The Commitment Problem of Secured Lending[*]

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March 2011

Abstract

The paper challenges the argument that collateral boosts debt capacity and provides a new rationale for the use of trade credit. In a setting with uncertainty, two inputs and investment unobservability, we show that a firm-bank secured credit contract is time-inconsistent: Once credit has been granted, the entrepreneur has an ex-post incentive to alter the input combination towards the input with low collateral value, thus jeopardizing total bank revenues. Anticipating the entrepreneur's opportunism, the bank offers a non-collateralized credit contract, thereby reducing the surplus of the venture. One way for the firm to commit to the contract terms is to purchase inputs on credit and pledge them to the supplier in case of default. Observing the input investment and having a positive stake in the bad state, the supplier acts as a guarantor that the input mix specified in the bank contract will be actually purchased and that the entrepreneur will stick to the contract terms. The analysis concludes that trade credit facilitates the access to bank financing, in line with recent evidence.

Keywords: collateral, commitment, trade credit.
JEL classification: G32, G33, K22, L14.

[*]We thank Stefan Ambec, Alberto Bennardo, Arnoud Boot, Emilia Garcia-Appendini, Marco Pagano, Enrique Schroth, Lucy White and the participants to seminars at the University of Amsterdam, Bocconi University and Cass Business School and to the 2010-EEA Congress in Glasgow for useful discussions. The usual disclaimer applies.

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Introduction

The paper challenges the argument that collateral boosts debt capacity and provides a new rationale for the use of trade credit. More specifically, the paper argues that pledging an asset as collateral to give the lender greater protection against losses in default, not necessarily increases external financing. Collateral might indeed introduce in the bank lending relationship a problem of moral hazard in the form of asset substitution. Trade credit can be used by the entrepreneur to mitigate this problem.

We construct a model where firms produce facing uncertain demand and using two inputs with different degrees of tangibility, and thus different collateral values. Two sources of financing are available: bank and trade credit. Financiers have different capabilities. Being specialized financial intermediaries, banks have a cost advantage in financing the firm. However, banks do not observe the amount of inputs purchased and thus invested. In contrast, suppliers have an information advantage: Being the providers, they observe input purchases.

Firms prefer bank financing because it is cheaper. In particular, they prefer secured bank financing. Collateral gives the lender greater protection against losses in default, thereby increasing the amount of external financing and the total surplus of the lending relationship. However, because of the unobservability of input investment, upon receiving the bank loan, the entrepreneur has an incentive to alter the input combination toward the input with higher productivity but lower collateral value. This jeopardizes bank expected revenues, by reducing the liquidation income in the bad state. Anticipating that it will not break even, the bank gives up the secured contract, thus causing an efficiency loss.

One way for the firm to commit to the contract terms is to purchase a fraction of the collateralizable inputs on credit and pledge them to the supplier in case of default. Because trade credit is more costly than bank credit, the entrepreneur only buys a small amount of the inputs on credit. Observing the input investment and having a stake in default state, the supplier implicitly *guarantees* that the quantity of inputs specified in the financial contracts, and thus available for liquidation to creditors, is actually purchased. Through trade credit, the entrepreneur commits to the input combination which is ex-ante efficient. As a consequence, the entrepreneur is able to pledge his inputs as collateral to the bank, obtains larger bank financing and produces higher profits. It follows that, when investment is non-contractible, trade credit facilitates the access to bank loan by making the secured contract available to banks and entrepreneurs.

This analysis relies on the assumption that the entrepreneur is the only contracting party facing a commitment problem. However, upon granting the loan, supplier and entrepreneur could jointly agree to alter the input combination at the expense of the bank. In this case, having the supplier acting as a financier only shifts the commitment problem from the entrepreneur to the supplier. If the cost of such a collusive deal is small enough, a small amount of trade credit may be no longer sufficient to overcome the commitment problem. Then, an increasing fraction of the inputs must be pledged to the supplier and financed by him. In the extreme case in which collusion is costless, the only way for the entrepreneur to exploit the pledgeable income of assets is to sign a secured contract with the supplier and an unsecured contract with the bank. Suppliers and banks finance the purchase of the tangible input in different proportions. The higher the collateral value of assets, the larger the financing provided by the supplier. However, since trade credit is more expensive, the cost of signing a secured contract with the supplier could be so high to neutralize the benefits of trade credit use. If this is the case, the optimal contract is a combination of an unsecured bank credit contract and a pure input supply contract (the supplier is not a financier).

Finally, by relating the cost of collusion to the number of firm's input providers, we identify new relations between the structure of the up-stream market and the firm's financing decisions, including not only the mix of trade and bank credit, but also the type of contract (collateralized versus uncollateralized). Specifically, we argue that trade credit facilitates the firm's access to collateralized bank loan the higher is the degree of competition of the up-stream market. Moreover, while bank credit is increasing in the degree of competition of the up-stream market, trade credit is decreasing in it and therefore larger when the supplier is a monopolist. Since a different mixture of bank and trade credit corresponds to a different input combination, we identify new relations between technological choices and the up-stream market structure. Specifically, firms use technologies more intensive in intangible assets when the up-stream markets are competitive than when they are concentrated.

Our paper is related to two strands of the literature. The first one focuses on the role of collateral in lending relationships. The second one on the determinants of firm's reliance on trade credit. The literature on collateral has identified several theoretical reasons for the popularity of secured lending. The simplest one assumes uncertainty in the firm revenues and argues that collateral reduces losses in case of default (lender's risk reduction). A second strand of the literature highlights the benefits of collateral in mitigating asymmetric information problems. In case of adverse selection, by conveying valuable information to the bank about the borrowers' default risk, collateral can be a signaling instrument (Bester, 1985; Chan and Kanatas, 1985; Besanko and Takor, 1987 a,b). Collateral also helps solving a variety of moral hazard problems like asset substitution, under-investment and inadequate effort supply (Stulz and Johnson, 1985; Chan and Thakor, 1987; Boot and Thakor, 1994). All these papers point to the idea that borrowing not only against returns but also against assets provides the lender greater protection against losses in the event of default and increases the firm's debt capacity. An extensive literature also investigates which characteristics of an asset affect its ability to raise external financing. Some papers focus on the degree of asset tangibility (Almeida and Campello, 2007), while others relate the asset debt capacity to its redeployability (Williamson, 1988; Shleifer and Vishny, 1992) or to the easiness of shifting its property to creditors in case of distress (Hart and Moore, 1994).[1] Our paper identifies a new characteristic: the investment contractibility. We argue that if the investment in a given asset is not contractible, this asset has no debt capacity when pledged as a collateral, although tangible and highly redeployable. Our result not only challenges the accepted view that collateral boosts the firm's debt capacity through a lender risk reduction. It also shows that the use of collateral itself may introduce in the bank-firm relationship a problem of entrepreneur's opportunism (in the form of ex-post asset substitution) that was absent in the unsecured debt contract. For the investment contractibility to play a role in our story, we crucially need a project with two inputs, one of which used as inside collateral. The assumption of a two-input-technology is novel. The related literature focuses on projects with only one input and outside collateral. In our model, the time-inconsistency of the bank secured contract comes from the entrepreneur having an ex-post incentive to alter the input combination toward the input with low collateral value. With only one input (or with outside collateral), the non-contractibility of investment would be immaterial, as the loan size could be used to infer the input choice.

This discussion raises the question which type of bank loan better fits our story. In practice, firms largely use secured loans as opposed to financing primarily based on the firm's cash-flow. Different types of secured loans are offered by banks. Real-estate based lending or loans collateralized by movable goods (like cars, trucks, etc.) have characteristics that depart from our theoretical setting. First, the problem of investment unobservability is not so relevant in this case as, being registered goods, their exact value is known to the bank. Second, the credit is generally granted directly to the seller of the asset or to the notary (for real asset) or to the leasing company (for movable goods). This implies that the entrepreneur does not have the possibility to misuse the bank money. A secured

[1] Several empirical papers document that asset tangibility and salability increase debt capacity (see, among others, Almeida and Campello, 2007; Campello and Giambona, 2009; Benmelech, 2009; Rampini and Viswanathan, 2010).

bank loan that better fits our model is Asset Based Lending (ABL). ABL is a short-term financing (typically, three years maturity) used to support working capital needs. In case of ABL, the bank avoids paying screening costs and lends in exchange of some generic collateral. Collateral generally includes accounts receivable, inventories, machineries and equipments (not real estate). Since the collateral value of ABL is clearly affected by input purchases which are not easily observable by the bank, ABL is likely to be sensitive to the commitment problem analyzed in our model.[2]

Our paper is also related to the literature on trade credit. Papers in this literature have sought to explain why agents might prefer to borrow from firms rather than from financial intermediaries. The traditional explanation is that trade credit plays a non-financial role. That is, it reduces transaction costs (Ferris, 1981), allows price discrimination between customers with different creditworthiness (Brennan et al., 1988), fosters long-term relationships with customers (Summers and Wilson, 2002), and even provides a warranty for quality when customers cannot observe product characteristics (Long et al., 1993). Financial theories (Biais and Gollier, 1997; Burkart and Ellingsen, 2004, among others) claim that suppliers are as good as or better financial intermediaries than banks. In Biais and Gollier (1997) and Burkart and Ellingsen (2004) this is due to an information advantage of suppliers over banks. Within a context of limited enforceability, Cuñat (2007) shows that suppliers can enforce debt repayment better than banks by threatening to stop the supply of intermediate goods to their customers. Fabbri and Menichini (2010) show that trade credit can be cheaper than bank credit because of the liquidation advantage of the supplier.

Our paper is mostly related to the financial theories and in particular to Biais and Gollier (1997). Like them, we assume a supplier's information advantage. However, while in Biais and Gollier (1997), such advantage concerns the borrowers' creditworthiness, in our paper it concerns the investment in the collateralized input. The implications of the supplier information advantage are very different between the two papers. In Biais and Gollier (1997), extending trade credit signals to the bank the borrower's quality and induces banks to extend credit to entrepreneurs with profitable projects that would have been rejected otherwise. In our model, by signaling that the investment in the collateralized asset has taken place as expected, trade credit makes the secured bank loan available. Thus, while collateral is crucial in our story, it plays no role in Biais and Gollier (1997).

