Trade Credit: Suppliers as Debt Collectors and Insurance Providers

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This article examines how in a context of limited enforceability of contracts suppliers may have a comparative advantage over banks in lending to customers because they are able to stop the supply of intermediate goods. Suppliers may act also as liquidity providers, insuring against liquidity shocks that could endanger the survival of their customer relationships. The relatively high implicit interest rates of trade credit are the result of insurance and default premiums that are amplified whenever suppliers face a relatively high cost of funds. I explore these effects empirically for a panel of UK firms. (*JEL*: G30, M130, D920)

Trade credit arises when a supplier allows a customer to delay payment for goods already delivered. In general, it is associated with the purchase of intermediate goods. Empirical evidence shows that the implicit interest rate in a trade credit agreement is usually very high as compared with the rates on bank credit. In spite of this apparent high cost, trade credit is widely used and represents an important part of firms' finance. Therefore, it is surprising that banks do not take over this potentially profitable business, offering more credit lines for financing commercial transactions. This article shows how the emergence of trade credit can be seen as a natural consequence of a commercial interaction, despite the existence of a competitive banking sector.

This result is based on two essential elements. First, suppliers are better able to enforce debt repayment than banks because they hold the threat of stopping the supply of intermediate goods to their customers. Second, suppliers may act as liquidity providers, supporting their customers whenever they experience temporary liquidity shocks. The necessary condition for these elements to exist is the presence of a surplus that is split between suppliers and customers if they continue to do business. In other words, there must be a link between the supplier and the customer that

I have benefited from the helpful comments of Nobu Kiyotaki, Heski Bar-Isaac, Andrea Caggese, Leonardo Felli, Maria Guadalupe, Vidhan Goyal, Maureen O'Hara, François Ortalo-Magné, John Moore, Javier Suárez, various anonymous referees, and seminar attendants and conference participants at NYU-Stern, Cornell University, EEA, EFA, and TMR network meetings. I thank the support of the Barcelona Economics Program of CREA and the Financial Markets Group (LSE). All remaining errors are my sole responsibility. Address correspondence to Vicente Cuñat, Universitat Pompeu Fabra, C/ Ramon Trias Fargas 25–27, Barcelona 08005, Spain, or e-mail: vicente.cunat@upf.edu.

doi:10.1093/rfs/hhl015 Advance Access publication July 1, 2006

makes it costly for the customer to find alternative suppliers and costly for the supplier to lose its current customers.

This approach helps to answer the following questions at the heart of the trade credit puzzle: why does trade credit appear to be so expensive? and why is trade financed by suppliers instead of banks?

The high interest rate on trade credit arises because of an insurance premium and a default premium. The insurance premium is related to the fact that suppliers foresee their customers' future needs of liquidity. Suppliers know that they may have to help customers in need of extra liquidity, so they will charge them a premium for providing insurance against potential liquidity shocks. The widespread phenomenon of late payment can be seen as the main instrument for this liquidity provision.

The default premium accounts for the fact that, in the model, suppliers lend when banks are not willing to lend. Suppliers use their extra enforceability power to lend on the basis of returns that are nonverifiable and stochastic. This makes trade credit riskier than bank debt. The model also shows that if suppliers face a higher cost of funds than banks, then they will transfer it to their customers. Furthermore, the additional cost will be amplified because of the high default risk. The high cost of trade credit is therefore only apparent. Trade credit is correctly priced and compensates the supplier for a higher cost of funds, the risk of default, and the cost of providing liquidity insurance.

The reason that trade credit appears to be an expensive form of finance lies within the structure of a standard trade credit contract. Contracts are either "two part" or "one part." A "two-part" contract has three elements: a discount on the price agreed upon if the buyer pays early, the number of days that qualify for early payment, and the maximum number of days for payment. For example, a common "two-part" contract is called "2–10 net 30," it means that if customers pay within 10 days of delivery, then they qualify for a 2% discount. Otherwise, they can pay up to 30 days after delivery. Although the first 10 days of the contract can be seen as a free credit period for transaction purposes, the second 20 days are costly. The discount for early payment implies an interest rate paid for credit received. In the case of the "2–10 net 30" contract, the customer is effectively receiving credit at a 2% rate for 20 days. Thus the equivalent one-year interest rate of this contract is about 44%. This is an extremely high rate compared with the market rate that a bank would charge for a similar type of loan.[1]

In contrast, "one-part" contracts do not have an explicit discount for early payment. Although these contracts may involve some form of free

[1] Ng, Smith, and Smith (1999) found that "2–10 net 30" is the most common deal in a sample of US firms. Other common deals such as "8–30 net 50" imply even higher implicit interest rates. In this case, the annual implied interest rate is 358%.

funding, it is probably more accurate to see them as loans whose interest rate is not observed by an outsider, because the price charged on goods may include the interest rate paid for trade credit.[2] The National Survey of Small Business Finance (NSSBF) shows that when firms deal with their main supplier, 49% of the contracts are one part.[3]

Despite this high cost, trade credit still constitutes a considerable share of firms' finance. For example, as summarized in Table 1, trade credit accounts for roughly one-fourth of the total assets of a representative firm and about half of the short-term debt in two different samples of medium-sized UK firms and small US firms.[4]

Furthermore, these levels tend to be higher in periods when buyers face temporary liquidity shocks. Suppliers seem to lend to their customers in financial trouble, even when banks will not. This additional lending may occur through financing a higher proportion of purchased goods or by extending the agreed maturity of the loans. In most cases, it occurs through late payment of already extended debts. That is, customers are allowed to pay even after the agreed repayment date of the trade credit contract. For example, in the NSSBF sample, 46% of the firms declared that they had made some payments after the due date during the last year. These late payments very often do not carry an explicit penalty for the customers. The liquidity premium identified in this article therefore can be interpreted as the value of this late payment option.[5]

The role of suppliers as creditors is in line with the fact that trade credit tends to be higher in small, young, and high growth firms because they have more difficulty in accessing other forms of finance than old established firms.[6]

Table 1
Relative size of trade credit (average over firms)

Country	Data set	Trade credit/assets (%)	Trade credit/total debt (%)	Trade credit/Short term debt (%)
United Kingdom	FAME	25	41	47
United States	NSSBF	17	35	50

FAME, Bureau Van Dijk database contains data on over 250,000 UK firms of all sizes; NSSBF, National Survey on Small Business Finance 4630 small and medium US firms.
FAME covers years 1993–2002 and NSSBF is a 1998 cross-section.

[2] A similar comment can be made about the early payment period of a "two-part" deal. Although these days seem to represent some form of free credit, they also can have a cost that is included in the price of the goods. However, this cost is unobservable to an outsider.

[3] Data from the 1998 NSSBF. In that sample, 46.4% of the firms forgo the discount for early payment in at least half of their purchases.

[4] Financial Analysis Made Easy (FAME) is a database of 210,000 medium and large UK firms from 1993 to 1999 (see Section 3.1), whereas NSSBF is a sample of 3000 small US firms in 1998.

[5] In the 1998 NSSBF sample, 43% of the deals did not carry any explicit penalty. The median penalty rate for the deals with an explicit penalty was an annual rate of 29.7%.

[6] See Nilsen (1994; 2002), Elliehausen and Wolken (1993), and Berger and Udell (1998).

However, the empirical part of the article shows that the relationship between the age of a firm and the levels of trade credit used is nonlinear. Newborn firms start with low levels of trade credit that build very quickly in the early years of the firm's life. This reinforces the hypothesis that trade credit is related to the existence of a link between suppliers and customers. If this link takes time to build, then trade credit should grow as the relationship evolves.

The results of the model are consistent with the existing stylized facts, in particular with high implicit interest rates and the extensive use of trade credit. Furthermore, some of the empirical implications of the model are tested in Section 3; the findings support the existence of a link between suppliers and customers that takes time to build and leads suppliers to help their customers who experience temporary problems.

The explanation for trade credit in this article complements and expands the findings of previous articles. It identifies a justification for trade credit that has not yet been formalized and tests empirically for the qualitative predictions of the model.[7] The model here differs from those in the existing literature in various ways. First, it justifies the existence of trade credit on the basis of suppliers being able to enforce debt repayment better than banks. This extra enforceability power comes from the link that makes both suppliers and customers costly to substitute. In the model, this link takes the form of intermediate goods that are specific to the buyer. Although this idea has been discussed already in a series of articles, most notably Petersen and Rajan (1997), no article has formalized it yet.

Perhaps, the closest model to this interpretation is Bolton and Scharfstein (1990). In their model, a monopolistic financier uses the threat of not refinancing its borrowers as a way to enforce debt repayment. Being a monopolistic financier in this situation is equivalent to having the right to shut down the borrowing firm at the moment when it needs refinancing. Suppliers' use of the threat of not supplying more intermediate goods is similar to this idea, although suppliers need not be monopolists, but simply have an advantage in producing the particular input required by their customers. In this sense, a multiplier effect is at work: trade credit levels are forward looking because they depend on the future value of the relationship between supplier and customer, whereas bank credit is backward looking and depends on the collateral accumulated in previous periods. These two effects reinforce each other, and a limited relationship in fact can increase the levels of both trade credit and bank credit used significantly. The idea of a relationship surplus seems more appropriate when used to explain trade credit than bank credit, given that some

[7] For an extensive review of theoretical and empirical literature on trade credit, see Petersen and Rajan (1997), Smith (1995), and Mian and Smith (1992).

suppliers may have very strong links with their customers and that banks, in general, seem to be easier to substitute.

