higher, as in the financing of new technologies. In Allen and Gale information is a good. Despite their different focus, Rajan (1992) and Diamond and Rajan (2001) can also indirectly rationalize a negative impact of informed finance on innovation. Rajan (1992) analyzes a model in which informed lenders can hold up firms and extract rents, reducing entrepreneurs' incentive to exert effort ex-ante. Rajan and Zingales (2000) argue that, since innovative technologies are particularly opaque, for innovative firms it can be especially difficult to escape the hold-up addressing outside financiers. Moreover, the resulting downward distortion in entrepreneurial effort can be severe since innovative technologies require substantial endeavor on the part of the management. In Diamond and Rajan (2001), banks develop specific liquidation skills and cannot commit to use their liquidation skills on behalf of dispersed depositors. This allows them to hold up depositors. Expecting this hold-up, ex-ante dispersed investors require a high interest rate, discouraging the funding of projects. Rajan and Zingales (2000) argue that innovative projects are likely to be particularly illiquid and exposed to this problem.[4] In Rajan (1992) and Diamond and Rajan (2001), information is neutral, that is it does not bias lenders towards mature technologies.

On the empirical side, our results are consistent with the findings of the studies on finance and growth and particularly with Carlin and Mayer (2002), who analyze the impact of financial structure on different types of economic activity. Carlin and Mayer (2002) find that, while banking systems fare well in sustaining fixed capital formation, the development of equity markets is positively correlated with R&D activity.[5]

A caveat is necessary. Throughout the analysis, we identify intermediated finance with relationship funding and arm's length finance with transactional funding. Since we focus only on the ability of financiers to gather information, the distinction between transactional and dispersed finance is irrelevant for our purposes. Moreover, introducing dispersed finance would complicate the analysis.

The paper is organized as follows. In section I, we present the model. In section II, we apply the model to explaining the evolution of the financial structure. In section III, we discuss extensions. In section IV, we conclude. Lengthy proofs are in Appendix.

I The Model

A Setup

Environment and Technology Consider a three date economy ($t = 0, 1, 2$) with one entrepreneur and two or more investors. There are two goods: a final good, and indivisible, productive assets (machines). A machine can be of two vintages or types: traditional and new. Agents consume final good at date 2 deriving utility $u(c_2) = c_2$. The entrepreneur has no endowment while, at date 1, each investor has one unit of final good.

Production takes place between date 1 and date 2. The entrepreneur can run a mature technology and transform one unit of final good into a traditional machine. At date 2, the project is successful with probability p and the machine is converted into $y > 1$ units of final good or unsuccessful with probability $1-p$, the machine yields zero but it can be liquidated outside the firm. At date 1, with probability $1-\gamma$, the entrepreneur experiences a positive technological shock and gains also access to a new technology. This technology is isomorphic to the mature one but more productive. The entrepreneur can transform one unit of final good into a new machine. At date 2, the project is successful with probability p and the machine is converted into $Y > y$ units of final good or unsuccessful with probability $1-p$, the machine yields zero but it can be liquidated outside the firm.[6]

The environment is characterized by a partial non-verifiability of output: a fraction $\lambda < 1$ of the output produced in a project is verifiable and contractible while the rest can be stolen by the entrepreneur. We impose a lower bound on the value of λ as follows

$$\lambda > \frac{1}{py}. \tag{1}$$

Restriction (1) guarantees that, despite the limited output verifiability, the mature technology can be funded both by a transactional and by a relationship lender (see below).

To complete the description of the technology, we have to specify the scrap value of a machine. We assume that, gross of any liquidation cost, a liquidated machine, whether traditional or new, can be converted by any agent into $A < 1$ units of final good.

Financing At date 1, investors can store or lend their endowment to the entrepreneur. We assume that the entrepreneur borrows only from one investor that we call lender henceforth. In particular, at date 0, before a credit contract is written, the entrepreneur can establish a relationship or a transactional link with the lender. Henceforth, we denote a relationship (transactional) lender with subscript $i = R$ (T). The strength of the credit link determines the ability of the lender to monitor the firm at date 1. Let μ_{Li} denote the monitoring intensity of a lender of type i. If the entrepreneur establishes a relationship, the lender will have higher ability to monitor, facing a monitoring cost of $c_R\mu_{LR}^2/2$. If the entrepreneur establishes a transactional link, the lender will face a monitoring cost of $c_T\mu_{LT}^2/2$ with $c_T > c_R$. These assumptions capture the idea that a relationship lender is likely to have more frequent contacts with the borrower, easier access to the documents of the firm or, in some circumstances, to have representatives on the board of the firm (as in Germany and Japan). This will allow her to gather information more easily.

We characterize lenders and their activity of information collection in accordance with previous literature. We borrow from Diamond and Rajan (2001) the idea that, by monitoring, the lender achieves skills to liquidate the assets of the entrepreneur. Precisely, we assume that, when an agent liquidates the machine, she faces a transaction cost proportional to the liquidation value A of the machine. In particular, we let $(1-\mu_j)A$ be the units of final good lost by agent j in liquidation, with $j = E$ (entrepreneur), I (investor) and L (lender).[7] We normalize the liquidation ability of the entrepreneur to zero, that is $\mu_E = 0$. In fact, according to Habib and Johnsen (1999) (p. 145), "it is reasonable to assume that he [the entrepreneur] lacks the skill even to identify the asset's next best use or to recognize clearly the occurrence of the bad states, in which case he risks maintaining it in a suboptimal use". Since it matters only for the analysis of efficiency, we defer the specification of the liquidation ability of the investors who do not fund the entrepreneur (μ_I) and the related discussion on the nominal or real nature of the liquidation cost.