One prediction of our model is that trade credit facilitates the access to collateralized bank

[2] In the last two decades in the U.S. there has been a steady increases of ABL: In 1992, there were \$90 billion of ABL in the U.S. as opposed to \$326 billion (which corresponds to the 22% of the total short term credit) in 2002 and and \$590 billions in 2008. See the book by Greg Udell for more information about the characteristics of ABL.

financing, suggesting a complementarity between bank and trade credit, which is in the spirit of some recent empirical evidence.[3] Cook (1999) documents that trade finance raises the likelihood that a Russian firm obtains a bank loan. Giannetti et al. (2008) show that U.S. firms using trade credit can secure financing from relatively uninformed banks. Alphonse et al. (2006) document that the more trade credit U.S. firms use, the more indebted towards banks they are, in particular firms with a short banking relationship. Along the same lines, Gama et al. (2008) find that trade credit allows younger and smaller firms in Spain and Portugal to increase the availability of bank financing. Finally, Garcia-Appendini (2010) documents that small, non financial U.S. firms are more likely to get bank credit if they have been granted trade credit from their suppliers. The evidence provided by the last papers seems to suggest that the complementarity hypothesis is more relevant for young and small firms with a short banking relationship. This is an interesting finding that could be explained within our theoretical framework. Young, small firms with a short banking relationship are more opaque and also might lack incentives to commit to the contract terms in lending relations (or simply they are perceived by banks to lack incentives) since the cost of deviating from the contracts (i.e., loosing reputation) is still relatively small. So, these firms are the ones that benefit most from the use of trade credit. In contrast, larger and older firms, which are more likely to be public and have stronger relationships with banks, care more about their reputation and therefore have less incentive to misbehave.

The paper is organized as follows. Section 1 presents the model. Section 2 describes the commitment problem that plagues an exclusive entrepreneur-bank lending relationship when the project to be financed uses two inputs. In Section 3, we show that trade credit can solve the commitment problem in a setting where collusion is never profitable because too costly. In Section 4, we extend the model to the case of profitable collusion and we identifies the conditions that make trade credit beneficial to the lending relationship. Section 5 discusses the robustness of our theoretical setting. Specifically, Subsection 5.1 questions the role of the supplier as an informed lender and discusses alternative interpretations. Subsection 5.2 discuss the degree of information sharing between supplier and bank which is needed in our model. Subsection 5.3 links the cost of reaching a collusive agreement to the number of suppliers and delivers new testable predictions on the relation between firm financing decisions and the structure of the up-stream market. Section 6 concludes.

[3] In Biais and Gollier (1997), trade credit allows credit-constrained firms to get (un-collateralized) bank loan. In Burkart and Ellingsen (2004), trade credit also increases the amount of bank credit limit, but this is a second order effect holding only for a selected group of firms.

1 Setup and model assumptions

A risk-neutral entrepreneur has an investment project that uses two inputs, called capital (K) and labor (N). Let I_K, I_N denote the amount of investment in capital and labor inputs. The amount of the input invested is converted into a verifiable state-contingent output y^σ, with $\sigma \in \{H, L\}$ and $y^H > y^L$. The good state ($\sigma = H$) occurs with probability p. Uncertainty affects production through demand (i.e., production is demand-driven). At times of high demand, invested inputs produce output according to an increasing and strictly concave production function $f^H(I_K, I_N)$. At times of low demand, there is no output ($y^L = 0$), but unused inputs have a scrap value and can be pledged as collateral to creditors. Inputs are substitutes, but a positive amount of each is essential for production.

The entrepreneur is a price-taker both in the input and in the output market. The output price is normalized to 1, and so is the price of the two inputs.[4]

The entrepreneur has no internal wealth, so he needs external funding from competitive banks ($L_B \geq 0$) and/or suppliers ($L_S \geq 0$).

Banks and suppliers play different roles. Banks lend cash. The supplier of labor provides the input, which is fully paid for in cash. The supplier of capital, however, not only sells the input, but can also act as a financier, lending inputs.

Cost of funds. Banks have an intermediation advantage relative to suppliers as they face a lower cost of raising funds on the market ($r_B < r_S$). This assumption is consistent with the role of banks as specialized financial intermediaries. Moreover, suppliers are likely to be themselves credit constrained.

Collateral value. Inputs have value when repossessed in default. We assume that only capital inputs can be pledged while labor has zero collateral value. We assume that the two financiers are equally good in liquidating the unused capital inputs and their liquidation value in case of default is given by $C = \beta I_k$, with $0 < \beta < 1$.[5]

Information. Banks and suppliers differ in the type of information they possess. Providing the input, suppliers of capital and labor can costlessly observe that an input transaction has taken place. Banks cannot observe any input transaction and the cost of acquiring this information is too high to make observation worthwhile.[6] The information advantage assumption is commonly accepted in

[4] This normalization is without loss of generality since we use a partial equilibrium setting.

[5] This assumption allows us to highlight the commitment role of trade credit. Giving the supplier a comparative advantage in liquidating the capital input would not alter our qualitative results, as long as this advantage is not too high, i.e., $\beta_S \leq \frac{(1-p)\beta_B r_S}{(r_B - p r_S)}$. In this latter case, the liquidation advantage would make trade credit cheaper than bank credit and therefore strictly preferred. This case has been analyzed in Fabbri and Menichini (2010).

[6] Full unobservability from the bank and full observability from the suppliers are not crucial in our analysis. We could

the theoretical literature and frequently interpreted as a natural by-product of the selling activity of the supplier. Suppliers are often in the same industries as their clients, and they often visit their customers' premises. In our setting, this assumption is even more reasonable, given that the information asymmetry refers to the input purchases. Extensive anecdotal evidence supports this assumption. The most recent example is the case of Siemens. In 2010, Siemens has created its own bank, Siemens Bank Gm-bH, mainly to provide lines of credit to its more important clients.

Contracts. The entrepreneur-bank contract specifies the loan, L_B, the state-contingent repayment obligation, R_B^σ - which depends on the output realized and on the size of the loan - and the share of the collateral obtained in case of default, γ. That with the supplier of the tangible input specifies the amount of credit L_S, the input purchase I_K, the state contingent repayment obligation, R_S^σ, which depends on the size of the loan and on the output realized, and the share of the collateral obtained in case of default, $(1-\gamma)$. Since output is zero in the low state ($y^L = 0$), limited liability implies that repayments to bank and supplier are also zero ($R_B^L = R_S^L = 0$).[7] To save notation, we thus remove the state superscript index from our variables.

Last, given that the labor is fully paid for when purchased, the contract between entrepreneur and worker specifies the amount of labor, I_N.

Each party is protected by limited liability.

Fig. 1 summarizes the sequence of events: In $t = 1$, banks and suppliers make contract offers specifying the size of the loan L_B, L_S, the repayment obligations, $R_B(\cdot)$, $R_S(\cdot)$, the share of the collateral that goes to the bank and the supplier in case of default $\gamma, (1-\gamma)$, the amount of tangible input to be purchased, I_K. More specifically, banks (and suppliers) propose a set of contracts which may range from the fully secured contract, with $\gamma = 1$, to the unsecured one, with $\gamma = 0$, passing through the partially secured one with $0 < \gamma < 1$. In $t = 2$, the entrepreneur chooses among contract offers and receives credit from financiers; in $t = 3$ the investment decisions are taken, I_K, I_N; in $t = 4$, uncertainty resolves; and in $t = 5$, repayments are made.

still get our results by assuming that both banks and suppliers can partially observe the inputs, as long as suppliers have an information advantage over banks.

[7] Banks and suppliers can still get a repayment in the low state by having the right to a share of the scrap value of unused inputs.

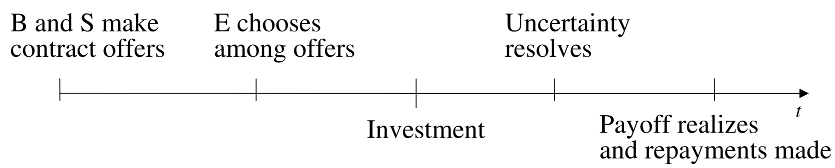

Figure 1: Time-line

2 The firm-bank contract without commitment

In this section, we show that the non-contractibility of the investment to the bank makes any entrepreneur-bank secured contract time-inconsistent and therefore not available to contracting parties. To make this point clear, we first analyze the benchmark case, where investment is observable to the bank and therefore contractible. We derive the well-known result that secured lending is the optimal contract since it increases the surplus of the lending relationship through a risk reduction for the lender. Then we consider the case of non-contractible investment.

Benchmark Case: Contractible Investment. In period $t = 1$, all financiers make contract offers. Since bank credit is cheaper, in period $t = 2$ firms only sign bank contracts and get financing. In period $t = 3$, firms buy and invest the inputs. The amount of inputs and financing solve the following optimization problem ($\mathcal{P}^{\mathcal{C}}$):

$$\max_{I_K, I_N, L_B, R_B} EP = p\left[f\left(I_K, I_N\right) - R_B\right] \tag{1}$$

$$\text{s.t. } pR_B + (1-p)\, C \geq L_B r_B, \tag{2}$$

$$L_B \geq I_N + I_K. \tag{3}$$

Condition (2) is the bank's participation constraint and states that banks participate to the venture if their expected returns cover at least their opportunity cost of funds. Competition among banks implies that (2) is binding. The resource constraint (3) requires that input purchase cannot exceed available funds. Solving (2) for R_B and using the resource constraint (3), the objective function (1) becomes:

$$\max EP = pf(I_K, I_N) - r_B(I_K + I_N) + (1-p)\beta I_K. \tag{4}$$

The solution to this problem leads to the following proposition:

Proposition 1 *When investment is contractible, the bank offers a collateralized credit contract with loan $L_B^*(I_K^*, I_N^*) = I_K^* + I_N^*$, repayments $R_B^{H*}(I_N^*, I_K^*) = \frac{1}{p}\{(I_N^* + I_K^*) r_B - (1-p)\beta I_K^*\}$ in the high state, and βI_K^* in the low state, with I_K^*, I_N^* solving the first order conditions (20) and (21).*

Proof. In the Appendix. ■

Figure 2 displays the optimal input combination when the entrepreneur can commit to the investment level implied by the collateralized credit contract (point A). The input mix is stretched toward capital since its positive collateral value makes the actual tangible input price, equal to $r_B - (1-p)\beta$, lower than the price of the intangible one, r_B. Notice that in our model, the selling input price, which by assumption is set equal to one for both inputs for simplicity, differs from the actual input price. The actual price also includes the cost of credit used to finance input purchases. This cost might differ between financiers (bank versus supplier) but also within the same financier among inputs. For example, when the contract used is a collateralized bank debt, the cost of credit of the collateralized input will be lower than the cost of credit of the un-collateralized one, the difference being the pledgable income of the collateral. It follows that the two inputs will have a different actual price although both the initial selling price and the financier are the same. In contrast, when the contract used is a pure debt contract, inputs have the same cost of credit, namely r_B, and thus also the same actual price.