With respect to the Bolton and Scharfstein article, another distinctive feature is that the same link that allows the enforcement of debt repayment also forces suppliers to help their customers when their relationship is at stake. Therefore, suppliers will include an insurance premium in their trade credit contracts because they foresee that they will provide liquidity when their customers experience small problems. This is not simply restricted to renegotiation in case of default but rather is more insurance against liquidity shocks that the customer may face. This is modeled as an explicit bail out in the form of extra funds or extra goods delivered on credit, but it also can be seen as extra flexibility in terms of payment. In particular, the phenomenon of late payment that is widespread in trade credit can be considered evidence of this help.[8] Furthermore, the link arises naturally as the consequence of a technology that is more productive with ongoing relationships; it is not the consequence of a monopolistic supplier.

Another difference between this article and most of the existing literature is that, in equilibrium, all firms use both trade credit and bank credit, even if banks are relatively more competitive lenders than suppliers. Suppliers also can issue trade credit when their customers have exhausted all of their available bank credit.[9]

The idea of suppliers as liquidity providers is related to a new stream of literature that concentrates on the role of trade credit in liquidation, default, or renegotiation. For example, Frank and Maksimovic (1999) and Santos and Longhofer (2003) explained the existence of trade credit as the result of suppliers having an advantage in liquidating intermediate goods in case of default by their buyers, given that they have the distribution channels to re-sell them.[10,11] Wilner (2000) assumed that suppliers incur sunk costs that are specific to their buyers; in case of renegotiation of debts, suppliers therefore give more concessions to customers than

[8] Calomiris, Himmelberg, and Wachtel (1995) and Nilsen (1994; 2002) showed how large healthy firms borrow in downturns as a way to extend more finance to their liquidity-constrained customers.

[9] So far, only Biais and Gollier (1997) and Frank and Maksimovic (1999) presented models in which bank and trade credit are mixed optimally. According to Biais and Gollier, customers choose the right proportion of trade credit and bank credit to commit credibly to avoiding collusion with their suppliers. In Frank and Maksimovic, low-quality buyers get only trade credit, whereas high-quality buyers get mixed finance. Both models rely on the existence of a single monopolistic financier. Our model proposes an alternative explanation for this mix, based on the verifiability of the returns of the customer. The results of Section 3.2 support our hypothesis, showing a high sensitivity of this mix with respect to the levels of collateral of the firm.

[10] Frank and Maksimovic concentrated on the role of trade credit when goods are seller-specific, whereas this article studies the effect of the good being buyer-specific. Also note that, the legal right of the supplier to claim back intermediate goods usually does not apply when these goods have been transformed (see Franks and Sussman, 2005).

[11] However, Burkhart and Ellingsen (2004) showed that the relative illiquidity of intermediate goods as compared with cash makes trade credit useful in solving some agency problems between creditors and borrowers.

banks do. Both models conclude that suppliers will specialize in financing buyers with low creditworthiness, for whom liquidation is more likely to occur. So, high interest rates associated with trade credit reflect the fact that low quality firms self-select toward being financed by their suppliers.

In Section 3, I test some of the implications of the model with an extensive panel of UK firms. The results show how trade credit tends to be higher as the relationship between suppliers and customers continues. Measures of firm performance and liquidity shocks also are used to provide evidence of the support given by suppliers to their customers when they experience small problems. Finally, trade credit is negatively correlated with collateral levels, supporting the implications of the theoretical model.

The structure of this article is as follows: Section 1 contains the model. In Section 2, the question of suppliers as insurance providers is explored in more depth comparing supplier insurance with alternative forms of insurance. In Section 3, the empirical implications of the model are explored, and Section 4 concludes.

1. The Model

The model explains that trade credit is a natural result of the existence of limited commitment problems that make debt repayment difficult to enforce in an environment where firms are tied by commercial or technological links. In this section, I first describe the different agents involved in the model and the production technology of the customers. Then I introduce how agents bargain and the structure of cash flows that is implied by this bargaining. Next, a certain equilibrium structure is conjectured, and I determine the equilibrium values of the different endogenous parameters of the model. Finally, I show that this conjecture is effectively an equilibrium. The model aims to provide a stylized idea of the effects at work when we consider the existence of trade credit as a consequence of the relationship between suppliers and customers.

1.1 Agents

What follows is a discrete-time model with infinite periods. There are three types of agents: banks, suppliers, and customers. All agents live forever, are risk-neutral, and maximize future discounted profits. Throughout the article, and for the sake of clarity, I will refer to the supplier as “she” and the customer as “he.” Banks have deep pockets, with access to unlimited funds. They discount their future cash flows by a factor $\beta < 1$ so they are willing to lend or borrow at a market interest rate r such that $\beta \equiv 1/1 + r$. Suppliers also have deep pockets and the same discount factor β. Therefore they are also willing to lend or borrow at the banks’ rate. Later, I relax this assumption to allow for suppliers facing a higher cost of funds than banks.[12] Suppliers also provide their customers with the intermediate goods necessary for production. They produce these goods with a constant-returns-to-scale technology, and a unit cost normalized to one. There may be two kinds of inputs: generic goods, which can be provided by any supplier and serve any customer, and specific goods, which have been tailored to the needs of a single customer and only can be provided by a particular supplier.

Finally, customers are endowed with a limited amount of wealth, w_t, that may be considered exogenous in the first period but is endogenously determined afterward depending upon investment and consumption decisions. Customers are also relatively impatient with respect to deep pockets, having a discount factor $\delta < \beta$. Each customer can run only one business at a time.

Assumption 1. *There are more suppliers than customers.*

So, in the absence of any link between suppliers and customers, the customers can search at no cost for suppliers who sell them inputs at cost.

1.2 Technology

At the beginning of each period, the customer invests a variable amount of funds, I_t, in buying intermediate inputs that, at the end of the period, generate a return equal to $Y_i I_t$. The productivity parameter, Y_i, can take two different values: either Y_h or Y_l with $Y_h > Y_l$. The indicator $i \in (h,l)$ is therefore associated to a high or a low return. The probability of obtaining a high or a low return depends on which of the two available types of technology is used: either a startup technology using generic inputs or a mature technology using specific inputs. The probability of a high return is γ with the startup technology and α with the mature technology, with $\alpha > \gamma$. The mature technology is therefore more productive than the startup technology. However, the choice of technology is not free. Agents begin by using the generic technology until they have a successful period (high return); only then can they use the specific technology. They can continue to use the specific technology until they have an unsuccessful period, which leads them back to the generic technology. In other words, the technology choice follows a Markov process with transition probabilities γ and $(1 - \alpha)$.

The rationale for assuming this technology structure is as follows: the startup technology represents a stage at which the customer tries different prototypes in search of a successful product. Thinking of γ as relatively small, the customer will have to try for several periods until he generates

[12] See also Emery (1984) and Schwartz (1974) for models based on suppliers having superior access to financial markets.

a successful product. By assumption, the startup stage uses generic inputs that can be provided by any supplier; so the inputs are perfectly substitutable. Once the customer has had a successful period, the particular prototype can generate a blueprint that is ready for mass production; so, the customer can use the mature technology which is much more productive. The inputs used in the mature technology have special characteristics. Initially, they can be produced by any supplier, but after one period they only can be produced by the particular supplier that produced them first.[13] So, the mature technology is more productive, but it is specific to a particular supplier–customer partnership. If the supplier or the customer decides to sever the relationship, then this productive advantage will be lost and the customer will have to return to the startup stage. This is an important element of the model: after using the mature technology for one period, suppliers can enforce debt repayment by threatening customers with finishing their relationship, bringing them back to the use of a less productive startup technology. This can also happen exogenously with probability $(1-\alpha)$ representing a situation in which the blueprint becomes obsolete.

The mature production technology has one final element: a liquidity shock that occurs with probability υ just before the return of the firm is realized. This shock can take the form of any kind of problem that the firm experiences requiring additional inputs to continue producing. The structure of this liquidity shock is the following: the cost of the shock is LI_t. If the firm invests LI_t in solving "the problem," then production continues and a high return may result with probability α. However if the firm decides not to invest this sum, then the project is certain to be unsuccessful and to produce a low return.[14] This liquidity shock can be seen as the existence of a breakdown in the production process that costs LI_t units of inputs to repair, but it also could be interpreted as a delay in production that costs LI_t.

Assumption 2. $L < \alpha(Y_h - Y_l)$.

So it is always profitable for the customer to pay for the liquidity shock if he has sufficient funds.

Assumption 3. *Structure of returns.*

The customer consumes a proportion of investment cI_t during the production process. The role of cI_t in the model is to rule out infinite

[13] One way to interpret this is that the supplier patents the processes needed to produce these specific inputs. This structure is different from standard matching models. The link here is generated by producing with the mature technology and not just by having a successful period.

[14] The liquidity shock is modeled similarly to Holmström and Tirole (1998). For simplicity, the shock cannot occur in the generic technology, as the interesting results arise when the supplier has to decide whether to help the customer or not. If there was such a shock in the generic technology, then customers would have to face it through precautionary saving and third-party insurance deals.

postponement of consumption. This consumption can be seen as private benefits enjoyed by the entrepreneur while producing, or as wages, or as a minimum level of dividends. Also, a proportion θI_t of the value of the firm can be used as collateral to secure debt repayment. The introduction of collateral in the model allows for exploring the interaction between bank credit and trade credit. Customers can borrow from banks up to $\beta\theta I_t$ every period, but any additional borrowing needs to be enforced by some credible threat. The rest of the returns are not verifiable and cannot be collateralized; that is, no contract based on these returns can be enforced in court.[15] This precludes in particular the writing of a standard debt contract on them. It is useful to redefine these remaining returns as follows:

$$Y_h I_t = cI_t + \theta I_t + R_h I_t$$
$$Y_l I_t = cI_t + \theta I_t + R_l I_t.$$

Thus, $R_h I_t$ and $R_l I_t$ represent the portion of customer returns that can be used freely but are genuinely nonverifiable, because the rest of the returns can be backed by collateral or must be consumed.