We introduce two crucial assumptions on the liquidation skills of the lender. First, we assume that these skills are specific to the type of machine she has monitored. In other words, if the lender has achieved skills in liquidating the type of machine employed in a technology, she will not benefit from these skills when liquidating the machine of the alternative technology. With this assumption, we want to capture the fact that productive assets differ across technologies, especially when technologies are specialized. Second, we assume that the lender can monitor a traditional machine but not a new machine. With this assumption, we want to capture the idea that a lender finds probably more difficult to collect information on a technology on which she has no previous experience.

At date 1, before the possible realization of the technological shock, in order to allow the entrepreneur to adopt the new technology, the lender must implement a costless action specific to the new technology. This action can be thought as giving advice or transmitting information to the entrepreneur. Alternatively, we could assume that the new technology requires the injection of additional funds at date 1.[8] By setting the lender's refinancing at an arbitrarily small level, there would be no change in our results. The assumption that this action is necessary only for the new technology is for simplicity.

Information and Contract Monitoring and the action of the lender necessary for the new technology are non-verifiable and, hence, non-contractible. If we interpret the action of the lender as a refinancing of the project, the assumption that this is non-contractible can reflect the fact that a lender can never fully commit to refinance an entrepreneur at intermediate stages. In different contexts, for example, Rajan (1992) and Dewatripont and Maskin (1995) introduce an analogous assumption. The technological shock is non-verifiable either and no contract can be contingent on it. This implies that, while a contract can be contingent on the technology implemented, if the new technology is not adopted, a court cannot verify whether the entrepreneur has chosen to implement the mature technology or the technological shock has not occurred.

At date 0, the entrepreneur and the lender write a contract that specifies the date 1 loan to the entrepreneur and the date 2 repayments to the lender in case of success, contingent on the technology adopted. As for the proceeds from the liquidation of the machine in case of failure, following Diamond and Rajan (2001), we assume that the lender cannot commit her liquidation skills ex-ante. This implies, that regardless of the allocation of the proceeds specified in the contract, the lender can threaten to withhold her skills at the liquidation stage and force a renegotiation of the contract. As in Diamond and Rajan, we also assume for simplicity that the lender has all the bargaining power vis-a-vis the entrepreneur in any such renegotiation and can extract all the surplus associated with her higher liquidation ability. This implies that the lender's expected return from liquidation is $\mu_L A$ (zero) if the mature (new) technology is adopted.[9]

Summary Below we summarize the sequence of events. In Figure 1 we report the time line.

Date 0. The entrepreneur chooses an investor and establishes a relationship or a transactional credit link with her. The entrepreneur and the lender write a contract.

Date 1. The lender monitors the firm and chooses whether to carry out a costless action necessary for the adoption of the new technology. The entrepreneur experiences a technological shock with probability $1-\gamma$. If the shock is realized and the lender has implemented the action necessary for the new technology, in period 2 the entrepreneur has access to a new, highly productive technology besides the mature one. The

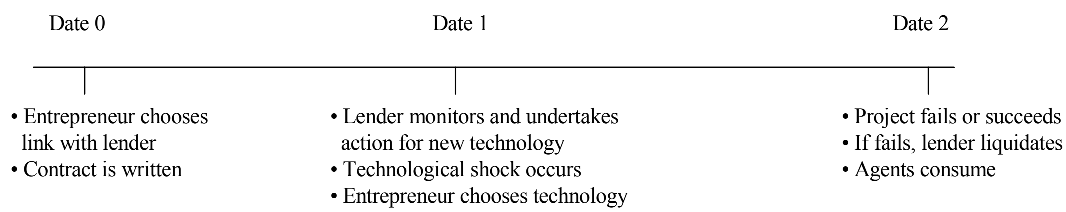

Figure 1: Time Line

entrepreneur chooses the technology.

Date 2. The project succeeds or fails. If the project fails, the lender recovers and liquidates the machine of the entrepreneur.

B Equilibrium

We solve the model by backward induction. First, we analyze the technology choice of the entrepreneur. Then, we solve for the date 1 monitoring and action of the lender before the possible realization of the technological shock. After that, we derive the contract between the entrepreneur and the lender at date 0. Finally, we solve for the funding choice of the entrepreneur.

Date 1 Consider first the case in which the technological shock has not occurred or it has occurred but the lender has not carried out the action necessary for the new technology. The entrepreneur' s net return from adopting the mature technology is $y - R_i^E$, where R_i^E stands for the repayment due to the lender if the mature technology is implemented. Consider now the case in which in the previous stage the technological shock has occurred and the lender has implemented the action necessary for the new technology. The entrepreneur will adopt the new technology if its return net of the repayment due to the lender (R_i^N) exceeds the net return from the mature technology and the zero return from inaction, that is $Y - R_i^N > \max\left\{y - R_i^E, 0\right\}$.

Consider now the decision of the lender of whether to carry out the action for the new technology. The only relevant case is when, conditional on the lender undertaking this action and the positive technological shock being realized, the entrepreneur is expected to adopt the new technology. The lender compares her expected return X_i^N if she allows the entrepreneur to adopt the new technology with her expected return

X_i^E if the new technology is never adopted. X_i^N and X_i^E are equal to

$$X_i^N = (1-\gamma)R_i^N p + \gamma\left[R_i^E p + (1-p)A\mu_{Li}^N\right] - \frac{c_i}{2}\mu_{Li}^{N2}; \quad (2)$$

$$X_i^E = R_i^E p + (1-p)A\mu_{Li}^E - \frac{c_i}{2}\mu_{Li}^{E2}. \quad (3)$$

In (2) (respectively (3)), μ_{Li}^N (μ_{Li}^E) stands for the monitoring of the lender if she expects (does not expect) that the new technology will be adopted, if the technological shock is realized. Note that monitoring increases the lender's return from liquidation only if the mature technology is adopted. In fact, the lender cannot use the information obtained on the traditional machine when she redeploys the new machine. Moreover, the lender cannot monitor a new machine.