Non-contractible investment. The result in Proposition 1 is obtained under the assumption that the entrepreneur can commit to the investment level specified in the bank contract at $t = 1$. However, if investment is unobservable, at $t = 3$, once the loan L_B^* has been granted, the entrepreneur can increase his profits by altering the input combination and worrying only about honoring his repayment obligations in non-defaulting states.[8] Thus, the entrepreneur re-optimizes by solving

[8] Because output is verifiable, any return from production will be claimed by creditors and the entrepreneur will get zero return if he does not repay the loan in full.

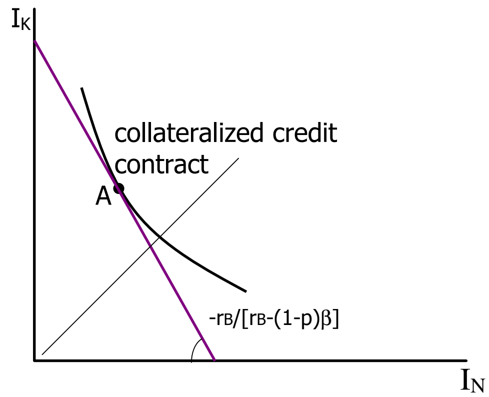

Figure 2: Input combination when investment is contractible. Point A represents the optimal input combination when the entrepreneur can commit to the investment level implied by the collateralized credit contract signed with the bank.

programme $\mathcal{P}^{\mathcal{D}}$:

$$\max_{I_K, I_N, R_B} \; pf\left(I_K, I_N\right) - pR_B \tag{5}$$

$$\text{s.t. } R_B \geq R_B^*, \tag{6}$$

$$L_B^* \geq I_N + I_K, \tag{7}$$

where constraint (6) requires the repayment to the bank in the high state be no less than the one promised in the secured commitment contract (i.e. R_B^* in Prop. 1), while the resource constraint (7) requires that the total input expenditure is no higher than the loan obtained in the secured commitment contract (i.e. L_B^* in Prop. 1).

The solution of the previous problem implies that the entrepreneur buys the same amount of tangible and intangible inputs, namely $\hat{I}_K\left(L_B^*, R_B^*\right) = \hat{I}_N\left(L_B^*, R_B^*\right)$. This input combination is represented by point B in Figure 3. Point B lies to the right of point A on a higher isoquant. Indeed, the new isocost line is flatter than the one going through point A. Since the debt contract used to finance the input purchases of point B is a pure debt bank contract, the cost of credit of the two input is the same and equal to r_B. Therefore the relative input price is 1, which is lower than the relative input price implied by the collateralized credit contract, namely $\left(r_B / \left[r_B - (1-p)\,\beta\right]\right)$ used to finance the input purchases of point B. The new isocost line passes through point A, being still possible to afford the original contract even at the new input prices. By the concavity (and smoothness) of the production function, the new input combination lies on a higher isoquant, with larger production and higher expected profits, and involves a decrease in I_K an increase in I_N.

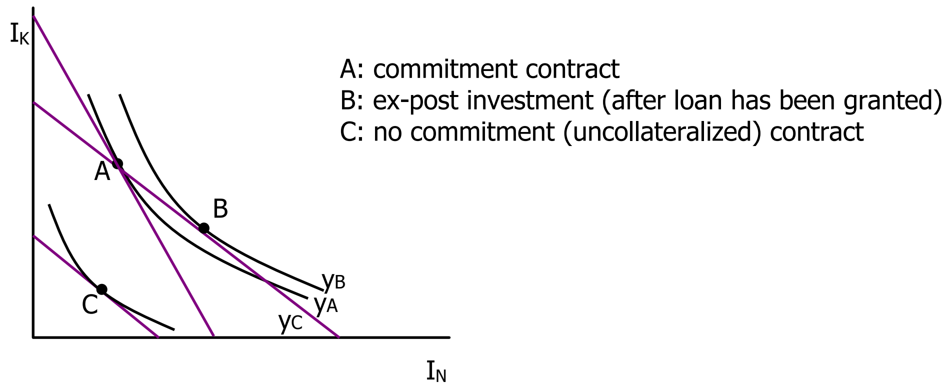

Figure 3: Input combination with and without contractible investment. Point A represents the optimal input combination when the entrepreneur can commit to the investment level implied by the secured credit contract signed with the bank (commitment contract). Point C shows the optimal input combination when the entrepreneur cannot commit to the input combination specified in the bank contract (no commitment contract). Point B is the input combination that the entrepreneur would ex-post choose upon receiving the bank loan. This is not an equilibrium contract since the bank does not break-even.

However, the lower investment in the capital input implies that the firm cannot meet its repayment obligations in case of default. Thus, in point B the bank makes negative expected profits. Anticipating that it will not break even, the bank will only be willing to sign an unsecured credit contract with all the repayment obligations paid for in the good state: $R_B = \frac{1}{p} L_B r_B$. Using L_B from the resource constraint (3), the objective function (1) becomes:

$$\max_{I_K, I_N} pf\left(I_K, I_N\right) - \left(I_N + I_K\right) r_B.$$

The solution to this programme is described in the following proposition:

Proposition 2 *When investment is non-contractible, the bank offers an unsecured credit contract lending* $\bar{L}_B = \bar{I}_K\left(p, r_B\right) + \bar{I}_N\left(p, r_B\right)$, *and getting a repayment only in non-defaulting states* $\bar{R}_B = \frac{1}{p}\bar{L}_B r_B$. *The level of investment in the collateralizable input is* $\bar{I}_K\left(p, r_B\right) = \bar{I}_N\left(p, r_B\right)$, *strictly lower than the one obtainable under commitment. There is an efficiency loss due to the inability to pledge inputs as collateral.*

Proof. In the Appendix. ■

Point C in Figure 3 shows the optimal input combination when the investment is not observable to the bank and the entrepreneur cannot commit to the input combination specified in the contract. Unlike point A, the bank loan and thus the investment in capital and labor are lower. The new isoquant y_C is below y_A and in point C it has the same slope as in point B. While the bank is indifferent between points A and C - it gets zero profit in either case - the entrepreneur's profits are lower in point C. This is because the lower debt capacity, implied by the inability to pledge inputs as collateral reduces the overall investment size.[9]Thus, if he could, the entrepreneur would rather commit to the investment level of the collateralized credit contract (point A). Figure 3 gives a visual representation of the benefit of collateral. Pledging the collateral implies a move from point C to point A and therefore an increase in total production. $Y_A - Y_C$ thus represents the loss of surplus due to the lack of commitment of the entrepreneur as a consequence of the investment non-contractibility of the tangible input. Notice that in point C (as well as in point B), the two actual input prices are the same, since inputs are financed though a pure debt contract, where the cost of credit of each input is equal to r_B. This explains why the input combination of point C implies an equal amount of tangible and intangible (as in point B).

3 The commitment role of trade credit

So far we have shown that when investment is non-contractible and the project to be financed needs two inputs with different collateral values, the bank will offer only an unsecured contract. In this section, we introduce the supplier of the tangible as a second financier. We show that, by observing the input transactions, the supplier has a natural information advantage which can be used to overcome contract incompleteness.[10] We proceed in two steps. First, we derive the optimal firm-bank-supplier contract and the input combination as as a function of the share of the collateral accruing to the bank, γ. Then, we find the optimal γ, which allows us to fully characterizes the optimal contracts. The parameter γ represents the involvement of the bank in financing the venture. The higher γ, the better for the firm, given that bank financing is the cheapest source of credit. However, the entrepreneur needs to signal its commitment to the bank. Otherwise, he will not be able to pledge the tangible assets as collateral to the bank. He can credibly signal his commitment by giving up some bank credit in exchange of supplier credit. $1 - \gamma$ represents therefore how costly is for the entrepreneur to buy commitment from

[9]We are assuming here that inputs not pledged to any creditor are valueless to the entrepreneur in case of default.