Assumption 4. $\beta[\theta + \alpha R_h + (1-\alpha)R_l - \upsilon L] < 1.$

The expected discounted returns of the firm, excluding those that must be consumed, do not cover investment costs, even when the technology is specific and the discount factor β is used. This assumption rules out infinite investment, even if the customers somehow could commit the noncollateralizable part of returns.[16]

Assumption 5. $\delta[c + \theta + \gamma R_h + (1-\gamma)R_l] > 1.$

The project has positive net present value (NPV), even at the startup stage.

1.3 Cash flows and bargaining

In addition to paying for intermediate goods, the customer and the supplier may exchange funds at any time. This exchange is modeled in a very general way, defining $d_i I_t$ and $p_{ij} I_t$, where $d_i I_t$ is the payment from the supplier to the customer at the beginning of a period and $p_{ij} I_t$ is the payment from the customer to the supplier at the end of a period. The indicator $i \in (s,m)$ refers to the types of technology (startup or mature). The payment at the beginning of the period is contingent on the technology used (subindex i), whereas the repayment at the end of the period is

[15] The need for an external threat to enforce debt repayment is also present in Kiyotaki and Moore (1997), Hart and Moore (1994; 1998), and Hart (1995).

[16] However this does not necessarily mean that firms decrease in size with time, because it does not preclude the possibility that $\theta + \alpha R + (1-\alpha)r - \upsilon L > 1$.

also contingent on the technology used and, furthermore, on the realization of the productivity parameter (subindex j). Note that no particular structure on d or p is imposed other than the technology and the bargaining game between the agents.[17,18]

To determine the cash flow structure between agents, I assume a simple bargaining process: The supplier makes a "take it or leave it" offer to the customer at the beginning of every period; the customer can either accept it or switch to another supplier. Obviously, if the customer is using specific inputs and switches to another supplier, then he will have to use the generic technology again. If a supplier and a customer split, I assume that they never meet again, to rule out reputational equilibria.

The only subgame perfect equilibrium in this bargaining game is for the supplier to make an offer to the customer that leaves him indifferent between accepting it or switching to another supplier. This generates two different surplus distributions between the supplier and the customer, depending on whether the customer is using the startup technology or the mature technology.

1.4 Equilibrium

I begin conjecturing the following equilibrium structure: the customer invests all available funds in the project, even during the startup stage. When the liquidity shock hits in the mature stage, the supplier bails the customer out by paying for the shock. The customer does not keep any precautionary saving or acquire any insurance against the shock to force the supplier to pay for it.

According to this conjecture, the expressions for the value functions of suppliers and customers are the Bellman equations that represent the overall expected discounted value of future dividends of a firm. The two state variables in the model are the customer's wealth and the type of technology used. All of the parameters in the model are linear in terms of the wealth of the firm, so without loss of generality, the value function of a customer in the startup stage can be written as Sw_t, where S is the total future expected discounted value of consumption/dividends that one unit of wealth will produce for a customer in the startup stage. Similarly, the value function of a customer in the mature stage can be written as Mw_t.

[17] In particular, we do not stipulate that any term has to be positive. In fact, as we will see, some values of p and d are zero in equilibrium.

[18] One should also note that the payment of $p_{ij}I_t$ and receiving d_iI_{t+1} are contemporaneous, because the end of one period coincides with the beginning of the next one. Agents do in fact bargain at that point on the difference between them, and the model could in fact be written in net terms (Cuñat, 2002). However the formulation here is much more intuitive, as it emphasizes the short-term nature of the trade credit contract.

$$Sw_t = cI_t^S + \delta[\gamma M w_{t+1}^h + (1-\gamma) S w_{t+1}^l] \tag{1}$$

$$Mw_t = cI_t^m + \delta[\alpha M w_{t+1}^h + (1-\alpha) S w_{t+1}^l]. \tag{2}$$

Where I_t^S is the level of investment for the firm in the startup stage; w_{t+1}^h is the future wealth of the firm conditional on a high return and w_{t+1}^l is the level of wealth of the firm conditional on a low return. The total expected discounted value of the customer's firm in the search stage is therefore: the level of immediate consumption, $I_t^S c$, plus the discounted value of becoming a firm with wealth w_{t+1}^h, using the mature technology with probability γ, or a firm with wealth w_{t+1}^l, using the startup technology with probability $(1-\gamma)$.

Given that investment and the final wealth of the firm also can be expressed as linear functions of the initial wealth of the firm (1) can be expressed as a value function that does not depend on w_t, and a similar equation for M can be derived.[19]

$$S = \frac{1}{1-\beta\theta-d_s}\delta\{c + [\gamma M(R_h - p_{sh}) + (1-\gamma)S(R_l - p_{sl})]\} \tag{3}$$

$$M = \frac{1}{1-\beta\theta-d_m}\delta\{c + [\alpha M(R_h - p_{mh}) + (1-\alpha)S(R_l - p_{ml})]\}. \tag{4}$$

The first term of each expression is a leverage factor. The term in braces is the continuation value of each invested unit. Note that there is no payment relative to the liquidity shock. This is because of the conjecture that customers will not keep any precautionary saving to force suppliers to pay for the liquidity shock. Later, I will also prove that not having any precautionary saving is the optimal strategy from the point of view of the customer. The value functions for the suppliers also can be expressed as proportional to the size of the customers that they finance. Using lower case letters to define the value functions of the supplier, $m\varpi_t$ and $s\varpi_t$:

$$\begin{aligned} s = \frac{1}{1-\beta\theta-d_s} & (-d_s + \beta\{\gamma[m(R_h - p_{sh}) + p_{sh}] \\ & + (1-\gamma)[s(R_l - p_{sl}) + p_{sl}]\}) \end{aligned} \tag{5}$$

$$\begin{aligned} m = \frac{1}{1-\beta\theta-d_m} & (-d_m + \beta\{\alpha[m(R_h - p_{mh}) + p_{mh}] \\ & + (1-\alpha)[s(R_l - p_{ml}) + p_{ml}] - vL\}). \end{aligned} \tag{6}$$

[19] See Appendix.

The startup function includes an initial payment of $-d_s$ to the customer, plus the discounted value of the future contingent repayments p_{ij}, and the transitions to further startup or mature stages, conveniently re-scaled by the customer's new wealth. The mature-stage function also accounts for the possibility of helping the customer with the payment of L with probability v. There are eight endogenous parameters and four equations. The four extra conditions necessary to solve the model come from the bargaining game between suppliers and customers.

Three of the conditions relate to the fact that suppliers are more abundant than customers. Thus when the generic technology is in use, customers take all the surplus, and no debt repayment is enforceable. In other words, $s = 0$ and $p_{sl} = p_{ml} = 0$. Furthermore, bargaining and the technology structure together imply that $p_{sh} = 0$. This is because suppliers become "specific" after they have produced with the mature technology for one period, and p_{sh} is the payment from customers to suppliers at the end of the first successful period (in other words at the beginning of the period where they are going to use the mature technology for the first time). At this point in time, suppliers are still perfectly interchangeable, so no repayment is enforceable. These bargaining outcomes, together with Equations (5) and (6), determine the value of d_m as a function of p_{mh}.[20]

$$d_m = \beta(\alpha p_{mh} - vL). \tag{7}$$

The interpretation of (7) is quite straightforward. The payment from the supplier to the customer, d_m, equals the discounted value of the expected repayment at the end of the period αp_{mh} minus the expected cost of supporting the customer with extra funds in case he suffers a liquidity shock, $-vL$. This makes the contract look like a trade credit contract in which the supplier finances a proportion of intermediate goods, d_m, and the face value of that credit is p_{mh}. However, there is a probability of default $(1 - \alpha)$; also, the supplier has to take into account that she may need to provide extra funds to support the customer. The trade credit contract emerges only with the mature technology, because no debt repayment is feasible in the startup stage. The exchange of funds at the end of a successful mature technology period can be interpreted as the following: when the customer gives the supplier $p_{mh}I_t$, he qualifies for a rollover of the previous trade credit contract. In net terms, this represents a payoff from the customer to the supplier, because $p_{mh}I_t > d_m I_{t+1}$. Overall, the series of net cash flows of

[20] It is clear now that d_s is also zero given that, after a startup period, no debt repayment is enforceable, regardless of the productive result. Another way to see that d_s is zero is that both s and m are zero.

trade credit looks like a perpetuity. The net cash flow (after repayment and refinancing) in every period is positive for the supplier except the first period in which suppliers finance their customers up to the discounted value of all future rents that they expect to extract.

1.4.1 Interest rates when suppliers face the same cost of funds as banks. Expression (7) can be re-written in terms of interest rates. If the interest rate in a trade credit contract follows the relationship $d_m(1 + r_{tc}) = p_{mh}$ and the market interest rate follows the relationship $(1 + r) = (1/\beta)$, then the interest rate can be expressed as:

$$1 + r_{tc} = (1 + r)\left(1 + \frac{1 - \alpha}{\alpha} + \frac{\beta v L}{d_m \alpha}\right). \tag{8}$$

The first set of relevant results from the model are a direct consequence of Expression (8). The interest rate implicit in trade credit has two premium terms. The first is a default premium, $(1 + r)\frac{1-\alpha}{\alpha}$. Suppliers know that if the customer firm is unsuccessful, then they will not be able to receive further payments from the customer. Default occurs with a probability $(1 - \alpha)$, and the default loss per unit loaned is $\frac{(1+r)}{\alpha}$. Second, $(1 + r)\frac{\beta v L}{d_m \alpha}$—which can be simplified to $\frac{vL}{d_m \alpha}$—is an insurance premium that measures the expected payments that the supplier may have to make to bail out customers with liquidity problems. These two premiums explain the apparently high cost of borrowing from suppliers. Suppliers on average break even, and the high implicit interest rates on trade credit with respect to bank credit account for the higher risk of default on trade credit and for the possibility that customers will need to be bailed out or will incur late payments.