We assume that, when indifferent, the lender does not allow the new technology. Comparing X_i^N and X_i^E and operating algebraic manipulations, the lender will then allow the new technology if and only if

$$(1-\gamma)p(R_i^N - R_i^E) > (1-p)A(\mu_{Li}^E - \gamma\mu_{Li}^N) - \frac{c_i}{2}(\mu_{Li}^{E2} - \mu_{Li}^{N2}). \quad (4)$$

The incentive constraint of the lender (4), is the first of the two key trade-offs of the analysis. The right hand side of (4) captures the decrease in the net return from liquidation that the lender expects if she allows the new technology. This loss is positively related to the monitoring intensity μ_{Li}^E and to the monitoring gap $\mu_{Li}^E - \mu_{Li}^N$. Hence, the lender will allow the new technology only if the contract guarantees her a sufficiently higher repayment if the new technology is adopted, that is only if $R_i^N - R_i^E$ satisfies (4). To solve for the trade-off in (4), we need to derive the monitoring intensities μ_{Li}^N and μ_{Li}^E that maximize X^N and X^E respectively. It is straightforward that $\mu_{Li}^N = [\gamma(1-p)A]/c_i$ and $\mu_{Li}^E = [(1-p)A]/c_i$ for $c_i = c_T,\ c_R$.

Contract The contract specifies a loan of one to the firm. Since there are more investors for one entrepreneur, the credit market is competitive and the contract maximizes the entrepreneur' s expected return subject to the constraint that the lender expects zero profits at least.

First, consider a contract such that at date 1 the new technology is never adopted. We can then focus on the repayment R_i^E for the mature technology. This repayment has to satisfy the non-negative profit condition of the lender $X_i^E \geq 1$, the limited liability constraints of the entrepreneur $R_i^E \leq \lambda y$ and of the lender $R_i^E \geq 0$. Consider then a contract that leads to the implementation of the new technology, if the technological shock is realized. In order to induce the lender to carry out the action for the new technology, such a contract must guarantee to the lender a higher repayment for the new technology. In particular, $R_i^N - R_i^E$ must satisfy the lender's incentive compatibility constraint (4). In addition, the contract must satisfy the non-negative profit condition of the lender $X_i^N \geq 1$, the borrower's limited liability constraints $R_i^N \leq \lambda Y$ and $R_i^E \leq \lambda y$ and incentive constraint $Y - R_i^N > y - R_i^E$ and the lender's limited liability constraints $R_i^E \geq 0$ and $R_i^N \geq 0$.

Proposition 1 summarizes the first result of the paper, showing that a relationship lender is more "conservative" than a transactional lender, that is she allows the adoption of the new technology in fewer circumstances.

PROPOSITION 1: *Suppose that* $Y - y > \Delta y$ *(see the Appendix for the value of* Δy*). For regions of the parameter space such that contracts can be written that allow the adoption of the new technology under relationship funding, contracts can be written that allow the adoption of the new technology under transactional funding. However, the converse does not hold.*

PROOF: In Appendix.

The intuition behind Proposition 1 can be obtained by observing constraint (4). The repayment gap $R_i^N - R_i^E$ that can be specified in an incentive contract is bounded above. On the one hand, the repayment R_i^N if the new technology is adopted is constrained above by the limited liability constraint of the entrepreneur $R_i^N \leq \lambda Y$. On the other hand, for a given R_i^N, the repayment R_i^E if the mature technology is adopted is constrained below by the lender's participation constraint $X_i^N \geq 1$ or limited liability constraint $R_i^E \geq 0$. Hence, for some regions of the parameter space, in (4) the left hand side falls short of the right hand side for any feasible pair (R_i^N, R_i^E). In these regions of the parameter space, the lender is expected to prevent the adoption of the new technology. This is more likely to happen if the lender has established a relationship with the entrepreneur. Because of her lower monitoring cost, a relationship lender becomes more familiar than a transactional lender with a traditional machine, that is in (4) the right hand side is higher.[10] Therefore, the regions of the parameter space in which under transactional funding the right hand side of (4) exceeds its the left hand side are a subset of the corresponding ones under relationship funding.

Henceforth, we focus on regions of the parameter space such that it is possible to give incentives to fund the new technology only to a transactional lender. This is the case of interest for our analysis and the

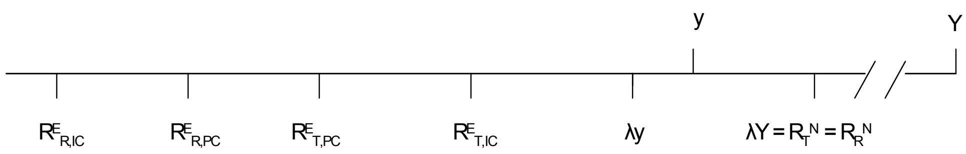

Figure 2: Configuration of Repayments

corresponding configuration of returns and repayments is represented in Figure 2. For simplicity and to render our argument more clear, we also focus on regions of the parameter space such that, under transactional funding, it is possible to write an incentive contract with the lender that guarantees her zero profits without violating the lender's limited liability constraint $R_T^E \geq 0$.

Figure 2 subsumes a region of the parameter space such that, even setting the repayment R_i^N for the new technology at its maximum level λY, it is possible to write a contract that simultaneously satisfies the lender' s incentive and compatibility constraints only if the lender is transactional. In fact, unlike for the transactional lender, for the relationship lender the repayment for the mature technology that guarantees her zero profits ($R_{R,PC}^E$) is higher than the maximum one that gives her incentives to allow the new technology ($R_{R,IC}^E$). Lemma 1 solves for the contract conditional on the type of funding.

LEMMA 1: *The entrepreneur never adopts the new technology under relationship funding. The contract with a relationship lender specifies*

$$2pc_R R_R^E = 2c_R - (1-p)^2 A^2. \tag{5}$$

Under transactional funding, if the technological shock is realized, the entrepreneur always adopts the new technology. The contract with a transactional lender specifies R_T^N and R_T^E such that

$$\frac{(1+\gamma)A^2(1-p)^2}{2pc_T} \leq R_T^N - R_T^E \leq Y - y, \tag{6}$$

$$2pc_T\left[(1-\gamma)R_T^N + \gamma R_T^E\right] = 2c_T - \left[\gamma(1-p)A\right]^2, \tag{7}$$

$$0 \leq R_T^E \leq \lambda y,\ 0 \leq R_T^N \leq \lambda Y. \tag{8}$$

PROOF: In Appendix.