[10]In our model, the supplier acts as the informed lender. In Section 6, we discuss an alternative interpretation of the informed lender.

the supplier. The optimal γ is the one that allows the entrepreneur to buy a credible commitment at the lowest cost. When bank and supplier can both provide external finance, the optimization problem is the following:[11]

$$\max_{L_B,L_S,R_B,R_S I_K,I_N,\gamma} EP = p\left[f\left(I_K,I_N\right)-R_B-R_S\right], \quad (8)$$

$$\text{s.t. } pR_B+(1-p)\gamma C = L_B r_B, \quad (9)$$

$$pR_S+(1-p)(1-\gamma)C = L_S r_S, \quad (10)$$

$$L_B+L_S \geq I_N+I_K, \quad (11)$$

$$R_S \geq \beta I_K \quad (12)$$

where (8) denotes the entrepreneur's expected profits. Conditions (9) and (10) represent the participation constraints of competitive banks and suppliers, respectively. The parameter γ represents the share of the collateral accruing to the bank (and $1-\gamma$ the one accruing to the supplier). Condition (11) is the resource constraint when trade credit is also available. Last, constraint (12) requires the repayments to the supplier be non-decreasing in revenues. In practice, this condition prevents the supplier to be used exclusively as a liquidator. In our model, the entrepreneur prefers bank credit to trade credit since the first is cheaper. However, pledging the tangible inputs to the suppliers increases the loan size. Thus, the entrepreneur would like to use the supplier only as a liquidator. In this case, the supplier would get the collateralized value of the inputs in the bad state, in exchange of a payment to the entrepreneur in the good state. This would imply a contract where the repayments to the supplier are positive in the bad state and negative in the good one. Being interested in the supplier's role as financier, we do not allow for such contract and require monotonicity of repayments. The solution to the above maximization problem is described in Proposition 3:

Proposition 3 *The firm-bank-supplier contract has investment $I_K^*(\gamma), I_L^*(\gamma)$, and displays the following properties:*

- *the supplier gets a secured contract with flat repayments across states: an amount $L_S^*(\gamma) = \frac{1}{r_S}(1-\gamma)\beta I_K^*(\gamma)$ is lent in exchange for the right to a share $1-\gamma$ of the collateral value of the unused inputs ($\beta I_K^*(\gamma)$) in the default state and to a repayment $R_S^*(\gamma)=(1-\gamma)\beta I_K^*(\gamma)$ in the high state.*

[11] In the presence of a commitment problem, the set of bank contract offers made at $t=1$ does not include the fully secured contract, but ranges from a partially secured one with $\gamma<1$, to a fully unsecured one, with $\gamma=0$.

- *the bank gets a secured contract with increasing repayments: an amount* $L_B^*(\gamma) = I_K^*(\gamma) + I_N^*(\gamma) - \frac{1}{r_S}(1-\gamma)\beta I_K^*(\gamma)$ *is lent in exchange for the right to a share* γ *of the collateral value of the unused inputs* $(\beta I_K^*(\gamma))$ *in the default state and to a repayment* $R_B^*(\gamma) = \frac{1}{p}\left[\left(\frac{r_B}{\beta} - \frac{r_B}{r_S}(1-\gamma) - (1-p)\gamma\right)\beta I_K^*(\gamma) + I_N^*(\gamma) r_B\right] > \gamma\beta I_K^*(\gamma)$ *in the high state.*

- *expected profits are increasing in* γ *:*

$$\left(1 - \frac{r_B}{r_S}\right)\beta I_K^*(\gamma) > 0$$

Proof. In the Appendix. ■

Proposition 3 derives the optimal contract as a function of γ. An interior γ would imply that the entrepreneur is taking trade credit in exchange of a share of the collateralized inputs. This would signal to the bank the entrepreneur's willingness to respect the terms of the bank contract and would boost secured bank credit. However, borrowing from the supplier is expensive. The entrepreneur wants to minimize trade credit reliance. To overcome the trade-off between the need to signal commitment and the incentives to input cost reduction, we assume that trade credit cannot fall short of some minimum level, due for example to some input indivisibility:[12]

$$L_S \geq L_{S\,\min}. \tag{13}$$

Under condition (13), the optimal value of γ and all the other contract terms are derived as a function of $L_{S\,\min}$.[13] Solving the participation constraints (9) and (10) for R_B and R_S, the resource constraint (11) for L_B and using the binding constraint (13), problem $\mathcal{P}_{\mathcal{S}}$ reduces to:

$$\max_{L_B, I_K, I_N} \; pf(I_K, I_N) - r_B(I_N + I_K) + (1-p)\beta I_K - (r_S - r_B) L_{S\,\min}. \tag{14}$$

Except for the last term in $L_{S\,\min}$, that represents the extra-cost the firm has to incur to credibly commit, the objective function is equivalent to the general one with contractible investment (see expression 4). Thus, the optimal levels of I_K and I_N coincide with those obtained at point A of Figure 1. However, the properties of the financial contracts differ and are described in the following proposition:

Proposition 4 *The firm-bank-supplier contract in which the firm takes a minimum amount of trade credit* $L_{S\,\min}$ *has first-best investment,* I_K^*, I_N^**, and displays the following properties:*

[12] Only entire inputs can be liquidated and not portions of them.

[13] Although seemingly special, this assumption allows us to highlight the commitment role of trade credit. In Section 4, we endogenize γ by extending the model to the case of collusion between entrepreneur and supplier.

- *the supplier gets a secured contract with flat repayments across states:* $\bar{\gamma}\beta I_K^*$ *in the default state and* $R_S^H(L_{S\min}) = (1-\bar{\gamma})\beta I_K^* = r_S L_{S\min}$ *in the high state.*

- *the bank gets a secured contract with increasing repayments: an amount* $L_B^*(L_{S\min}) = I_K^* + I_N^* - L_{S\min}$ *is lent in exchange for the right to a share* $\bar{\gamma} = 1 - \frac{r_S L_{S\min}}{\beta I_K^*}$ *of the collateral value of the unused inputs* (βI_K^*) *in the default state and to a repayment* $R_B^H(L_{S\min}) = \frac{1}{p}\left[r_B L_B^*(L_{S\min}) + r_S L_{S\min} - (1-p)\beta I_K^*\right] > \bar{\gamma}\beta I_K^*$ *in the high state.*

Proof. Since the level of investment is the same as in the commitment contract, the only novel result concerns the properties of the financial contract, which have been derived using the reduced form objective function (14). ■

The commitment role of trade credit arises from the supplier providing a share of the capital inputs on credit and having the right to a share $1-\bar{\gamma}$ of the collateral value of the same input in case of default. When both conditions are satisfied, the entrepreneur does not have any incentive to ex-post alter the input mix. The intuition is the following. Suppose he does it. The seller would observe the entrepreneur's misbehavior and he would anticipate a lower repayment in the bad state and no break-even. As a consequence, the seller would refuse to finance the input purchase. The only way to get credit from the supplier is thus honouring the contract terms. Although the bank does not observe the firm-supplier contract, it can foresee the participation of the supplier to the venture and anticipate the commitment effect of trade credit. Trade credit implicitly signals that the bank loan will be used to purchase the inputs as specified in the bank contract.

Using trade credit to induce commitment however is costly, since bank credit is the cheapest source of external finance. The cost of commitment is $(r_S - r_B) L_{S\min}$, i.e., the extra per-unit cost $(r_S - r_B)$ the firm has to incur to use trade credit rather than bank credit. Being fixed, it has no effect at the margin on the choice of I_K and I_N. Thus, the firm sets I_K and I_N at their first-best levels. However, this cost reduces the firms' profits and, if too high, can cause losses that make it profitable for the firm to shut down. Graphically, the equilibrium, if it exists, lies on point A of Figure 2. The benefit of trade credit is that the firm gets a larger loan. Most of the injection of new liquidity comes from the bank itself through the secured credit contract. Thus, we get the following prediction:

Prediction 1. *When investment is non-contractible, trade credit facilitates the access to bank financing by making the secured contract available to bank and entrepreneur.*

4 Firm-supplier collusion

So far, we have introduced a supplier in the lending relationship with the task of creating commitment. But, actually, we have only shifted the commitment problem. Suppose that entrepreneur, bank and supplier have originally agreed on the contract terms described in Prop. 3. Once obtained the loan from both financiers, $L_B^*(\gamma)+L_S^*(\gamma)$, the entrepreneur may then propose the supplier an agreement to alter the input mix at the bank's expense. More specifically, entrepreneur and supplier might decide to honour the contracted repayment with the bank only in the high state and keeping unchanged the total credit received from financiers. This collusion agreement is profitable for the supplier as long as he breaks even under the new contract terms, i.e.:

$$pR_S + (1-p)(1-\gamma)\beta I_K \geq L_S^*(\gamma) r_S. \tag{15}$$

where $L_S^*(\gamma)$ is the loan provided by the supplier under the original agreement (see Proposition 3). If agreed, the new arrangement allows to increase overall profits at the expense of the bank. Any collusive rent - the difference between the return under deviation and the return under commitment - is then shared between entrepreneur and supplier. However, several factors can make it difficult to reach such an agreement.[14]In this case, let's define $\alpha \in [0,1]$ as the fraction of the return from deviation which is lost in reaching an agreement. Then next proposition defines the collusion rent and describes some of its properties.

Proposition 5 *The collusion rent is* $(1-\alpha)Y^{\mathcal{D}}(\gamma) - Y^*(\gamma)$, *where* $Y^{\mathcal{D}} \equiv pf_H\left(I_K^D, I_N^D\right) + (1-p)(1-\gamma)\beta I_K^D$, *is the total surplus from collusion and* $Y^* \equiv pf_H(I_K^*, I_N^*) + (1-p)(1-\gamma)\beta I_K^*$, *is the surplus from sticking to the original contract defined in Prop. 3. The collusion rent is increasing in* γ *and decreasing in* α.

Proof.

$$\frac{\partial\left[(1-\alpha)Y^{\mathcal{D}} - Y^*\right]}{\partial\gamma} = -(1-p)\beta\underbrace{\left(I_K^{dev}(\gamma) - I_K^*(\gamma)\right)}_{<0} > 0$$

where $I_K^{dev}(\gamma)$, $I_N^{dev}(\gamma)$ is the investment in tangible and intangible input respectively under collusion.

■

[14] For example, when the firm uses several suppliers, finding an agreement among many people can be time consuming. Section 5.1 links the cost of collusion to the structure of the up-stream market.

Thus the set of contract offers made by the bank is restricted to those that guarantee a non positive collusion rent, i.e. that satisfies the following condition:

$$(1-\alpha) Y^{\mathcal{D}}(\gamma) - p\left[f^{H}(I_K, I_N) - R_B^H - R_S^H\right] \quad \leq \quad 0. \tag{16}$$

It follows that the optimal γ, and therefore the contract terms and the input combination depends on the the cost of collusion. To investigate how firm's financing and investment decisions depends on the cost of collusion, we divide the analysis in three cases. First, we assume that collusion is so costly that it is never profitable ($\alpha = 1$). This case has been already analyzed in Section 3: The entrepreneur sticks to the commitment contract, where the bank offers a collateralized loan and the supplier provides the lowest possible amount of trade credit. Second, we consider the case where collusion is still costly but profitable ($0 < \alpha < 1$). Lastly, we assume that collusion is costless, so that entrepreneur and supplier can grab the entire surplus from their agreement ($\alpha = 0$). The next two sections deal with the last two cases.