1.4.2 Interest rates when suppliers face a higher cost of funds than banks. So far, suppliers have been modeled as deep pockets, with the same cost of funds as banks. At this point, if suppliers faced a higher cost of funds than banks, then they would transmit this higher cost in an amplified way to their customers. This effect can be seen in Expression (8) where a higher cost of funds for the supplier would be reflected as a higher interest rate r_s (and the corresponding lower β). The interest rate on trade credit therefore would be

$$1 + r_{tc} = (1 + r_s)\left(1 + \frac{1 - \alpha}{\alpha}\right) + \frac{vL}{d_m \alpha}. \tag{9}$$

An increase of one unit in the interest rate that suppliers face would generate an increase in the interest rate that customers pay for their trade credit of $(1+\frac{1-\alpha}{\alpha})$ units. Thus if suppliers have relatively poor access to financial markets, then they will transmit this problem in an amplified way to their trade credit lending. The reason for the amplification is that the cost of the expected default rates on trade credit will be higher.

A higher cost of funds for suppliers also would make bank collateralized loans with interest rate r strictly preferable to collateralized loans given by suppliers with interest rate $r_s > r$. However, even when suppliers face a higher cost of funds than banks, they can still lend through trade credit once collateral has been exhausted, with an interest rate $r_{tc} > r_s$.

1.4.3 Amount of trade credit granted. Equations (7) and (8) reflect the value of the trade credit loan as a function of the expected repayment. The customer's value functions now can be used to determine the total size of trade credit. To do so, one needs to calculate the maximum repayment that can be enforced by the supplier. This has to make that the customer is indifferent between repaying and keeping the relationship with his supplier, or defaulting and going back to the search stage. In terms of the value functions, this means that $(R_h - p_{mh})M = R_h\, S$. This condition, together with (3) and (4), determines the maximum level of debt repayment, p_{mh}, that is enforceable.

$$p_{mh} = \frac{R_h}{1-\beta\theta+\delta(R_h-R_l)(\alpha-\gamma)}[d_m+\delta(\alpha-\gamma)(R_h-R_l)]. \tag{10}$$

Equations (7) and (10) lead to an expression for p that depends only on exogenous parameters.

$$p = \Delta[\delta(\alpha-\gamma)(R_h-R_l)-\beta vL]. \tag{11}$$

The term $\delta(\alpha-\gamma)(R_h-R_l)-\beta vL$ measures the total differential expected productivity between the mature and the startup technology. The total amount of trade credit is a function of the maximum amount of repayment that suppliers can enforce. This is a function of the difference in productivity between the mature technology and the startup technology; in other words, the punishment that suppliers can impose on customers in case of default through terminating the relationship. The term Δ, equal to $\frac{R_h}{1-\beta\theta-\delta(\gamma-\alpha)(R_h-R_l)-R_h\beta\alpha}$, is a dynamic multiplier reflecting how a small difference in productivity between the mature and the startup technology may sustain an amount of trade credit that is several times higher than the one-period productivity differential. This is because the amount of enforceable trade credit is a forward-looking function of this differential, whereas the amount of collateralizable credit, and also trade credit, is a function of total investment that is partly a backward-looking function of wealth.

The second set of results of the model is summarized in Equation (11). To enforce trade credit repayment, the supplier can threaten the customer with ending the relationship and forcing the supplier to return to the startup prototype stage. This would cost the customer $\delta(\alpha - \gamma)(R_h - R_l)$ per period per unit invested. However, the dynamic nature of the supplier–customer interaction, and the presence of collateral, amplifies this cost to $\Delta[\delta(\alpha - \gamma)(R_h - R_l)]$ per unit of wealth of the customer. This would be the maximum enforceable level of trade credit. However, the supplier has to take into account that she will have to help the customer if she experiences a liquidity shock. The expected cost of this help per unit of wealth of the customer is $\Delta\delta\beta vL$.

1.5 Equilibrium verification

This section shows that the equilibrium conjectured in the previous section satisfies all of the conditions for an equilibrium and that, under certain conditions, it is unique. We confirm this by checking that no agent has an incentive to deviate from this equilibrium taking the strategies of the other agents as given. In principle, deviations may involve more than one period. However, the "unimprovability principle" guarantees that if no deviation of one period is optimal, then deviations of more than one period are also not optimal; thus the conjecture is an equilibrium.[21] Three decisions need to be confirmed: the level of investment of the customer, the decision to bail out the customer in case of a liquidity shock, and the cash flows between the supplier and the customer.

1.5.1 The customer's investment decision. One possible deviation from the conjectured equilibrium would occur if customers decided to invest less than the maximum available investment level. Is investing all possible funds the optimal strategy? Given that customers have limited borrowing capacity, the positive NPV rule becomes a necessary condition for investing. However, it is not sufficient, because customers will choose the strategy with the maximum NPV and not just any strategy with a positive NPV. Two potential strategies could yield a higher NPV than investing as much as possible in the search stage. One would be to split the project into a series of infinitely small projects to maximize the probability of at least one success. This is precluded by the assumption that customers only can follow one project at a time. The other strategy is an intertemporal version of the previous one; it would be to invest a small amount of

[21] See Kreps (1990) for an intuitive explanation of the "unimprovability principle."

money in the startup project and leave the rest in a bank account until a successful idea arrives. This strategy can be excluded if the instantaneous consumption associated with investing in the startup strategy is bigger than the option value of waiting for one period to see whether the project is successful.

Proposition 1. *There is a threshold level $\delta^* \in (0,\beta)$ such that for every $\delta < \delta^*$ it is optimal for the customer to invest all available funds in the project even in the startup stage.*

Proof. See Appendix.

Assumption 6. $\delta < \delta^*$.

1.5.2 Helping customers hit by a shock. To see whether it is optimal for suppliers to help their customers when they are hit by a liquidity shock, one first has to think in terms of the bargaining game between the two. Suppliers make a take-it-or-leave-it offer to their customers, so it is clear that if the customers had the funds to avoid the shock themselves, then they would have to do so. Suppliers only will pay when customers have no funds to deal with the shock and, at the same time, when it is less costly for them to pay for it than to lose the customer.

Proposition 2. *Suppliers will always pay for the liquidity shock as long as customers have no funds to pay for it, and the cost of losing the customer exceeds the cost of paying for the shock.*

Proof. If the customer keeps no precautionary saving and has no external insurance, then the only alternatives that the supplier has are to help the customer or to lose him. The supplier will choose the alternative that has the higher payoff for her. ■

At that point, the cost of losing the customer is αp_{hm}.

Assumption 7. $L < \frac{\alpha\Delta}{1+\beta v}[\delta(\alpha-\gamma)(R_h - R_l)]$.

This is the necessary and sufficient condition for the cost of paying LI_t to be smaller than the cost of losing the customer.

1.5.3 Renegotiation. I also confirm that agents do not have an incentive to renegotiate the payment of p_{hm} and d_m. Let us start with the payment of d_m the first time that the mature technology is used. At that point in time, d_m gives all the discounted surplus to the customer; so, there is no incentive on the customer's part to deviate. The supplier deviate from that payment, but at that point suppliers are still perfectly substitutable, so any payment below d_m would mean that the customer would switch to another supplier. So there is no incentive on the supplier side to deviate.

With respect to the payment of p_{hm} and d_m in later periods, these payments are contemporaneous, so they must be analyzed jointly. On the customer side, p_{hm} is such that the customer is indifferent between repaying it and qualifying for a further "mature technology" period that includes financing a proportion d_m of intermediate goods or defaulting and going back to the startup stage. So there is no incentive on the customer side. Therefore, the only deviation left to be verified is whether there is an incentive on the supplier side to forgive some repayment to the customer. Keeping d_m constant, suppliers have a trade off in the determination of p_{hm}. On the one hand, the higher p_{hm}, the higher proportion of surplus goes to the supplier. On the other hand, increasing p_{hm} reduces the wealth and the growth rate of the customer, thus potentially reducing the future surplus for both agents. However, Assumption 4 guarantees that the first effect dominates. Therefore extracting as much surplus as possible is optimal from the supplier's point of view.

Proposition 3. *Suppliers will extract all the extra surplus from the customer when using the mature technology after the first period, making* $M(R_h - p_{hm}) = S$.

Proof. See Appendix.

It is interesting to see that in net terms, the succession of trade credit contracts looks like a growing perpetuity, with an initial payment of $d_m I_t$ from the supplier to the customer on the first mature period and further payments of $p_{hm}I_t - d_m I_{t+1} > 0$ from the customer to the supplier in the periods following. In that sense, any forgiveness would be like an investment of the supplier in the growth of its customer, but Assumption 4 guarantees that this type of investment will not pay, as the public returns of the customer firm are too low.[22]

2. Supplier Insurance Versus Other Forms of Insurance

So far, the conjecture has been that the customer does not take any precautions against a possible liquidity shock, to force the supplier to pay for it. The supplier will agree to pay it as long as the cost is sufficiently small as compared with the rents extracted from the customer. Customers have other potential strategies for dealing with the payment of the liquidity shock. In particular, they could have some precautionary saving or

[22] The process also can be seen as an initial price discount that helps the supplier *capture* the customer and extract future rents. This is similar to the result in some of the literature on related lending, most notably Petersen and Rajan (1995). For static models on trade credit used as a price discrimination device, see Brennan, Maksimovic, and Zechner (1988) and Smith (1987).

they could sign an insurance contract with a third party such as a bank. In this section, I show that the optimal strategy for customers is to use their suppliers as insurance providers.