The result that, under transactional funding, the entrepreneur always adopts the new technology if the technological shock is realized has a straightforward intuition. If the entrepreneur does not aim at adopting the new technology, she will certainly prefer relationship funding. In fact, relationship funding is less costly since a relationship lender recovers more value from the traditional machine if the project fails and, therefore, needs to be compensated with a lower repayment if the project succeeds. Lemma 1 shows also that for an entrepreneur borrowing from a transactional lender has a higher expected cost than borrowing from a relationship lender. In fact, by direct inspection, $R_R^E < \left[(1-\gamma)R_T^N + \gamma R_T^E\right]$. Note, however, that this higher cost is not entirely attributable to the higher monitoring cost faced by a transactional lender (see more on this below).

Funding Choice We now solve for the entrepreneur's funding choice.[11] The trade-off the entrepreneur faces is the following: on the one hand relationship funding does not allow the adoption of the new technology if the technological shock is realized, while transactional funding gives the entrepreneur freedom in her technology adoption (proposition 1). On the other hand, relationship funding offers the entrepreneur inexpensive financing for the mature technology, thanks to the higher monitoring ability of a relationship lender (lemma 1). Proposition 2 formalizes the selection criterion followed by the entrepreneur.

PROPOSITION 2: *The entrepreneur will prefer transactional funding strictly if and only if*

$$p(1-\gamma)(Y-y) > \frac{1}{2}\left(\frac{1}{c_R} - \frac{\gamma^2}{c_T}\right)(1-p)^2 A^2. \tag{9}$$

PROOF: In Appendix.

Note that, besides the productivity and monitoring gaps, two additional elements affect the trade-off in (9). When the entrepreneur adopts the new technology, the liquidation skills achieved by the lender are wasted. Moreover, expecting this, the lender monitors less. These factors increase the repayment that the entrepreneur must offer to the lender in case of success and are captured by the term γ^2 in the right hand side of (9). These factors originate from the lower redeployability of the new machine and are not directly related to the monitoring advantage of a relationship lender, as proxied by $c_T - c_R$.

Welfare We now assess the welfare loss that the conservatism of relationship lenders generates relative to a benchmark economy in which a relationship lender always allows the adoption of the new technology.

For this purpose, we need to specify the nature of the liquidation cost. The liquidation cost can be either a real resource loss or a transfer to another agent in the economy.[12] We can formalize the case in which the liquidation cost is nominal in our set up. For example, we can think that one of the investors who does not fund the firm becomes an efficient asset liquidator and achieves skills to redeploy the machine, whether traditional or new, at no cost ($\mu_I = 1$). Hence, this liquidator can obtain A units of final good from any type of machine. Consider what happens if the entrepreneur, the lender and the liquidator bargain over the liquidation proceeds of the machine and the liquidator has full bargaining power vis-a-vis the lender and the entrepreneur. Assuming a simple generalized Nash-bargaining, it is easy to see that the liquidator will extract all the surplus associated with her advantage in redeployment relative to the lender, which equals $(1-\mu_L)A$ and no output loss will be realized. For the rest, the results of the model will carry through.

Proposition 3 summarizes the welfare loss that obtains in our economy according to the nature of the liquidation cost.

PROPOSITION 3: *(i) Suppose that the liquidation cost is nominal. In the first best, the new technology would always be adopted if the technological shock is realized. The expected welfare loss when (9) does not hold is* $p(1-\gamma)(Y-y)$ *(respectively zero when (9) holds).*

(ii) Suppose that the liquidation cost is real. In the first best, the new technology would be adopted if and only if

$$2pc_R(Y-y) > (1+\gamma)(1-p)^2A^2 \tag{10}$$

If (9) holds (does not hold) and (11) is satisfied the welfare loss is L_W ($L_W^{'}$)

$$L_W = \frac{\gamma^2}{2}\left(\frac{1}{c_R}-\frac{1}{c_T}\right)(1-p)^2A^2, \tag{11}$$

$$L_W^{'} = p(Y-y) - \frac{(1-p)^2A^2(1+\gamma)}{2c_R}. \tag{12}$$

If neither (9) nor (11) hold the welfare loss is zero.

PROOF: In Appendix.

Expression (10) shows that if the liquidation cost is real and the new technology is adopted, the higher productivity of the new technology in case of success will come at the cost of a lower redeployability of the machine in case of failure. However, (4) is a more stringent condition than (10). This shows that the conservatism of relationship lenders tends to depress to rate of adoption of the new technology below its first best. In fact, the entrepreneur can adopt the new technology only by borrowing from a transactional financier and this implies wasting the higher liquidation skills of a relationship financier.

C Comparative Statics

We can relate the conservatism of relationship lenders and the funding choice of the entrepreneur to the structural characteristics of the firm and the economy as proxied by the parameters of the model. In Table 1, we summarize our comparative statics results.

We start from the choice of a relationship lender of whether to allow the new technology. We assess how a change in the parameters affects the propensity of a relationship lender to allow the new technology relative to a transactional lender. Whenever the region of the parameter space in which it is possible to write an incentive contract with a relationship lender shrinks (broadens) more than the corresponding one for a transactional lender, we say that the former becomes relatively more (less) conservative. It is easy to show that: i) The higher is the probability of success of the project p, the lower is the relative conservatism of a relationship lender. In fact, the stronger conservatism of a relationship lender arises from her higher ability to liquidate the machine and this ability is less relevant when the probability of default is lower; ii) The higher is the gap between the monitoring cost of a transactional and a relationship lender $c_T - c_R$, the stronger is the relative conservatism of a relationship lender. In fact, a higher $c_T - c_R$ increases the comparative advantage of a relationship lender in liquidating the machine; iii) The higher is the scrap value A of the machine, the stronger is the relative conservatism of a relationship lender. In fact, a higher A increases the gap between the liquidation losses that a relationship and a transactional lender suffer if the new technology is adopted.