4.1 Costly collusion

In this section, we study the impact of costly collusion ($0 < \alpha < 1$) on the optimal contract. The bank can prevent collusion by restricting the set of contract offers so as to reduce the maximum rent obtainable from deviating. In particular, since the collusion rent is decreasing in γ, the bank can offer contracts with a lower γ, thus implying a larger use of trade credit and lower profits for the entrepreneur. Thus, for any given cost of collusion, the set of contract offers made by the bank is restricted to those with $\gamma \leq \hat{\gamma}(\alpha)$ where $\hat{\gamma}(\alpha)$ is the one making the entrepreneur indifferent between sticking to the contract and deviating (i.e., condition 16 is binding).[15] Since trade credit is more costly than bank credit, the firm will minimise trade credit reliance and will accept the bank contract offer with the highest possible γ, i.e., $\hat{\gamma}$. For any given cost of collusion, the next proposition defines the optimal contract:

Proposition 6 *When colluding is mildly costly, the collusion-proof contract has investment* $I_K^*(\hat{\gamma}(\alpha)), I_L^*(\hat{\gamma}(\alpha))$, *with* $\hat{\gamma}(\alpha)$ *solving (38), and displays the following properties:*

[15] As standard in contract-theoretic framework, in this case we assume that he chooses the option preferred by the investor.

- *the supplier gets a secured contract with flat repayments across states: an amount* $L_S^*(\hat{\gamma}(\alpha)) = \frac{1}{r_S}(1-\hat{\gamma}(\alpha))\beta I_K^*(\hat{\gamma}(\alpha))$ *is lent in exchange for the right to a share* $1-\hat{\gamma}(\alpha)$ *of the collateral value of the unused inputs* $(\beta I_K^*(\gamma))$ *in the default state, and to a repayment* $R_S^{H*}(\hat{\gamma}(\alpha)) = (1-\hat{\gamma}(\alpha))\beta I_K^*(\hat{\gamma}(\alpha))$ *in the high state;*

- *the bank gets a secured contract with increasing repayments: an amount* $L_B^*(\hat{\gamma}(\alpha)) = I_K^*(\hat{\gamma}(\alpha)) + I_N^*(\hat{\gamma}(\alpha)) - \frac{1}{r_S}(1-\hat{\gamma}(\alpha))\beta I_K^*(\hat{\gamma}(\alpha))$ *is lent in exchange for the right to a share* γ *of the collateral value of the unused inputs* $(\beta I_K^*(\hat{\gamma}(\alpha)))$ *in the default state and to a repayment* $R_B^{H*}(\hat{\gamma}(\alpha)) = \frac{1}{p}\left[\left(\frac{r_B}{\beta} - \frac{r_B}{r_S}(1-\hat{\gamma}(\alpha)) - (1-p)\hat{\gamma}(\alpha)\right)\beta I_K^*(\hat{\gamma}(\alpha)) + I_N^*(\hat{\gamma}(\alpha)) r_B\right] > \hat{\gamma}(\alpha)\beta I_K^*(\hat{\gamma}(\alpha))$ *in the high state;*

- *expected profits are increasing in* $\hat{\gamma}(\alpha)$.

Prop. 6 shows that when collusion is mildly costly, the bank can reduce the scope for a collusive agreement by reducing its stake in the bad state - the maximum share of the collateral to be liquidated -, which also implies a lower bank participation to the venture. Increasing fractions of the input must be financed by the supplier with a fall in profits (because of a higher input cost and lower external financing) and consequently a fall in the collusion rent. We can therefore interpret the degree of supplier participation to the financing of the venture as the cost to buy the commitment role of trade credit. The cost of commitment depends negatively on the cost of collusion. When the cost of colluding is high, buying commitment from the supplier is cheap since a small amount of trade credit is enough to eliminate the incentive to collude. Conversely, when the cost of colluding is small, buying commitment is very costly since a large share of inputs need to be financed with trade credit to remove the entrepreneur incentive to collude with the supplier.

4.2 Costless collusion

When colluding is costless ($\alpha = 0$), the collusion rent is positive for any $\gamma > 0$ (see Prop.). The bank can remove the incentive to collude only by offering an uncollateralized credit contract ($\gamma = 0$). In that case, there is nothing to be gained from colluding with the supplier, since no assets are pledged as a collateral to the bank and therefore no extra profits can be obtained by altering the input combination. . Using $\gamma = 0$, the participation constraints (9) and (10) become:

$$pR_B = L_B r_B, \tag{17}$$

$$pR_S + (1-p)C = L_S r_S. \tag{18}$$

Thus, the firm maximizes (8), subject to the participation constraints (17), (18), the non-decreasing repayment condition (12) and the resource constraint (11).

Proposition 7 *The collusion-proof firm-bank-supplier contract has the following properties:*

- *the firm invests* $\tilde{I}_K(r_S) < I_K^*, \tilde{I}_N(r_S) < I_N^*$;
- *the supplier gets a collateralized credit contract with flat repayments across states: an amount* $\tilde{L}_S = \frac{\beta \tilde{I}_K}{r_S}$ *is lent in exchange for the right to the entire collateral value of the unused inputs* $(\beta \tilde{I}_K)$ *in bad states and to a repayment* $\tilde{R}_S = \beta \tilde{I}_K$ *in good states;*
- *the bank gets a non-collateralized credit contract with increasing repayments: an amount* $\tilde{L}_B = \tilde{I}_N + \tilde{I}_K - \frac{\beta \tilde{I}_K}{r_S}$ *is lent in exchange for a repayment* $\tilde{R}_B = \frac{1}{p}\left(\tilde{I}_N + \rho \tilde{I}_K - \frac{\beta \tilde{I}_K}{r_S}\right) r_B$ *only in good states and no repayment in bad states.*

Proof. In the Appendix. ■

Proposition 7 states that the supplier finances and liquidates the full collateral value of the tangible input (not the full input purchases). The bank no longer offers a set of contracts, but a unique unsecured contract. Having no longer a stake in the firm's low state return, the bank is paid only in the high state. This arrangement removes completely the firm-supplier incentives to deviate and therefore then need of any commitment. The investment in capital and labor corresponding to this case is represented by point E in Figure 4. Point E lies on a lower isoquant than point A, but on a higher one than point C. Thus, although this contract cannot replicate the first-best (point A), the entrepreneur is better-off using both trade and bank credit (point E) than signing only an unsecured contract with the bank (point C).

4.3 When take trade credit?

Trade credit has costs and benefits. The benefit is the commitment effect which brings larger external financing. However, since trade credit is more expensive than bank loans, that benefit comes at a cost. The cost can be relatively low when a small amount of trade credit is enough to create commitment and thus the funding mainly comes from the bank. This case is discussed in Section 3 and represented by point A in Fig. 2. However, when the supplier faces herself a commitment problem, a small amount of trade credit is not enough. In particular, when collusion is costless or when its cost is low enough, the only way for the entrepreneur to pledge assets is to let the supplier to liquidate their full collateral

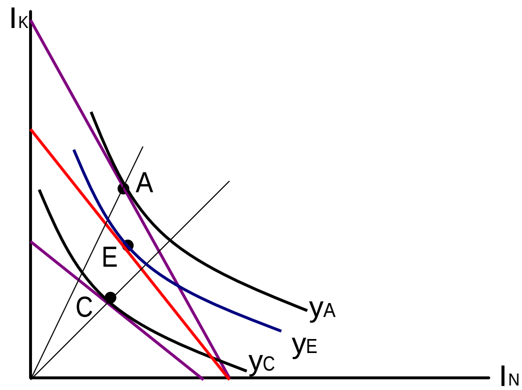

Figure 4: Trade credit and the input combination. Point A represents the optimal input combination when the entrepreneur can commit to the investment level implied by the collateralized credit contract signed with the bank (collteralized bank credit contract). Point C shows the optimal input combination when the entrepreneur cannot commit to the input combination specified in the bank contract and trade credit is not available (uncollateralized bank credit contract). Point E is the optimal input combination when trade credit acts as a commitment devise (collateralized trade credit plus unsecured bank credit).

value.The equilibrium corresponding to this case is represented by point E in Fig. 4. Capital inputs are then mainly bought on credit at a higher price. In this case, buying the commitment from the supplier can be so costly to overcome the benefits. This section discusses the conditions under which the costs exceed the benefits.

Proposition 8 *When supplier and entrepreneur can costlessly collude at the expense of the bank, the entrepreneur will choose between the unsecured bank credit contract described in Prop. 2 and the firm-bank-supplier contract described in Prop. 7, where the collateral is fully pledged to the supplier. The entrepreneur is better off using the first contract if and only if:*

$$\frac{r_B}{p} < r_S \tag{19}$$

Economic interpretation of condition (19). One difference between the two above contracts is that under the first contract (Prop.2) the bank finances the full amount of the tangible input purchases, while under the second contract (Prop. 7) bank and supplier together finance the purchase of the tangible input, although by different shares and at different prices. r_B/p is the cost for the entrepreneur of using the unsecured bank contract (Prop. 2). Since under this contract, the bank only gets paid in the high state, the repayment due by the entrepreneur to the bank must be high enough to compensate for the probability of default, i.e., r_B/p. The higher the probability of default *(1-p)*, the higher the (average) repayment and the higher the cost of using the unsecured bank credit. r_S is the cost of using the firm-bank-supplier secured contract (Prop. 7). Given that the supplier contract is a flat contract, r_S is also the average repayment due by the entrepreneur to the supplier for one unit of credit.

When $r_B/p > r_S$ having the supplier acting as a financier implies a welfare improvement. This case is represented by point E in the first diagram (1st scenario) of Figure 5. Point E lies on a higher isoquant than point C, suggesting that involving the supplier as a financier generates higher surplus than using only bank credit through an unsecured credit contract. In the opposite case, relying on trade credit to access a secured credit contract is so costly to make it worthwhile for the firm to give up trade credit and sign only a non-collateralized credit contract with the bank. This case is represented by point E in the second diagram (2nd scenario) of Figure 5. Point E lies on a lower isoquant than point C.