Precautionary saving means that customers could save in a bank account the discounted entire amount of the shock, βLI, and use that saving if the shock hits. If the shock does not occur, then these funds are added to the initial wealth of the firm at the beginning of the next period. Precautionary saving is more costly than the other two strategies. Compared with bank insurance, precautionary saving is equivalent, in expected returns, to paying an insurance premium $\beta \upsilon LI$ and saving an amount $\beta(1-\upsilon)LI$ for the next period. But Proposition 1 and Assumption 6 make saving suboptimal with respect to investing, so precautionary saving is therefore dominated by writing an insurance contract with a third party that involves only paying the premium, $\beta \upsilon LI$. In other words, bank insurance dominates precautionary saving.[23]

However, precautionary saving can be observed empirically, and many firms hold liquid assets even when they have good access to trade credit. This could be justified in the model if customers expected larger a liquidity shock than what the supplier would be willing to support. Precautionary saving thus would be used on top of the help from suppliers. Bank insurance also could be used for this purpose.

Bank insurance means paying a fair insurance premium, $\beta \upsilon LI$, per period, to a bank who will pay the liquidity shock whenever it happens. In pure cost terms, bank insurance and supplier insurance are equivalent. However, supplier insurance strictly dominates bank insurance in the presence of any contracting friction, verifiability problems, or renegotiation. This is because supplier insurance is an equilibrium result of the interaction between both commercial partners. It is renegotiation proof; there is no need for a written contract; and the supplier will always bail out the customer as long as the customer has no other way to deal with the shock and the continuation value for the supplier exceeds the cost of bailing out the customer. Even if the shock is sometimes nonverifiable, and a written insurance contract is not always enforceable, then the customer still can use the supplier as lender of last resort.

Also, to some extent, supplier insurance is unavoidable. Suppliers cannot credibly commit to not bailing out their customers who experience a liquidity shock and who do not have any funds, or alternative insurance, to cover it. So, there will always be an insurance premium included in the cost of trade credit. The only way to avoid paying this premium is if the customer takes alternative precautions and can prove to the supplier that no bail out will be needed. This may prove a difficult task, as the customer could always secretly cancel the contract with the third party. If

[23] See Appendix for details.

the supplier believed that she would have to pay for the shock anyway, then she would still charge the insurance premium. Thus, the customer would be paying twice for the same coverage. Any kind of contracting costs also would give the advantage to supplier insurance.

Proposition 4. *If customers can credibly commit to get bank insurance, then bank insurance is equivalent to supplier insurance in cost terms.*

Proof. See Appendix.

Both banks and suppliers are deep pockets facing the same discount rate. Both expect to make zero profits on average in their interaction with customers. So, it is an intuitive result that the cost of getting insurance from either of the agents is the same. One assumption that would give suppliers a cost advantage over third-party insurers would be if suppliers faced a higher cost of funds than banks.[24] In this case, suppliers would be cheaper insurers than banks, because they would discount the insurance premium at more favorable terms. This effect also would be amplified by the multiplier Δ (see Section 1.4).

So far, LI could be interpreted as a monetary payment. However, it also could be seen as the cost of a delay in production. This interpretation may be closer to the phenomenon of late payment. If a customer's production is delayed, then suppliers will receive the next payment of p later. The cost of this delay can be summarized by LI. By this interpretation, supplier insurance would be completely unavoidable. Suppliers would face the cost of this delay, and they could cover themselves with a third-party insurance if they wished to, but no insurance scheme on the customer's side would be feasible. Within the monetary interpretation of LI, the only situation in which supplier insurance would not be available would be if Assumption 7 did not hold. In this case, the link between the supplier and the customer is too weak. The supplier would rather lose the customer than pay LI. If this were the case, then bank insurance would be the optimal strategy for the customer.

3. Empirical Analysis

The model in Sections 1 and 2 explains some of the stylized facts regarding trade credit, such as the apparently high interest rates implicit in the discount for early payment, and the existence of trade credit in the presence of an efficient banking sector. Moreover, the model has a series of testable implications that can be used to assess its relevance and for

[24] For example, if suppliers also were cash constrained and had access to a liquid and reversible production technology that yielded more than $\frac{1}{\beta}$ units of nonverifiable returns per period per unit invested, in which they could invest their "spare" funds.

comparing it with other competing theories of trade credit. The main empirical implications of the model are as follows.

First, the levels of available and effective trade credit should be higher whenever the link between suppliers and customers is tight. That is, higher levels of trade credit are expected when intermediate goods are very specific, when suppliers have private information about their customers or, in general, when suppliers are costly to substitute.[25] In the model, this is a direct consequence of Expression (11) and Proposition 2. A tighter link allows suppliers to enforce a higher level of trade credit and makes them more prone to helping their customers through additional trade credit if necessary. The main difficulty that arises when testing this hypothesis is that it is hard to find an unambiguous measure of the degree of substitutability of suppliers. To overcome this problem, I use as a proxy for the degree of relationship between suppliers and customers the age of recently created firms. This is the best available approximation to the length of the relationship between suppliers and customers, and it should be negatively correlated with the degree of substitutability of suppliers. In the model, the build up of the relationship takes the form of a discrete jump that follows a stochastic process: the level of trade credit of a newborn firm is zero up to a certain point in time, when it suddenly rises to a level $d_m I$. In practice, this process may be gradual as the links between a supplier and a customer build up during long periods.

Second, as seen in Proposition 2, firms experiencing liquidity problems should use their suppliers as lenders of last resort. Several regressions explore this issue: in the first set of regressions, I relate trade credit to the level of liquid assets in the firms. Then, to capture a more dynamic relationship between trade credit and changes in liquidity, I regress trade credit against sudden drops in liquidity or dividends; then I relate use of trade credit to changes in the overall performance of the firm. This is closest in interpretation to some of the predictions of the model. The model also predicts that suppliers should not support their customers when they experience liquidity shocks that are too large relative to the value of the link with their suppliers. The regressions that relate the ratio of trade credit over total debt to firm performance show that trade credit shrinks dramatically whenever firms experience large negative shocks. This provides some evidence in favor of this prediction. However, it is hard to find a good measure that quantifies the value of a supplier–customer link, so a direct test of this prediction is difficult to construct.

[25] The model does not directly address the idea of suppliers having superior information about their customers. However, any kind of informational advantage that would make customers more productive with their long-term supplier than with an alternative one would fit in the model. This is not to be confused with informational asymmetries in the spirit of standard relationship lending models, like Biais and Gollier (1997) where suppliers have an advantage in determining the creditworthiness of their customers.

Finally, the proportion of trade credit used with respect to other forms of finance should depend on the level of collateral that firms have. The higher the level of collateralizable assets, the lower the expected proportion of trade credit. This result is almost imposed by the assumptions of the model. However, it is relevant to test this assumption, especially because alternative theoretical models have paid little or no attention to the determination of the "mix" between trade credit and other forms of credit.[26]

3.1 Data description

To test the implications of the model, I use a subsample of the FAME–Bureau Van Dijk (BVD) database. This database is collected by Jordans and BVD for commercial use and includes balance sheet data, profit and loss statements, and some complementary information on 210,000 firms from 1993 to 2002, including many small and newborn firms.[27] I restrict the analysis to manufacturing firms, retailers, and wholesalers thus reducing the sample to an unbalanced panel of approximately 39,500 firms with an average of 5.2 observations per firm.[28]

This database has two particular characteristics that make it especially appealing. First, it contains both quoted and not quoted firms and many small firms. Second, the high number of observations is ideal for performing nonparametric estimations, which are particularly important when some of the implications tested are highly nonlinear. Using a panel also allows for controlling for the presence of individual heterogeneity and for the possible endogeneity of trade credit decisions. I use individual fixed effects and a Generalized Method of Moments (GMM) instrumental variables approach in all the panel regressions to address these issues.

The dependent variables used throughout this section are *trade credit divided by total assets* and *trade credit divided by total debt* (total debt includes trade credit). These correspond to parameters d_m and $d_m/(d_m + \theta)$ in the model. As independent variables of interest, I use *age*, corresponding to the age of the firm in days, transformed into a noninteger number of years; *growth* that is the annual growth rate of assets; *liquid assets* or the total amount of cash and bank deposits divided by total assets, and *collateral* constructed as the total amount of land and

[26] The change in *trade credit divided by assets* as a function of collateral can be seen in the model by taking the derivative of Expression (11) with respect to θ. The derivative is positive and grows with the degree of the link.

[27] It contains all the UK firms satisfying one or more of these criteria: turnover greater than £700,000, shareholders funds greater than £700,000, or profits greater than £40,000. It also contains less detailed data on a sample of 100,000 firms that satisfy turnover being greater than £500,000, current assets greater than £250,000, current liabilities greater than £250,000, or pre-tax profit greater than £25,000.

[28] I drop firms in sectors such as agriculture, fishing, mining, financial intermediation, other services, real estate, public administration, and so on, because in these sectors buying intermediate goods from a supplier represents only a small part of the firm inputs. Therefore, trade credit is of little relevance.