We now consider the choice of the entrepreneur between relationship and transactional funding, conditional on a relationship lender not allowing the adoption of the new technology. Observing (9), it is easy to infer that: iv) The higher is the productivity gap between the old and the new technology $Y - y$, the higher

Table 1: Comparative Statics Results

Variable	Conservatism	Transactional Funding
Productivity Gap $(Y - y)$	-	Positive
Monitoring Gap $(c_T - c_R)$	Positive	Negative
Probability of Success (p)	Negative	Positive
Probability of Shock $(1 - \gamma)$	-	Ambiguous
Assets Value (A)	Positive	Negative

is the entrepreneur's incentive to choose transactional funding. In fact, only transactional funding allows the adoption of the new technology; v) Expectedly, the higher is the gap between the monitoring cost of a transactional and a relationship lender $c_T - c_R$, the lower is the entrepreneur's incentive to choose transactional funding; vi) The higher is the probability of success of the project p, the higher is the incentive to choose transactional funding. In fact, not only the productivity difference between the two technologies matters only when the project is successful, but also, the higher is the probability of success, the lower is the monitoring gap between a relationship and a transactional lender; vii) The probability of the technological shock $1-\gamma$ affects the trade-off in (9) ambiguously. On the one hand, the more likely is the shock, the higher is the advantage that transactional funding offers by allowing the adoption of the new technology. On the other hand, a higher probability of the shock reduces the monitoring incentive of a transactional lender and also increases the risk that any reusability of the machine achieved by a transactional lender gets wasted; viii) The higher is the value A of the machine of the firm, the lower is the incentive to choose transactional funding. In fact, A is positively related to the monitoring gap between a relationship and a transactional lender and to the loss from foregoing the high liquidation skills of a relationship lender.

The most striking prediction is associated with the value of the assets of the firm. The model predicts, for example, that small firms and firms with a low ratio tangible/intangible assets adopt new technologies more frequently. This would happen because their informed financiers would be less conservative in the financing of new technologies and because these firms would find less costly to forego the benefits of informed finance in order to achieve freedom in technology adoption. Interestingly, this prediction is consistent with the results of existing empirical studies. For example, using data from a cross-section of Italian manufacturing firms, Guiso (1998) analyzes the exposure of high-tech firms to credit rationing. He finds that the share of real assets has no power in explaining the probability that these firms are rationed by banks, despite the frequent claim that the availability of pledgeable assets helps to overcome informational and agency frictions between borrowers and lenders. The lack of a negative correlation between the value of real assets and the probability of rationing of these innovative firms could stem from the fact that firms with more real assets are more exposed to lenders' conservatism and that their lenders use rationing to prevent the adoption of new technologies.[13]

II An Application: Finance and Development

We believe that the model is subject to several applications. We now formalize one, exploring the implications of our analysis for the evolution of the financial structure. A stylized fact observed since Gurley and Shaw (1967) is that the banking system plays a key role at intermediate stages of development while financial markets for direct debt and equity develop when per capita income and wealth increase further.[14] Since Adam Smith, economists have also argued that development leads to the adoption of increasingly complex and specialized technologies. In other words, as the economy develops, more productive but less flexible technologies are introduced, with the flexibility of a technology being captured by the reusability of its tools in the production of a different good.[15] In the twentieth century, this process has allegedly culminated with the diffusion of mass production. Piore and Sabel (1984, p. 27) argue that "Mass production, as we have seen, means the creation of general goods through specialized resources. The more general the goods, [...] the more specialized the machines and finely divided the labor that go into their production".

We now show that our model can link these two stylized facts. Our prior is that, as technologies become more specialized and the reusability of traditional machines in new technologies declines, the specificity of banks' information on mature technologies increases. This could happen, for example, because the differences across distinct types of productive machines increase. Using this argument in our framework, we show that in developed economies, banks, meant as informed lenders, have less incentives to allow the adoption of new technologies. In order to escape this "technological sclerosis", firms can rely on less informed (transactional) forms of finance, such as arm's length financial markets.

We now allow the economy to go through different stages of development. We let the indicator variable $t \in [0,\ 1]$ denote the stage of development, with a higher t standing for a higher stage of development. In the economy, there is a continuum of entrepreneurs of mass one and a continuum of investors of mass greater than one with whom entrepreneurs can establish relationship or transactional credit links. The entrepreneurs are homogeneous so that we can consider a representative entrepreneur. At each stage of development, the representative entrepreneur has access to two technologies: a mature technology and a new more productive technology. At a higher stage of development, the representative entrepreneur has access to technologies that are more productive on average. Precisely, we assume that $y + t$ and $Y + t$ are the productivity of the mature and of the new technology respectively, so that the productivity gap between the two technologies is $Y - y$, regardless of the stage of development.[16]

Consistent with the notion of development as specialization, we assume that more productive technologies are less flexible, that is their machines have a lower reusability in alternative technologies. We argue that the lower is the flexibility of the technologies, the higher is likely to be the specificity of lenders' information, that is the less a lender can use her information on a traditional machine in the redeployment of a new machine. Formally, we assume that at stage of development t, when liquidating a traditional (new) machine, a lender faces a transaction cost of $(1 - \mu_L)A$ ($[1 - \mu_L(1 - t)]\, A$). This specification captures the idea that the degree of development t is a sufficient statistic for the productivity of the technologies and for their flexibility. For a given monitoring intensity μ_L, the higher is the degree of development t and, correspondingly, the higher is the specialization of the two technologies, the lower is the reusability of the information on a traditional machine for a new machine. The rest of framework is unaltered.