5 Discussion and Robustness Analysis

5.1 Firm financing decisions and the up-stream market structure

The cost of reaching a collusive agreement, denoted by the parameter α, can be related to the structure of the up-stream market. For example, if the firm is using several suppliers because the up-stream market is very competitive, it is difficult to find a collusive agreement given that many people have to agree. This situation would correspond to the case of high α. Conversely, when the up-stream market is concentrated, it is relatively easier to find an agreement between entrepreneur and supplier. In this case, α would be low or even zero. Under this interpretation, our model delivers new relations not only between the number of suppliers and the use of trade credit but also between the up-stream market structure and both the amount and type of bank financing. Finally, since financing decisions affect input choices, we identify new relations between input choices and the up-stream market structure. Fig. 6 describes the optimal use of bank and trade credit and the optimal investment level for three different degrees of competition in the up-stream market.

When the up-stream market is very competitive ($\alpha = 1$), a minimum amount of trade credit is enough to generate commitment. Bank credit is collateralized and it is the main source of external

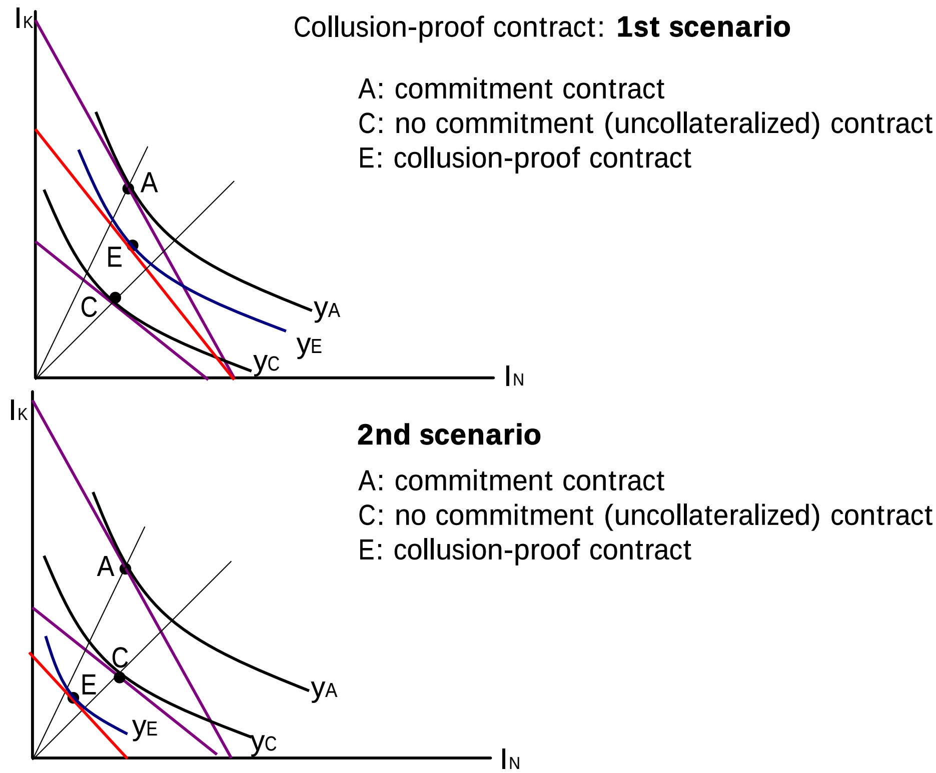

Figure 5: Collusion-proof contracts. The first diagram (1st scenario) refers to the case where the costs of using trade credit are lower than the benefits. Trade credit is used to solve a commitment problem between entrepreneur and bank. The optimal contract menu includes a non-collateralized bank contract and a collateralized trade credit contract. The optimal input combination is represented by point D. The second diagram refers to the case where the cost of using trade credit are larger then the benefits. The optimal contract menu includes a non-collateralized bank contract and pure input supply contract with the supplier. The optimal input combination is represented by point C.

financing, while trade credit is used in little amounts. This situation is represented in the first column of Table 6 and it corresponds to the case analyzed in Section 3 where the economy is able to reach the first-best. When the competition in the upstream market decreases (second column in Fig. 6), the cost of reaching a collusive agreement decreases as well. The only way to signal a credible commitment to the bank is to enlarge the use of trade credit, which however reduces the total surplus available in the economy (second best). The bank contract is still collateralized but bank financing is reduced compared to the previous case. In the extreme situation where there is only one supplier, i.e. the up-stream market is very concentrated and $\alpha = 0$ (see third column in Fig. 6), entrepreneur and supplier will always cheat at the expense of the bank. Thus, the bank only offers an uncollateralized credit contract. The firm extensively use trade credit but just to exploit the liquidation technology

Up-stream market structure and firm financing decisions

	Competitive mkt (α=1)	Intermediate mkt (0<α<1)	Concentrated mkt (α=0)
Trade credit	TC=Lsmin	Lsmin<TC<βI; decreasing in α	TC =βI
Bank credit	Collateralized; BC=all inputs-Lsmin	Collateralized; (1-β)I<BC<all inputs-Lsmin	Uncollateralized; BC=(1-β)I
Investment	First-best	Second-best	Third-best

Figure 6: Firm financing decisions in three different up-stream market structures.

of the supplier in case of default, rather than as commitment device. This discussion allows us to get the following predictions:

Prediction 2: *Trade credit facilitates the firm access to collateralized bank loan the higher is the degree of competition of the up-stream market.*

Prediction 3: *The amount of bank credit is increasing in the degree of competition of the up-stream market.*

Prediction 4: *Trade credit is decreasing in the degree of competition of the up-stream market, therefore larger when the supplier is a monopolist.*

Prediction 5: *Firms use technologies more intensive in intangible assets when the up-stream markets are competitive than when they are concentrated.*

5.2 How much information sharing between financiers do we need?

So far, we have shown that trade credit can be used by the entrepreneur to signal his willingness to stick to the ex-ante bank efficient contract. Once the bank gets this signal, it offers a collateralized loan. Does our story imply that the bank needs to observe the amount of trade credit taken or even the full properties of the supplier-entrepreneur contract? How much information sharing between bank and supplier is needed to access a collateralized bank loan?

In our model, the bank only needs to know that the supplier is lending some money. All the other relevant information, including the specific amount of trade credit offered, is inferred by the bank by solving the entrepreneur's optimization problem. The intuition is the following. In period $t = 1$, the bank (as well as the supplier) offers a menu of contracts (see the time-line in Fig. 1). Each contract offer has the characteristic to be the solution of the entrepreneur's optimization problem for any given combination of bank and trade credit. Contracts merely satisfying the bank's participation constraint would not be incentive compatible for the entrepreneur and therefore are not offered. The entrepreneur then chooses the contract that minimizes the total costs of external financing. This implies that when the entrepreneur chooses a given bank contract, the bank immediately infers how much trade credit will be taken by the entrepreneur as well as the repayment to the supplier in the good and in the bad state.

How reasonable is to assume that the bank knows that the supplier is providing some trade credit to the firm? Existing evidence shows that banks usually ask for financial information and for balance sheet data (which include data on account payables) when considering a credit application. In addition, banks have access to valuable information about trade credit by using credit bureaus. For example, the firm's trade credit payment history is routinely included in the credit reports provided by credit bureaus. This evidence suggests that in practice banks have more information about trade credit use than the one assumed in our model.

5.3 Is the supplier the only informed lender?

In our analysis, we assume the costly informed lender to be the supplier and the cheaper uninformed financier to be the bank. Other interpretations are however possible. We could assume that both financiers are specialized intermediaries but with different sets of information. For example, the costly informed financier is a relationship lender (also called local lender), while the lender providing cheaper funding with no or less information is an arm's-length lender. If we follow this interpretation, our results would predict that while local lenders can offer collateralized credit contracts, arm's-length lenders provide unsecured financing, in line with the existing evidence (Avery *et al.*; 1998; Zucherman, 1996; Frame *et al.*, 2001, 2004).

The reason why we do not follow this interpretation is related to the nature of the unobservability problem. A relationship lender is assumed to have a comparative advantage in collecting customer-specific information through multiple interactions (Boot, 2000). These features are mostly relevant when the unobservability concerns firms' characteristics, such as project quality or entrepreneurial effort. When the unobservability concerns investment, as in our setting, a specialized financial intermediary is not necessary: The relevant information is observed costlessly by the supplier by providing the input, with no need for multiple interactions. For this reason, the bank-supplier interpretation seems more natural in our framework.

Alternatively, we could interpret the informed lender as a lessor that receives a fee from the borrower for the use of the tangible inputs and retains the ownership on those assets. Although appealing, this interpretation is flawed as the lessor fails to solve the unobservability problem. To see why, consider the case analyzed in Section 3, in which the presence of the supplier allows the bank to offer a partially secured contract.

Can the lessor play the same role as the supplier? Consider a contract for the financing of a given amount of the intangible input and several units of the tangible input, say cars. The contract might state that a certain number of cars (say, 20) will be financed through a secured contract with the bank, while the remaining 30 through a leasing contract. Upon receiving the loan from the bank, the entrepreneur has an incentive to reduce the number of cars purchased with bank financing, say from 20 to 10. The lessor will not refrain the entrepreneur from buying a lower number of cars for two reasons: First, he does not observe the entrepreneur's reduction of 10 units of cars purchases. Second, even if he does, he has no incentive to stop the entrepreneur's opportunistic behavior: Being still the owner of his 30 cars, his return in defaulting states is never jeopardized by this reduction. Anticipating the entrepreneur's deviation, the bank will never propose such an agreement. This unilateral deviation from the contracted input mix is not feasible if the informed party is the supplier: He would observe it and prevent it from happening, in order to preserve the return he is promised in defaulting states, which is a fraction of the 50 initial cars.

Thus, while under a leasing contract a profitable unilateral deviation by the entrepreneur is always possible, under a trade credit contract such deviation is never possible unless the entrepreneur colludes with the supplier. This is the very reason why trade credit can provide commitment.