Table 2
Summary statistics

Variable	Mean	SD	q 10%	Median	q 90%
Trade credit/assets	0.25	3.54	0.03	0.17	0.49
Trade credit/total debt	0.41	0.25	0.09	0.38	0.78
Size	7.30	2.18	3.68	7.51	10.78
Inventories	0.23	0.18	0.03	0.19	0.48
Collateral	0.25	0.20	0.02	0.20	0.55
Liquid assets	0.12	0.17	0	0.05	0.35
Cost of sales	1.89	24.84	0.48	1.28	3.14
Growth	0.21	7.43	–0.18	0.05	0.45
Dividend cut	0.07	0.26	0	0	0
Liquid assets drop	0.06	0.23	0	0	0

fixed assets divided by total assets. To test the reaction of trade credit to unexpected changes in liquidity, I use two different dummy variables: *dividend cut* takes a value of 1 if dividends were cut from the previous year and zero otherwise. *Liquid assets drop* takes a value of 1 if the liquid assets variable dropped by more than 10% (that is 10% of the assets of the firm) in the previous year and zero otherwise. These variables have been used in the literature to identify new financing constraints and negative shocks to firm prospects.[29] Finally, several control variables are included in different specifications: *size* is the log of total assets, the variable *inventories* is the value of inventories divided by total assets, and *cost of sales* measured as annual cost of sales divided by total assets. All three control for the level of activity of the firm.[30] Finally, firm-fixed effects and year dummies are included in all of the regressions; some of them also include lagged dependent variables and sector-specific time trends. Table 2 displays some summary statistics for all of the relevant variables.

3.2 Results

3.2.1 Basic regressions. Table 3 summarizes the basic fixed-effect regressions with respect to liquid assets and collateral. Columns 1–3 correspond to the dependent variable *trade credit divided by total assets*. Column 1 present how trade credit use is higher in firms with low levels of collateralizable assets and low levels of liquid assets. Both effects are statistically significant. In economic terms, the effect of collateral is particularly strong. The difference between the first and third quartiles of the collateral variable is 0.31, which translates into an expected

[29] See Fazzari, Hubbard, and Petersen (1998) and Cleary (1999).

[30] Note that *cost of sales* plus the change in *inventories* add up to the total purchases of the firm over a year. There is a trivial relationship between total purchases and trade credit, so controls for firm activity must be added to the regressions. One way to interpret the inclusion of these controls is that they measure the baseline level of trade credit. Then, the firm deviates from it for contracting reasons.

Table 3
Basic regressions

	Trade credit/assets			Trade credit/total debt		
Dependent variables	1	2	3	4	5	6
Lagged dependent variable			0.123 (1.88)*			0.352 (24.89)***
Collateral	–0.1343 (43.91)***	–0.1336 (43.68)***	–0.148 (24.17)***	–0.3101 (44.22)***	–0.311 (44.35)***	–0.0377 (24.80)***
Liquid assets	–0.0948 (34.68)***	–0.0947 (34.65)***	–0.074 (14.62)***	0.1134 (14.32)***	0.1121 (14.17)***	0.048 (2.95)**
Inventories	0.0749 (22.04)***	0.0748 (22.02)***	0.086 (10.66)***	0.0923 (10.42)***	0.0926 (10.46)***	0.08 (4.41)***
Cost of sales	0.0079 (29.17)***	0.0078 (28.92)***	0.004 (2.34)**	0.0087 (14.99)***	0.0087 (14.99)***	0.0051 (1.29)
Size	–0.0137 (20.11)***	–0.0138 (20.21)***	–0.001 (0.50)	–0.0277 (16.77)***	–0.0284 (17.17)***	–0.047 (8.65)***
Sector-specific trends	No	Yes	No	No	Yes	No
Observations	170,600	170,600	110,016	92,339	92,339	49,391
Number of firms	37,130	37,130	26,468	24,155	24,155	14,375
R^2	0.07	0.07	—	0.05	0.06	—

Collateral, fixed assets/total assets; cost of sales, total cost of sales/total assets; inventories, finished and work in progress stocks/total assets; liquid assets, cash and liquid deposits/total assets; size, log of total assets.

Absolute value of *t*-statistics in parentheses. All regressions include as control variables: firm-fixed effects, year dummies, asset growth rates and age (not reported). Columns 2 and 4 include sector-specific time trends, and sectors are defined at three-digit Standard Industrial Clasification (SIC) level. Columns 3 and 6 use the GMM Arellano–Bond estimation procedure. GMM estimator uses first differences and includes up to three lags as instrumental variables *t*-statistic in parenthesis (*z*-statistic for GMM).

*, **, and *** significant at 10, 5, and 1%, respectively.

reduction in trade credit use of 4.03%. This is quite a large effect considering that the median of trade credit divided by total assets is 17.4%. These two results are consistent with the model's predictions, as firms should use more trade credit when they have less collateral and when they face additional liquidity needs. The results with respect to the control variables show that firms use more trade credit when they have higher levels of sales and inventories, probably reflecting a positive correlation between firm activity and trade credit use. The result on the inventories variable also could be related to the use of inventories as collateral. Columns 2 and 3 present some robustness checks of this specification. Column 2 adds as a control variable sector-specific time trends, to control for any differential behavior at the sectoral level that might not be fully captured by the year dummies. The effect of this inclusion is relatively small. Column 3 includes a lagged dependent variable and uses the Arellano–Bond (GMM) method to get a consistent estimator. This estimator uses an instrumental variable GMM procedure to avoid the problems of endogeneity associated with using a fixed-effects estimator when there is potential autocorrelation in the dependent variable. The Arellano–Bond estimator also corrects for any contemporaneous endogeneity problems, not just for those associated with the inclusion of a lagged dependent variable.[31] The results are qualitatively very similar, except for the fact that the coefficient on the size variable becomes smaller and statistically not significant. The coefficient on the lagged dependent variable is relatively small and statistically significant.

Columns 4–6 present the same regressions but use the level of trade credit divided by total debt as the dependent variable. The evolution of this variable shows the relative changes in trade credit with respect to other debt sources. The results show a strong negative correlation between trade credit and the levels of collateral. They also show a positive relationship between levels of liquid assets and trade credit. This result goes against the results of the model. However it could be driven by a positive correlation between trade credit and precautionary saving or by higher levels of both trade credit and liquid assets being associated with higher levels of activity for transaction purposes.[32] Given that trade credit is not the only source of additional liquidity for firms, it also could be that there is comovement of several borrowing sources whenever firms experience temporary liquidity shocks. To explore this issue further, the next

[31] The Arellano–Bond estimator allows for the unbiased and consistent estimation of the coefficients of a model of the type $y_{it} = \delta y_{it-1} + \beta x_{it} + \varepsilon_{it} + \delta_i$ where ε_{it} is a standard error term and δ_i is an individual error term, by taking first differences and using several lagged dependent variables (in first differences also) as instruments. See Arellano and Bond (1991).

[32] Ferris (1981) saw trade credit as a means of payment used to reduce transaction costs when the timing of the arrival of new supplies is uncertain. This is consistent with the existence of a free delayed payment period, like the first 10 days in the "2–10 net 30" deal. However, the model remains silent about why trade credit is so expensive and why firms are willing to pay such costs.

section substitutes the liquid assets variable for intertemporal measures of liquidity declines.

3.2.2 Liquidity shocks. The model predicts that trade credit should be higher whenever firms face unexpected liquidity shocks. A measure of liquid assets like the one used in Table 3 could simply be reflecting anticipated liquidity changes that should not have an effect on trade credit. For this reason, I substitute in Table 4 the measure of liquid assets for two measures of a liquidity shock that are quite standard in the existing literature. The measures are both dummy variables. The first measure takes a value of one whenever the firm faces a large drop in liquid assets (more than 10% as measured as a proportion of total assets which is considerable given that the average level of liquid assets is 12%). The second measure takes a value of one whenever there is a cut in dividend levels and zero otherwise. The results show how unexpected drops in liquidity lead to higher levels of trade credit in three out of four specifications. Only in the specification that relates a dividend cut to trade credit divided by total assets are the results not significant. The measure of trade credit divided by total debt is positively related to both measures of a liquidity shock. This shows that trade credit grows more than other forms of credit whenever firms face unexpected liquidity shocks.

To further explore the relationship between the use of trade credit and unexpected shocks, I run additional regressions relating trade credit to a measure of firm performance. Firm performance is measured using asset growth rates; this variable is closest in interpretation to the growth rates of the model. The model predicts a nonlinear relationship between trade credit and firm performance. The cost of trade credit can be very high if customers forego their early payment discounts. Therefore, customers will use costly trade credit as a financial instrument only when other forms of finance are scarce. When firms are growing fast and undertaking new investments, trade credit should grow, simply because other forms of finance may not be available. Also, when customers experience problems, they may need to finance a higher proportion of their purchase with trade credit and use late payment as a way to increase the amount of financing that they receive from their suppliers. Suppliers will be willing to finance their customers who are in trouble as long as the value of their relationship is higher than the cost of helping them. These two effects imply an expected "U-shaped" distribution of the relative levels of trade credit with respect to a "performance measure." The firms that are doing best, and the ones suffering slight problems, should be those that borrow more from their suppliers. To test this relationship empirically, I report two sets of regressions. The first two, shown in Figures 1 and 2 are nonparametric

Table 4
Liquidity shocks

	Trade credit/assets		Trade credit/total debt	
Dependent variables	1	3	2	4
Liquid assets drop	—	0.0035 (4.02)***	—	0.0109 (4.87)***
Dividend cut	–0.0006 (0.82)	—	0.0036 (2.20)**	—
Collateral	–0.1054 (40.72)***	–0.1060 (40.90)***	–0.3260 (55.82)***	–0.3271 (55.97)***
Inventories	0.1122 (38.76)***	0.1115 (38.46)***	0.0484 (6.51)***	0.0472 (6.35)***
Cost of sales	0.0013 (14.01)***	0.0013 (14.02)***	0.0104 (18.26)***	0.0104 (18.26)***
Size	–0.0182 (31.17)***	–0.0182 (31.19)***	–0.0231 (16.43)***	–0.0231 (16.43)***
Observations	205,780	205,780	113,099	113,099
Number of firms	39,599	39,599	26,468	26,468
R^2	0.05	0.05	0.05	0.05

Collateral, fixed assets/total assets; cost of sales, total cost of sales/total assets; dividend cut, dummy if dividends fell from last year nominal level; inventories, finished and work in progress stocks/total assets; liquid assets drop, dummy if liquid assets/total assets fell by more than 10% last period; liquid assets, cash and liquid deposits/total assets; size, log of total assets.