In this set up, condition (4) under which a lender allows the adoption of the new technology becomes:

$$(1-\gamma)p(R_i^N - R_i^E) > (1-p)A\left\{\mu_{Li}^E - [1-(1-\gamma)t]\,\mu_{Li}^N\right\} - \frac{c_i}{2}(\mu_{Li}^{E2} - \mu_{Li}^{N2}). \tag{4b}$$

A higher t not only increases the right hand side of (4b) directly but also discourages the lender from monitoring, reducing μ_{Li}^N. In turn, these effects render inequality (4b) more difficult to satisfy. We can then write the following proposition.

PROPOSITION 4: *Consider the regions of the parameter space assumed in section I. For each of these regions, there exists a threshold level of t such that above this threshold no feasible pair $(R^N,\ R^E)$ satisfies (4b) under relationship funding.*

PROOF: The proof is straightforward. Note that the case of the highest stage of development ($t = 1$) is the one analyzed in the basic model. Moreover, for $t = 0$ information is perfectly transferable across technologies and it will always be possible to satisfy (4b). Therefore, by applying an argument of continuity, the proposition follows.

Consider any of the regions such that proposition 4 holds and denote $\widehat{t}$ the corresponding threshold level of t. When $t < \widehat{t}$ relationship funding strictly dominates transactional funding since a relationship lender allows the choice of the new technology and, thanks to her lower monitoring cost, requires a lower repayment. When $t > \widehat{t}$, one of two cases occurs: if the expected productivity gain from adopting the new technology is smaller than the expected loss in terms of higher repayment, the representative entrepreneur will choose relationship funding. If the opposite holds, the entrepreneur will choose transactional funding. Interestingly, in the range $\left[\widehat{t},\ 1\right]$ a higher t renders transactional funding less appealing. In fact, since only a transactional lender finances the new technology, a decrease in the redeployability of the new machine increases the comparative advantage of choosing relationship funding and adopting the mature technology.[17] This implies that for a developed economy the choice of transactional funding is reversible and for very high levels of t the economy could switch back to relationship funding.

III Extensions

The analysis can be extended along different dimensions. First, we can relax the assumption that the value of pledgeable assets is the same across technologies. It is sometimes argued that firms that adopt new technologies have less assets to pledge as collateral, because new technologies have a higher ratio human capital/tangible assets. In our context, we could assume that a new asset can be converted in less units of final good than a traditional one ($A_N < A_E$). In particular, regardless of the reusability of information in the new technology, if the new asset cannot be converted at all into final good ($A_N = 0$) and the returns from the two technologies in case of success are as in section I, the results of propositions 1 and 2 will carry through. As for the result of proposition 3, this will carry through if the liquidation cost is real while, if the liquidation cost is nominal, the economy will suffer an output loss also when the new technology is adopted.

A second extension consists of relaxing the assumption that the new and the mature technology have the same output verifiability. In particular, one could argue that new technologies are more exposed to an output verification problem ($\lambda_N < \lambda_E$). In fact, since these technologies have not been implemented in the past, lenders could be less experienced in verifying their returns.[18] This extension would not alter the qualitative results of the paper. In fact, both under relationship and under transactional funding, a lower output verifiability of the new technology would shrink the regions of the parameter space in which its financing is feasible.

Finally, we can also extend the framework of section II by letting the productivity gap between the mature and the new technology change with development. In particular, as development proceeds and the average productivity of the technologies increases, the productivity gap between a new and a mature technology could increase, too. Under this alternative specification, a more conventional rationale arises for the increasing importance of uninformed finance. It can be that at intermediate stages of development, even if relationship lenders do not allow the adoption of the new technology, the productivity gap between the new and the mature technology is too small to forego the lower repayment required by relationship lenders. Only when t and the productivity gap grow further, entrepreneurs could prefer switching to transactional lenders and gaining access to the higher productivity of the new technology.[19] This explanation is observationally different from the one proposed in section II. If the transition in financial regime is the result of an increasing specialization of the technologies, we would expect a smooth increase in output when the economy switches from relationship to transactional funding. In fact, both at intermediate stages of development and at later stages, a fraction $1 - \gamma$ of entrepreneurs adopt the new technology. If the financial transition is instead the result of an increasing productivity gap between new and mature technologies, we would expect a jump in output when the economy transits from relationship to transactional funding. In fact, while at an intermediate stage of development all entrepreneurs adopt the mature technology, from the time the economy switches financial regime, a fraction $1 - \gamma$ of entrepreneurs implement the new technology.

IV Conclusion

We have analyzed an economy in which lenders' information on mature technologies hinders technological progress. Firms can forego the benefits of informed capital to gain freedom in the adoption of new technologies. By interpreting information as conservatism, we can explain why new technologies develop first in market-oriented financial systems and why development appears associated with an increasing importance of arm's length financial markets relative to intermediated finance. The most striking policy implication of the analysis is that subsidizing information acquisition in credit markets is not necessarily welfare improving. This implication can appear strong but it is more reasonable if we interpret it as a suggestion to tie subsidies for information acquisition to the past record of lenders in the financing of innovative technologies.

The next research step is casting the partial equilibrium analysis in a general equilibrium context and analyzing how the conservatism of financiers changes over the business cycle. We believe this can offer interesting implications for the cyclical pattern of firms' restructuring activity.