In the extreme case in which reaching a collusive agreement is costless, there is no secured contract the bank is willing to offer (see Section 4). Dealing with an informed party serves only to extract value from unused assets in default (and not to solve the commitment problem). In this case, both a leasing and a trade credit contract may serve this scope. Whether the entrepreneur will then use the supplier or the lessor as a liquidator will depend on the specific provisions of the bankruptcy codes and on the comparison between the liquidation abilities of the two financiers.[16]

6 Conclusions

This paper studies the role of collateral in lending and investigates how collateral interacts with different financing sources to jointly determine the firm's debt capacity and its input choices. Specifically, it provides a theoretical argument showing that when the investment in the tangible asset is not contractible, inside collateral may not be useful in boosting the borrower's debt capacity, despite being highly redeployable.

This prompts a "natural" role for alternative financing sources, namely trade credit, to help solving the problem. In particular, receiving credit from the supplier of the tangible input, who then observes whether the investment has taken place, allows to overcome the contract incompleteness and restores the beneficial effects of secured lending. The use of trade credit is also associated to technologies more intensive in tangible assets.

Although the empirical literature has highlighted the role of asset tangibility in increasing the firm's debt capacity, there is evidence that some tangible assets have low debt capacity, despite their high resalability, and the existence of a liquid secondary market. Our paper provides a theoretical argument for this evidence, highlighting investment contractibility as a determinant of debt capacity.

The paper also discusses alternative interpretations of the informed lender, focusing on relationship lending and leasing. We conclude that in our setting neither of these financing sources are viable instruments to solve the commitment problem.

[16] A liquidation advantage of leasing relative to secured lending has been modeled by Eisfeldt and Rampini (2009).

Appendix

Proof of Proposition 1. The first-best investment in capital I_K^* and labor I_N^* satisfies the following FOC's:

$$p\frac{\partial f_H(\cdot,\cdot)}{\partial I_K} = r_B - (1-p)\beta, \tag{20}$$

$$p\frac{\partial f_H(\cdot,\cdot)}{\partial I_N} = r_B, \tag{21}$$

obtained differentiating the reduced form objective function (4) wrt I_K and I_N. Using $I_K^*(p, r_B, \beta), I_N^*(p, r_B, \beta)$ in constraints (3) and (2) gives the optimal bank loan, $L_B^*(I_N^*, I_K^*)$, and the repayment in the good state, $R_B^{H*}(I_N^*, I_K^*)$, respectively:

$$L_B^*(I_N^*, I_K^*) = I_N^* + I_K^*, \tag{22}$$

$$R_B^{H*}(I_N^*, I_K^*) = \frac{1}{p}\left\{(I_N^* + I_K^*) r_B - (1-p)\beta I_K^*\right\}. \tag{23}$$

■

Proof of Proposition 2. The proof proceeds in three steps. The first step consists in showing that under non-contractible investment a secured credit contract is time-inconsistent. In the second step we analyze the input combination chosen after the loan has been granted, showing that it involves a lower investment in the collateralizable input and thus insufficient low state repayments to the bank to break even. In the third step we show that the bank may prevent this by offering an unsecured credit contract with a lower loan and a subsequent efficiency loss.

The first step has been proved in the main text.

To prove the second step, we first need to determine the optimal choice when the firm breaches the terms of the fully collateralized credit contract with contractible investment. Consider programme $\mathcal{P}_{dev}$ faced by the firm which has obtained a loan L_B^*. Solving the resource constraint (7) for $I_N(L_B^*, I_K) = L_B^* - I_K$ and substituting out in the objective function (5), the firm's problem is:

$$\max_{I_K} \; p f_H(I_K, L_B^* - I_K) - p R_H^{B*}$$

whence, differentiating wrt I_K

$$p\left(\frac{\partial f_H(\cdot,\cdot)}{\partial I_K} + \frac{\partial f_H(\cdot,\cdot)}{\partial I_N}\frac{\partial I_N}{\partial I_K}\right) = 0 \tag{24}$$

From $I_N(L_B^*, I_K)$, $\frac{\partial I_N}{\partial I_K} = -1$, whence from (24), we get $I_K = \hat{I}_K\left(L_B^*, R_H^{B*}\right)$, $I_N = \hat{I}_N\left(L_B^*, R_H^{B*}\right)$, with $\hat{I}_K\left(L_B^*, R_H^{B*}\right) = \hat{I}_N\left(L_B^*, R_H^{B*}\right)$ and $\hat{I}_K\left(L_B^*, R_H^{B*}\right) + \hat{I}_N\left(L_B^*, R_H^{B*}\right) = L_B^*$.

By studying the change in input demand induced by a change in relative input prices while keeping the loan constant,[17] the second step amounts to analyze how the demand for the two inputs changes with an increase in the price of input I_K (and a decrease in the relative price of I_N). By the concavity of the production function, the own-price effect is non-positive, which implies that there is a decrease in the demand for I_K. Because the loan is kept constant and the firm uses only two inputs, the

[17] This implies that at the new input prices it must be possible for the firm to afford the initial input combination.

cross-price effect is non-negative, i.e., the demand for input I_N must increase. The decrease in I_K implies that in default the collateral value of the input is insufficient to repay the bank, which does not break even. The bank offers an unsecured credit contract thereby reducing the loan provided.

The entrepreneur chooses I_K, I_N, R_H^B to maximize (1) subject to the participation constraint (2) with $C = 0$, and to the resource constraint (3). Solving (2) for R_H^B and using L_B from the resource constraint (3), the objective function (1) becomes:

$$\max_{I_K, I_N} pf^H (I_K, I_N) - (I_N + I_K) r_B.$$

The optimal input combination must satisfy the following first-order conditions:

$$p\frac{\partial f_H (\cdot, \cdot)}{\partial I_K} = 1 \quad (25)$$

$$p\frac{\partial f_H (\cdot, \cdot)}{\partial I_N} = 1 \quad (26)$$

which gives $I_K = \bar{I}_K (p, r_B)$, $I_N = \bar{I}_N (p, r_B)$, with $\bar{I}_K (p, r_B) = \bar{I}_N (p, r_B)$. Using these in (3) and (2) gives $\bar{L}_B = \bar{I}_K (p, r_B) + \bar{I}_N (p, r_B)$ and $R_H^B = \frac{1}{p} r_B \bar{L}_B$. ■

Proof of Proposition 3. Substituting the binding constraints in the objective function gives

$$\max_{I_K, I_N} pf^H (I_K, I_N) - (I_K + I_N) r_B + \beta I_K \frac{r_B}{r_S} (1 - \gamma) + (\gamma - p) \beta I_K$$

$$\max_{I_K, I_N} pf^H (I_K, I_N) - \left(I_N + I_K - \frac{1-\gamma}{r_S} \beta I_K \right) r_B + [\gamma (1-p) - p (1-\gamma)] \beta I_K$$

$$- \left(I_N + I_K - \frac{1}{r_S} \beta I_K \right) r_B - p\beta I_K \text{ per } \gamma = 0$$

$$- (I_N + I_K) r_B + (1-p) \beta I_K \text{ per } \gamma = 1$$

whence

$$p\frac{\partial f_H (\cdot, \cdot)}{\partial I_K} = r_B - \beta \frac{r_B}{r_S} (1 - \gamma) - (\gamma - p) \beta \quad (27)$$

$$p\frac{\partial f_H (\cdot, \cdot)}{\partial I_N} = r_B \quad (28)$$

The FOC on I_K (27) is increasing in γ

$$\frac{\partial (FOC_K)}{\partial \gamma} = \left(1 - \frac{r_B}{r_S} \right) \beta > 0$$

The expected profits are

$$p \left[f^H (I_K^* (\gamma), I_N^* (\gamma)) - R_B^{H*} (\gamma) - R_S^{H*} (\gamma) \right] = \quad (29)$$

$$pf^H (I_K^* (\gamma), I_N^* (\gamma)) - [I_K^* (\gamma) + I_N^* (\gamma)] r_B + \beta I_K^* (\gamma) \frac{r_B}{r_S} (1 - \gamma) + (\gamma - p) \beta I_K^* (\gamma).$$

By the envelope theorem, they are increasing in γ. ■

Proof of Proposition 4. First, notice that since bank credit is a cheaper source of credit ($r_S > r_B$ and $\beta_B = \beta_S$), the firm would never take it for financing reasons. However, a role of commitment can only arise if the supplier gets a share of the collateral in default states, however small this may be. To induce commitment at the lowest cost it is therefore sufficient to sign a liquidation contract with the supplier in which she liquidates a share of the collateral in the bad states in exchange for a minimal amount of trade credit. For the purpose of our analysis, we will abstract from pure liquidation contracts and focus on financial contracts in which, in exchange for a loan, each party gets a repayment which is non-decreasing in revenues. This implies that constraint (**??**) binds:

$$R_S^H = (1-\gamma)\,\beta_S I_K.$$

Using (13) and binding supplier participation (10), gives

$$\bar{\gamma} = 1 - \frac{L_{S\min} r_S}{\beta_S C} < 1$$

Last, using (9), (11), R_S^H and $\bar{\gamma}$, (8) writes as:

$$\max_{I_K, I_N} \; p f_H(I_K, I_N) - (I_N + I_K - L_{S\min})\, r_B + \left((1-p)\,\tfrac{\beta_S C - r_S L_{S\min}}{\beta_S}\beta_B - p r_S L_{S\min}\right)$$

Using $\beta_S = \beta_B$, the objective function reduces to the one obtained for the firm-bank contract (4) except for the extra term $(r_S - r_B)\, L_{S\min}$:

$$EP = p f_H(I_K, I_N) - (I_K + I_N)\, r_B + (1-p)\,\beta_S \rho I_K - (r_S - r_B)\, L_{S\min} \tag{30}$$

Thus, the first order conditions on I_K and I_N coincide with (20) and (21) and the level of investment is the same across the two cases. The only difference lies in the fact that the firm has to incur a fixed cost $(r_S - r_B)\, L_{S\min}$ to ensure that it has no ex-post incentive to alter the input combination specified in the ex-ante contract offer.