Absolute value of t-statistics in parentheses. All regressions include as control variables: firm-fixed effects, year dummies, asset growth rates, and age (not reported).

*, **, and *** significant at 10, 5, and 1%, respectively.

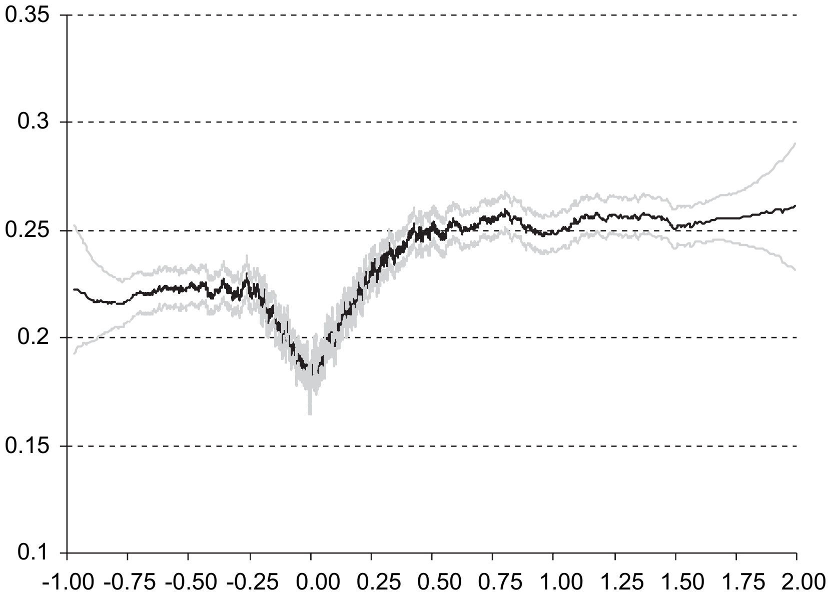

Figure 1
Trade credit/assets versus assets growth rate

regressions relating the level of *trade credit divided by assets* and *trade credit divided by total debt* to the growth rate of the assets of the firms in the sample.[33] The use of nonparametric regressions is justified for to capturing the expected nonlinear relationship between trade credit and firm performance.[34] The second two regressions are standard panel data regressions that include spline variables for eight splines of asset growth rates as summarized in Table 5. The coefficient on each spline variable corresponds to the slope of the piecewise linear function in the relevant

[33] Firms that have no activity have little or no trade credit (as they do not purchase anything). They also have growth rates that are close to zero. For this reason, I have not included in the estimation firms that declare themselves to be dormant, firms that are pure asset holders, and firms that declare zero sales or post exactly the same balance sheet for two consecutive years, to avoid the chance that they could artificially drive the results. Including these firms would induce us to estimate an unrealistic low level of trade credit for low growth firms.

[34] See Fan (1992) for a thorough explanation of the local linear estimation. With respect to other techniques [such as a Nadaraya–Watson estimator, Nadaraya (1964) and Watson (1964)], this type of nonparametric estimation has the advantage of being a consistent estimator even in the tails of the estimation and in the presence of frequency clustering among the data. This is particularly useful here, where the results for the firms in the left tail of the estimation are the most important and considering that the density of firms in different age intervals of the sample is not constant.

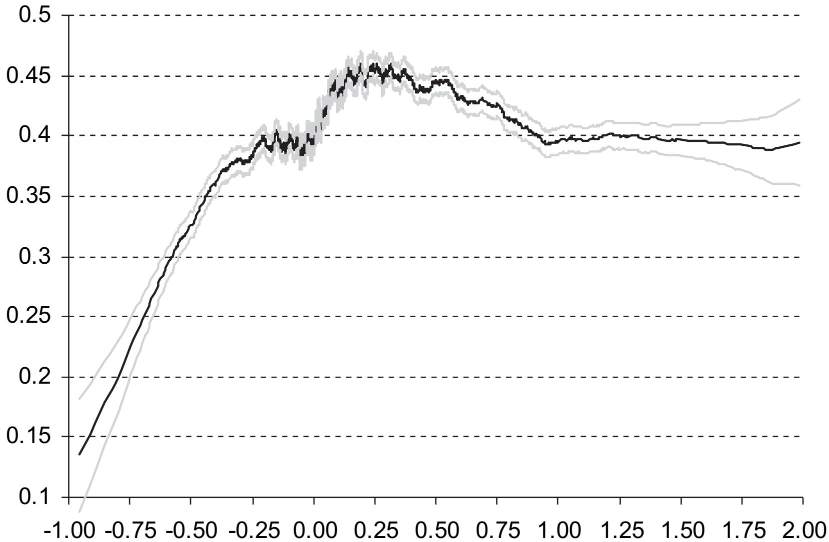

Figure 2
Trade credit/total debt versus assets growth rate

Table 5
Performance splines

	Trade credit/assets	Trade credit/total debt
Growth spline (–1 to –0.75)	0.1124 (1.27)	0.0844 (0.29)
Growth spline (–0.75 to –0.5)	0.0038 (0.15)	0.2984 (4.05)***
Growth spline (–0.5 to –0.25)	–0.0152 (1.51)	0.0889 (3.44)***
Growth spline (–0.25 to 0)	0.0296 (6.54)***	0.0869 (8.45)***
Growth spline (0–0.25)	0.0598 (16.43)***	0.0280 (3.58)***
Growth spline (0.25–0.5)	0.0281 (4.87)***	–0.0050 (0.40)
Growth spline (0.5–0.75)	–0.0042 (0.51)	–0.0362 (2.00)**
Growth spline (0.75–2)	0.0099 (2.86)***	0.0051 (0.67)
Liquid assets	–0.0904 (30.39)***	0.1175 (13.84)***
Collateral	–0.1128 (33.52)***	–0.2868 (37.95)***
Inventories	0.0951 (25.16)***	0.1024 (10.72)***
Cost of sales	0.0103 (34.13)***	0.0093 (15.23)***
Size	–0.0246 (29.39)***	–0.0489 (24.68)***
Observations	151,584	83,113
Number of firms	33,190	21,839
R^2	0.07	0.06

Collateral, fixed assets/total assets; cost of sales: total cost of sales/total assets; inventories: finished and work in progress stocks/total assets; liquid assets, cash and liquid deposits/total assets; size, log of total assets. Absolute value of *t*-statistics in parentheses. All regressions include as control variables: firm-fixed effects and year dummies (not reported).
*, **, and *** significant at 10, 5 and 1% respectively.

interval. Although the nonlinear regressions are more flexible in terms of capturing nonlinearities, the spline regressions can include as control variables all the relevant variables already included in previous tables.

The results with respect to *trade credit divided by total assets* show a clear "U-shaped" relationship between trade credit and asset growth rates. Trade credit is highest for the firms that grow at a faster pace. This is consistent with the fact that trade credit is relatively expensive. Firms use it only when they need to use all their borrowing capacity and have exhausted other available sources of finance (in this case, when they experience high growth rates). Also, newborn firms have higher levels of growth and higher levels of trade credit, as shown in the next section. The most interesting feature of the results shown in Figure 1 is on the left-hand side, where firms that experience slight problems (small–medium negative growth rates up to –30%) seem to have relatively high levels of trade credit as compared with firms that have low growth rates. This means that suppliers still lend to these firms that are suffering problems, so trade credit grows, or at least does not shrink at the same rate as assets do. This is evidence in favor of suppliers being seen as lenders of last resort. The aid that suppliers provide to their customers is probably not given by a direct monetary transfer but most likely by accepting late payment of already extended debts and by supplying more intermediate goods on credit. Firms in the middle range (zero growth and small positive growth rates) have relatively low levels of trade credit. In the model, this is justified because these are unsuccessful firms with low links to their suppliers. In practice, other complementary reasons also may be causing this slump. First, low growth firms may have smaller finance needs, so they can use cheaper ways of finance than trade credit. Second, firms that are not growing much may be buying relatively small amounts of intermediate goods, thus making it more difficult to have high levels of trade credit.

The results with respect to *trade credit divided by total debt* are less stark. Although trade credit seems to grow faster than other sources of funding for firms with high growth rates, there seems to be a constant ratio of trade credit to these alternative sources whenever firms experience low negative growth rates. Although it seems that different sources of finance are used to cope with small negative shocks, one has to keep in mind that, while other forms of finance (i.e. a credit line) would imply an additional cost whenever accessed, the use of late payment in trade credit quite often does not carry an explicit penalty. Figure 2 also shows that if firms experience large negative shocks, then trade credit seems to shrink faster than other forms of funding. In the model, this situation corresponds to a shock that is so large that the necessary additional funding from trade creditors exceeds the value of the relationship. Thus Proposition 2 is violated. The results in Table 5 are consistent with the ones in Figures 1 and 2. They show a higher use of trade credit for growing firms, although the evidence that they provide about suppliers helping their customers is weaker than the unconditional evidence of the nonparametric estimates.

3.2.3 Firm age. The main prediction of the model that one would like to test is whether trade credit is higher when the link between suppliers and customers is high. However, it is difficult to find an unambiguous variable that summarizes this link. One possibility is to measure the length of the relationship between suppliers and customers. Although many links already may be present from the first day of their commercial interaction, others may depend on learning-by-doing and on building a bilateral reputation. Even though there is no information in FAME–BVD about the length of the relationship between suppliers and customers, one can use the age of newborn firms as a proxy for this variable.