V Appendix

PROOF OF PROPOSITION 1:

The value of Δy satisfies

$$\Delta y = \frac{p\lambda Y - [1 - \gamma^2 (1-p)^2 A^2 / 2c_R]}{\gamma p}. \tag{1A}$$

Substituting the optimal levels of monitoring μ_{Li}^N and μ_{Li}^E into (4) and operating algebraic manipulations, we obtain

$$R_i^N - R_i^E \geq \frac{(1+\gamma)(1-p)^2 A^2}{2pc_i}. \tag{2A}$$

We must find whether contracts can be written such that (2A), the lender's zero profit condition and the entrepreneur's limited liability and incentive constraints hold. First, observe that R_i^N can be pushed up to its upper limit λY and R_i^E reduced in a way such that the lender's and the entrepreneur's expected returns are unaltered. Moreover, a higher R_i^N reduces the value of R_i^E that can be set in order to satisfy the lender's zero profit condition and increases the maximum value of R_i^E that must be set in order to satisfy (2A). Therefore, it is easier to satisfy simultaneously the lender's incentive and zero profit constraints when $R_i^N = \lambda Y$, that if it is not possible to write an incentive contract when $R^N = \lambda Y$, a fortiori it will not be possible when $R^N < \lambda Y$. Observe also that restriction (1) guarantees that, if $R_i^N = \lambda Y$ and the lender's zero profit condition is satisfied, the entrepreneur's limited liability constraint $R_i^E < \lambda y$ holds. Let $R_{i,PC}^E$ denote the value of R^E that solves the zero profit condition of a lender of type i when $R^N = \lambda Y$. $R_{i,PC}^E$ equals

$$R_{i,PC}^E = \frac{1 - \gamma^2 (1-p)^2 A^2 / 2c_i - (1-\gamma) p\lambda Y}{\gamma p}. \tag{3A}$$

In order to satisfy the lender's incentive constraint, $R_{i,PC}^E$ must satisfy

$$R_{i,PC}^E < R_{i,IC}^E = \lambda Y - \left[(1+\gamma)(1-p)^2 A^2\right] / 2pc_i$$

The difference between the repayments that satisfy a relationship lender and a transactional lender's participation constraints is

$$R_{T,PC}^E - R_{R,PC}^E = \frac{\gamma (1-p)^2 A^2}{2p} (\frac{1}{c_R} - \frac{1}{c_T}). \tag{4A}$$

From (2A) the difference between the repayments that satisfy a relationship lender and a transactional lender incentive constraints is

$$R^E_{R,IC} - R^E_{T,IC} = \frac{(1+\gamma)(1-p)^2 A^2}{2p}\left(\frac{1}{c_R} - \frac{1}{c_T}\right). \tag{5A}$$

Clearly, $R^E_{T,PC} - R^E_{R,PC} < R^E_{R,IC} - R^E_{T,IC}$.

Moreover, there exist feasible regions of the parameter space such that $R^E_{R,IC} = R^E_{R,PC} > 0$. In particular, using the expressions for $R^E_{R,IC}$ and $R^E_{R,PC}$, in order for the first equality to hold, it must be that

$$p\lambda Y = 1 + \frac{\gamma(1-p)^2 A^2}{2c_R} \tag{6A}$$

It is straightforward that there exist regions of the parameter space in which (6A) holds and $R^E_{R,PC} > 0$. Together with $R^E_{T,PC} - R^E_{R,PC} < R^E_{R,IC} - R^E_{T,IC}$, this implies that there exist regions of the parameter space in which the repayment that satisfies a transactional lender's incentive compatibility constraint exceeds the one that satisfies her participation constraint but the converse holds for a relationship lender (see figure 2). In these regions of the parameter space, it is possible to write a contract that gives incentives to a lender to allow the new technology if and only if the lender is transactional.

It remains to verify that the entrepreneur's incentive constraint can also be satisfied. The maximum repayment gap $R^N_i - R^E_i$ that satisfies a lender's participation constraint with the equality sign ($X^N = 0$) realizes when the lender is relationship ($i = R$) and R^N_R takes its maximum value, i.e. $R^N_R = \lambda Y$. This repayment gap equals Δy. From the restriction $Y - y > \Delta y$ in proposition 1, $Y - y$ always exceeds $\lambda Y - R^E_{R,PC}$.

PROOF OF LEMMA 1:

The monitoring levels of the two lenders are respectively $\mu^E_{LR} = (1-p)A/c_R$ and $\mu^N_{LT} = \gamma(1-p)A/c_T$. In fact, a transactional (relationship) lender does (not) expect that the new technology will be adopted if the technological shock is realized. After substituting the monitoring level of the relationship lender into the zero profit condition $X^E = 0$, we can solve for R^E_R. Note that restriction (1) guarantees that R^E_R in (5) satisfies the entrepreneur's limited liability constraint $R^E_R < \lambda y$. The contingent contract with a transactional lender must specify $R^N_T - R^E_T$ high enough to satisfy (4) and low enough to satisfy the entrepreneur's incentive compatibility constraint, which is $R^N_T - R^E_T \leq Y - y$. By substituting the monitoring level of a transactional lender into the zero profit condition $X^N = 0$, we obtain the required value of $(1-\gamma)R_T^N + \gamma R_T^E$. Finally, R_T^E and R_T^N must satisfy the entrepreneur's limited liability constraints.

PROOF OF PROPOSITION 2:

If she chooses transactional funding, the entrepreneur will expect a return of

$$W_T = p\left[(1-\gamma)(Y - R_T^N) + \gamma(y - R_T^E\right] \tag{7A}$$

If she chooses relationship funding, the entrepreneur will expect a return of $W_R = p(y - R_R^E)$. The entrepreneur will prefer transactional funding strictly if and only if $W_T > W_R$, that is, after substituting R_T^N, R_T^E and R_R^E and simplifying, if and only if condition (9) holds. It remains to verify that both the regions in which (9) holds and does not hold are non-empty. By substituting the value of $p\lambda Y$ in (6A) into the expression for Δy and operating algebraic manipulations, we obtain that the value of $Y - y$ that satisfies (9) with the equality sign exceeds Δy if and only if

$$\frac{1-\gamma}{c_R} < \frac{1}{1-\gamma}\left(\frac{1}{c_R} - \frac{\gamma^2}{c_T}\right) \tag{8A}$$

This condition can always be satisfied without violating previous restrictions on the parameters.