Substituting out I_K^* and I_N^* solving (20) and (21) in the bank participation constraint (9) and in the resource constraint, we obtain the properties described in the Proposition. ■

Proof of Proposition 5.

The ex-post optimisation programme with supplier collusion is given by problem $\mathcal{P}_S^{\mathcal{D}}$:

$$\max_{I_K, I_N, R_B^H, R_S^H} \; p\left[f_H(I_K, I_N) - R_B^H - R_S^H\right]$$

$$\text{s.t. } R_B^H \geq R_B^{H*}(\gamma), \tag{31}$$

$$L_S^*(\gamma) + L_B^*(\gamma) \geq I_N + I_K, \tag{32}$$

and to (15), where $L_B^*(\gamma), L_S^*(\gamma), R_B^{H*}(\gamma)$ are the commitment values of the loan and the bank repayment as defined in Proposition 3, constraint (31) requires the repayment to the bank in the high state be no less than the one promised in the commitment contract (i.e. $R_B^{H*}(\gamma)$), while the resource constraint (32) requires that the total input expenditure be higher than the loan obtained in the commitment contract.

Solution to this programme gives the return under collusion, $Y^{\mathcal{D}}(\gamma)$, which, compared with the return under commitment defines the collusion rent. This is increasing in γ, as shown in Proposition 5.

Solving programme $\mathcal{P}_{\mathcal{S}}^{\mathcal{D}}$, we get $I_K^{dev}\left(\gamma, L_B^*(\gamma), L_S^*(\gamma), R_B^{H*}(\gamma)\right), I_N^{dev}\left(\gamma, L_B^*(\gamma), L_S^*(\gamma), R_B^{H*}(\gamma)\right)$, $R_B^{Hdev} = R_B^{H*}(\gamma)$, $R_S^{Hdev} = \frac{1}{p}\left[L_S^*(\gamma) r_S - (1-p)(1-\gamma)\beta I_K^{dev}\left(\gamma, L_B^*(\gamma), L_S^*(\gamma), R_B^{H*}(\gamma)\right)\right]$.[18]
The return from deviating is

$$pf_H\left(I_K^{dev}(\gamma), I_N^{dev}(\gamma)\right) - pR_B^{H*}(\gamma) - L_S^*(\gamma) r_S + (1-p)(1-\gamma)\beta I_K^{dev}(\gamma)$$

Notice that $I_K^{dev}(\gamma) < I_K^*(\gamma)$. This implies that the payoff to the bank in case of default $\gamma\beta I_K^{dev}(\gamma)$ falls short of the contracted payoff $\gamma\beta I_K^*(\gamma)$ and the bank fails to break even.[19] **DIMOSTRARE**
Using from the commitment problem $L_S^*(\gamma) \equiv \frac{1}{r_S}\left[pR_S^{H*}(\gamma) + (1-p)(1-\gamma)\beta I_K^*(\gamma)\right]$, the return from collusion becomes

$$pf_H\left(I_K^{dev}(\gamma), I_N^{dev}(\gamma)\right) - pR_B^{H*}(\gamma) - pR_S^{H*}(\gamma) + (1-p)(1-\gamma)\beta\left(I_K^{dev}(\gamma) - I_K^*(\gamma)\right) \tag{33}$$

which is increasing in γ.
The benefits from colluding are then given by the difference between the two value functions (the return under deviation (33) and the return under commitment (29)):

$$pf_H\left(I_K^{dev}(\gamma), I_N^{dev}(\gamma)\right) - pR_B^{H*}(\gamma) - pR_S^{H*}(\gamma) + (1-p)(1-\gamma)\beta\left(I_K^{dev}(\gamma) - I_K^*(\gamma)\right) - \\ -p\left[f^H\left(I_K^*(\gamma), I_N^*(\gamma)\right) - R_B^{H*}(\gamma) - R_S^{H*}(\gamma)\right]$$

This reduces to

$$p\left[f^H\left(I_K^{dev}(\gamma), I_N^{dev}(\gamma)\right) - f^H\left(I_K^*(\gamma), I_N^*(\gamma)\right)\right] + (1-p)(1-\gamma)\beta\left(I_K^{dev}(\gamma) - I_K^*(\gamma)\right) = Y^{\mathcal{D}}(\gamma) - Y^*(\gamma).$$

By the envelope theorem, the derivative of the collusion rent with respect to γ is:

$$\frac{\partial\left(Y^{\mathcal{D}} - Y^*\right)}{\partial\gamma} = -(1-p)\beta\underbrace{\left(I_K^{dev}(\gamma) - I_K^*(\gamma)\right)}_{<0} > 0.$$

■

Proof of Proposition 6.
******MOVE THE PART BETWEEN ASTERICS TO THE APPENDIX**
Programme $\mathcal{P}^{\mathcal{CP}}$ below is the collusion-proof generalization of problem $\mathcal{P}_{\mathcal{S}}$:

$$\begin{aligned}
\max_{R_B^H, R_S^H L_B, L_S, I_K, I_N, \gamma} EP &= p\left[f^H(I_K, I_N) - R_B^H - R_S^H\right], \\
\text{s.t. } pR_B^H + (1-p)\gamma\beta I_K &= L_B r_B, && (34)\\
pR_S^H + (1-p)(1-\gamma)\beta I_K &= L_S r_S, && (35)\\
L_B + L_S &\geq I_N + I_K, && (36)\\
R_S^H &\geq \beta I_K && (37)\\
p\left[f^H(I_K, I_N) - R_B^H - R_S^H\right] &\geq (1-\alpha) Y^{\mathcal{D}}(\gamma). && (38)
\end{aligned}$$

[18] For notational simplicity, when referring to the optimal investment in the two inputs, we will henceforth consider only their dependence on γ.
[19] The argument is similar to the one used in Proposition 1. The proof is in the Appendix.

The constraints have the usual meaning. The only difference relative to problem $\mathcal{P}_S$ is the presence of the collusion-proof constraint (38) that ensures that the terms of the contract are such that the entrepreneur
has no incentive to deviate, and in which $Y^{\mathcal{D}}(\gamma)$ denotes the return from deviation, as defined in Proposition 5. ***

The solution to this problem proceeds in two steps. We first show that the firm-bank-supplier collateralized credit contract is prone to collusion between bank and supplier at the expense of the bank, and work out the optimal deviation. We then derive the collusion-proof contract.

1. The three constraints (15), (31) and (32) are all binding. Substituting them out in the objective function

$$pf_H\left(I_K, \left(L_S^*(\gamma) + L_B^*(\gamma) - I_K\right)\right) - pR_B^{H*}(\gamma) - L_S^*(\gamma) r_S + (1-p)(1-\gamma)\beta I_K$$

and differentiating wrt I_K gives

$$p\left(\frac{\partial f_H(\cdot,\cdot)}{\partial I_K} + \frac{\partial f_H(\cdot,\cdot)}{\partial I_N}\frac{\partial I_N}{\partial I_K}\right) + (1-p)(1-\gamma)\beta = 0 \tag{39}$$

From the resource constraint $I_N = L_B^*(\gamma) + L_S^*(\gamma) - I_K$, $\frac{\partial I_N}{\partial I_K} = -1$, whence from (39), we get

$$p\frac{\partial f_H(\cdot,\cdot)}{\partial I_K} + (1-p)(1-\gamma)\beta = p\frac{\partial f_H(\cdot,\cdot)}{\partial I_N}$$

DERIVARE $Y^{dev}(\gamma)$

2. The second part of the proof is the analogue of the one derived for Proposition 3 for a generic γ. In that case the value of γ was determined by the minimum exogenous level of trade credit necessary to generate commitment $(\bar{\gamma})$. In the present case the value of γ is endogenous $(\hat{\gamma})$ and obtains solving (38). This value depends on the cost of collusion α.

Using the properties of the contract described in Proposition 3, $\hat{\gamma}(\alpha)$ solves

$$p\left[f^H(I_K, I_N) - \frac{1}{p}\left(\left(I_N + I_K - \frac{1}{r_S}\left((1-\gamma(1-p))\beta I_K\right)\right)r_B - (1-p)\gamma\beta I_K\right) - \beta I_K\right] \geq (1-\alpha)Y^{dev}(\gamma)$$

where $Y^{dev}(\gamma)$...

To prove that $\hat{\gamma}$ exists we need to show that $(1-\alpha)Y^{dev}(\gamma) - Y^*$ is increasing in γ. ■

Proof of Proposition 7. Because $\beta_B = \beta_S$ and $r_S > r_B$, constraint (**??**) binds. Thus $R_H^S = \beta_S C$. Using R_H^S in (18) gives

$$L_S = \frac{\beta_S I_K}{r_S}$$

Using the resource constraint (11) to solve for $L_B = I_K + I_N - \frac{\beta_S I_K}{r_S}$ and the participation constraint (17) to solve for $R_B = \frac{1}{p}\left(I_K + I_N - \frac{\beta_S I_K}{r_S}\right)r_B$, the objective function (8) reduces to

$$\max_{I_K, I_N} pf_H(I_K, I_N) - \left(I_K + I_N - \frac{\beta_S I_K}{r_S}\right)r_B - p\beta_S I_K$$

which gives $\tilde{I}_K, \tilde{I}_N$ solving the following FOC's:

$$p\frac{\partial f_H(\cdot,\cdot)}{\partial I_K} - p\beta_S - r_B\left(1 - \frac{\beta_S}{r_S}\right) = 0 \quad (40)$$

$$p\frac{\partial f_H(\cdot,\cdot)}{\partial I_N} - r_B = 0 \quad (41)$$

Substituting out $\tilde{I}_K$ and $\tilde{I}_N$ in the constraints, we obtain the remaining properties described in the Proposition. ■

Proof of Proposition 8. In order to determine the threshold level of r_S above which the firm gives up a collateralized credit contract we compare the FOC's under the firm-bank no-commitment contract with those of the firm-bank-supplier collusion-proof contract. In particular using (25) and (40), we look for the value of r_S that makes the expected marginal cost of capital equal across the two cases. This value is equal to $r_S = r_B/p$ (and makes the firm indifferent between a collateralized credit contract, obtained by taking trade credit, and an unsecured credit contract using bank credit only). ■

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