PROOF OF PROPOSITION 3:

Suppose the liquidation cost is nominal. The expected return from the new (mature) technology is $pY + (1-p)A$ $(py + (1-p)A)$. Therefore, in the first best the new technology should always be adopted. By comparing the two returns and taking into account that the technological shock realizes with probability $1-\gamma$, we obtain the expected output loss that is $p(1-\gamma)(Y-y)$. Suppose now that the liquidation cost is real. In the first best, the entrepreneur would choose a relationship lender who in turn would allow the new technology whenever (10) holds. If (10) holds but (9) is not satisfied the expected loss $L_W^{'}$ is obtained by subtracting the right hand side of (10) from the left hand side. If both (9) and (10) hold the output loss L_W is obtained by comparing the expected liquidation proceeds of a relationship and a transactional lender. Finally, if neither (9) nor (10) hold the private equilibrium and the first best equilibrium coincide.

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Notes

[1]A crucial assumption of the model is that lenders have some control over the production decisions of a firm and the firm cannot bypass this control by switching to alternative sources of finance.

[2]Bhattacharya and Chiesa (1995) propose a model in which firms engaged in R&D establish bilateral relations with banks to prevent disclosure of proprietary information to competitors.

[3]Bencivenga, Smith and Starr (1995) model an economy in which highly productive technologies require longer gestation periods and can be funded only when secondary capital markets are liquid enough. Financial development, meant as an increase in the liquidity of secondary markets, allows funding more productive technologies, raising also the incentive to save. However, Bencivenga, Smith and Starr (1995) show that this does not always lead to a higher growth rate. Bencivenga and Smith (1991) construct an economy in which agents face idiosyncratic liquidity shocks and choose between an illiquid technology and a liquid, less productive one. Intermediaries allow diversifying the liquidity risk and investing in the highly productive technology. Saint Paul (1992) develops a similar idea. Financial markets allow diversifying technological risk but have relevant fixed entry costs. Multiple equilibria emerge from the interaction between financial development and technological innovation.

[4]La Porta, Lopez-de-Silanes and Shleifer (2001) argue that state-owned banks pursue political goals and prefer funding labour-intensive industries than strategic, innovative ones. In their context, banks' bias against innovative technologies is unrelated to their information.

[5]For different results see Beck and Levine (2002). They find that the financial structure is unrelated to the performance of R&D-based industries and to the formation of new establishments. They also find that industries that depend heavily on external finance do not grow faster in either bank-based or market-based financial systems. Levine and Zervos (1998) find a positive correlation between different measures of economic growth, including a measure of productivity growth, and indicators of stock market development and banking development. However, their results do not imply that both banks and stock markets favor technological innovation. In fact, the authors argue that their variable Productivity Growth is a conglomerate indicator of technological change, quality advances, and resource allocation enhancements.

[6]The assumption that the probability of success of the established and the new technology are equal is only aimed at simplifying the analysis. It is sometimes argued that new technologies have higher risk and this deters risk-averse investors from financing them. This aspect is beyond the scope of the paper.

[7]In a similar way, Bencivenga, Smith, and Starr (1995) assume that transaction costs exist in transacting capital in a secondary capital market and that these costs are proportional to the value of traded capital. Liquidation costs in selling assets in the secondary market include commissions, fees or also the time necessary to arrange a sale or purchase of an asset.

[8]Since it is not relevant for our analysis, we do not pin down the nature of the action that must be implemented by the lender to allow the adoption of the new technology.

[9]Alternatively, we could think of a framework in which the date 2 repayment can be contingent on the technology implemented but not on the success or liquidation of the project. If the entrepreneur defaulted on the agreed repayment, at date 2 the lender would have all the liquidation rights and could seize the liquidation proceeds of the productive asset up to the agreed repayment.

[10]When the monitoring cost of the lender c_i is lower, the left hand side of (4) can also be shown to be higher. This happens because, for a given repayment for the new technology R^N, the entreprenur can offer a smaller repayment R^E for the old technology. In fact, a lower monitoring cost implies that the average, expected repayment to the lender in case of success can be lower. This second effect is overwhelmed by the effect described in the text, so that a higher monitoring cost renders (4) more difficult to satisfy.

[11]If we consider the entrepreneur as a representative entrepreneur, this can also be interpreted as solving for the financial structure of the economy.

[12]An example of the former would be an additional effort an agent must personally bear to recover or liquidate assets. An example of the latter would be a fee an agent pays to an efficient liquidator of the assets, i.e. someone facing no liquidation cost.

[13]Guiso (1998) suggests that this result could stem from the lower risk aversion of wealthy firms and the resulting negative selection effect that higher collateral requirements could have.

[14]Carlin and Mayer (2002) find no evidence of a role of bank-firm relations in advanced countries while they find that in low income countries the development of the banking system supports bank-dependent industries.

[15]Saint Paul (1992) mentions home production and a pin factory as an example respectively of a flexible and an inflexible technology. "Home production, which is not very efficient, is relatively flexible because it uses general purpose tools which can be used to produce a fairly different good (p. 765)". Conversely "a pin factory involving a very careful decomposition of the tasks of constructing pins will be vulnerable to any change in the pin design which is most preferred (p. 765)".

[16]In section III, we relax the assumption that the productivity gap between the new and the mature technology is independent of the stage of development.

[17]Again there is both a direct and an indirect effect. As the reusability of the information for the new asset lowers, the entrepreneur faces a higher loss from choosing transactional funding. Moreover, the monitoring of the relationship lender does not change since she funds only the mature technology while the monitoring of the transactional lender decreases since with probability $1 - \gamma$ she funds the new technology.

[18]In a different context, for example, Boyd and Smith (1996) assume that firms can choose between a technology that has imperfectly verifiable returns and a technology that is less productive but has perfectly verifiable returns.

[19]Note that a change in the productivity gap between the mature and the new technology could also affect the possibility of satisfying inequality (4). For simplicity, we implicitly assume that (4) continues not to hold and we ignore this effect.