Figure 3 shows a local linear regression of *trade credit divided by total assets* as a function of the age of the firm for the entire sample. I compute the standard deviation of the estimator and present the 95% confidence interval. As shown, the level of trade credit grows quite a bit in the first year of the firm, then gradually decreases during the next periods. This is consistent with the prediction of the model. Customers do not receive much credit from their suppliers right away; it takes time to build the link with their suppliers that is necessary for borrowing. So far, other empirical studies based on linear regressions have found a negative relationship between trade credit and age. This corresponds to the negative slope from the fifth year onward shown in Figure 3. The nonlinear approach, also

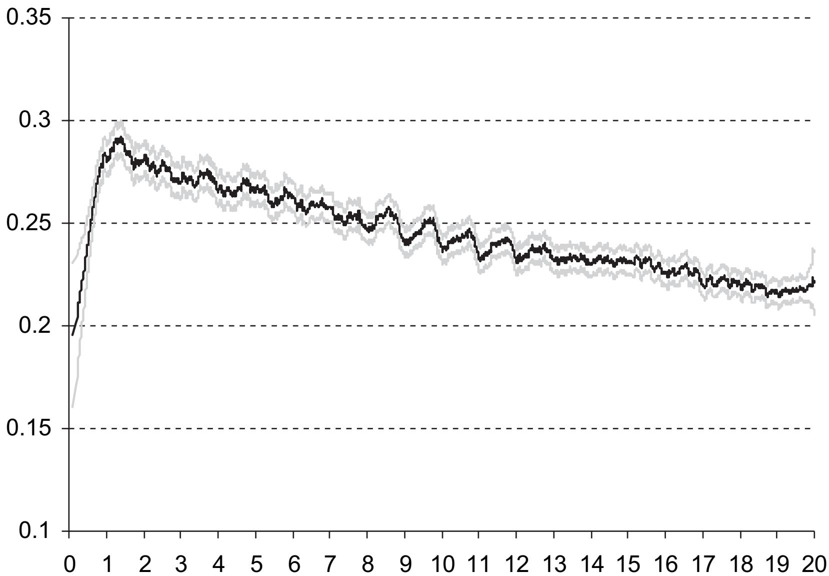

Figure 3
Trade credit/assets versus age of the firm

allows us to identify the initial increase in trade credit in the early years of a supplier–customer relationship. The 95% confidence interval reflects the lower density of firms in the left tail, but it is sufficiently narrow to allow us to accept a hump-shaped pattern. Figure 4 shows a similar regression but using *trade credit divided by total debt* as the dependent variable. Here the effect is more gradual: on average, trade credit starts at a relatively low level and then grows faster than other forms of funding during the first eight years of the firm's life. Again, the results confirm the implications of the model: with firms with older supplier–customer relationships having a larger share of trade credit in their total debt.

Two features seem to generate slightly different results from what is predicted by the model. First, the levels of trade credit of newborn firms are not zero. In the model, a newborn firm has zero trade credit because trade credit is assumed to be completely unenforceable and there are no links between suppliers and customers. In reality, trade credit is not completely unenforceable by law. So even if for new firms the suppliers are easy to substitute, then there is still scope for credit. In addition, significant links between suppliers and customers may already be in place at the very beginning of their interaction; for example, there may be one-off costs or search costs associated with finding a supplier, or the customer may already have a very detailed blueprint of the necessary intermediate goods, even at very early stages of the firm's life. There is

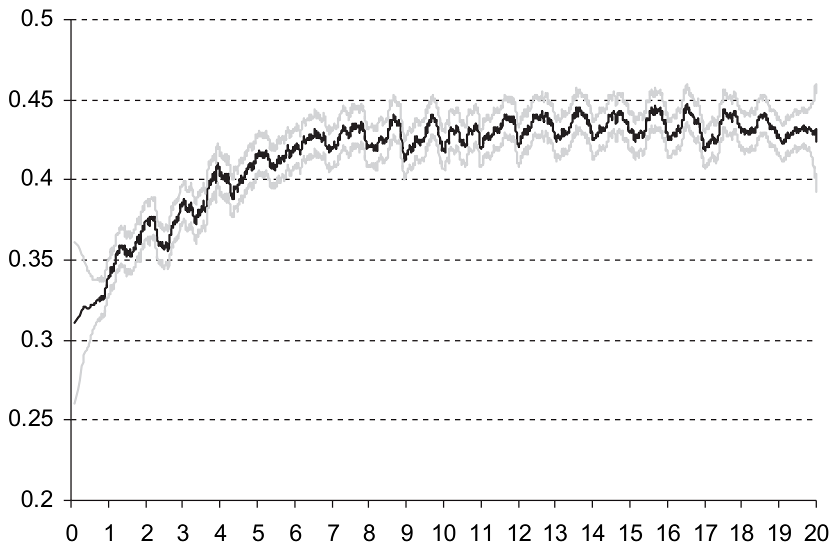

Figure 4
Trade credit/total debt versus age of the firm

Table 6
Age splines

Dependent variable	Trade credit/assets	Trade credit/total debt
Age spline (0–1)	0.0475 (4.85)***	0.0560 (2.96)***
Age spline (1–2)	−0.0019 (0.63)	0.0105 (1.66)*
Age spline (2–3)	−0.0033 (1.36)	0.0108 (2.12)**
Age spline (3–4)	−0.0036 (1.55)	0.0205 (4.23)***
Age spline (4–5)	−0.0042 (1.78)*	−0.0019 (0.39)
Age spline (5–6)	−0.0053 (2.25)**	0.0030 (0.62)
Age spline (6–7)	−0.0035 (1.47)	0.0055 (1.16)
Age spline (7–8)	−0.0035 (1.45)	0.0011 (0.24)
Liquid assets	−0.0985 (33.42)***	0.1171 (14.80)***
Collateral	−0.1346 (40.76)***	−0.3113 (44.43)***
Inventories	0.0824 (22.54)***	0.0885 (10.00)***
Cost of sales	0.0091 (31.48)***	0.0090 (15.24)***
Size	−0.0171 (22.97)***	−0.0308 (18.42)***
Observations	171,359	92,332
Number of firms	37,295	24,155
R^2	0.07	0.06

Collateral, fixed assets/total assets; cost of sales: total cost of sales/total assets; inventories, finished and work in progress stocks/total assets; liquid assets, cash and liquid deposits/total assets; size, log of total assets.
Absolute value of *t*-statistics in parentheses. All regressions include as control variables: firm-fixed effects and year dummies (not reported).
*, **, and *** significant at 10, 5, and 1%, respectively.

also a scope for positive levels of trade credit use among newborn firms because it can be used as a transaction device. The second main difference between the simulation and the results of the nonparametric regression is that, in the regressions, after the initial increase, the level of trade credit seems to go down as the firms grow older. In conjunction with the results of Figure 4, this implies that leverage in general is decreasing with firm age.

Table 6 summarizes the same regressions using splines and controlling for all the variables already present in Tables 2–4. The results are qualitatively very similar to the ones in Figures 3 and 4 with *trade credit divided assets* growing sharply on the first year of the firm and *trade credit divided by total debt* growing along several periods.

4. Conclusions

This article shows that the existence of trade credit may be justified as a result of the interaction between a supplier and a customer who engage in specific production processes in a context of limited enforceability of debts.

A certain technological specificity gives suppliers an advantage in enforcing noncollateralized debts. This advantage allows suppliers to lend beyond the maximum amount that banks are willing to lend. As a result, trade credit can exist even in the presence of a competitive banking sector. Customers are rationed in the market for bank credit, so trade credit allows them to increase their leverage. The extra enforceability power of suppliers comes from the fact that they can threaten to stop supplying intermediate goods to their customers. In the presence of some kind of product specificity, or a certain link between the supplier and the customer, finding a new supplier is costly, so customers will pay back their debts before they switch to another supplier.

However, this link works both ways. Not only customers are more willing to repay their suppliers but also suppliers will forgive debts and extend the maturity period of their credit when customers experience temporary liquidity shocks that may threaten their survival. In practice, firms in financial distress generally delay the payment of their trade credit due. This late payment rarely carries a monetary penalty or a cut in the flow of intermediate goods to the debtor. Their suppliers are effectively providing liquidity (as a continuous flow of intermediate goods sold on credit) as a means of increasing the survival chances of their customer. The model predicts that this type of insurance is more likely when the links between buyers and sellers are stronger; in other words, suppliers are more likely to help their customers if it is very costly for them to lose a customer.

Even though the model seems to be describing technological specificity, the ties between the supplier and the customer are not modeled explicitly; broader industrial links that are not strictly technological would still sustain the results of this analysis. Any kind of sunk cost (legal procedures, bargaining costs, search costs, etc.) incurred in starting a new commercial relationship, or production processes that benefit from learning-by-doing, or the build-up of reputation and trust between commercial partners, would have similar effects.

The implications of the model are supported by the empirical evidence. The evolution of trade credit levels with the age of the firm shows that suppliers do not lend much to their customers at the beginning of their commercial relationship but that the levels of credit build up as the relationship evolves. The build up of trade credit in the early years of a firm reinforces the interpretation that trade credit results from the existence of some degree of specificity between a supplier and her customers. The results are consistent through a set of complementary estimates that address possible nonlinearities, firm heterogeneity, and the possible presence of endogeneity problems. Trade credit seems to be more prevalent when firms have low levels of liquidity; in particular, the levels of trade credit are higher when firms experience liquidity shocks.

The empirical results also show that trade credit is used at the margin, when other forms of credit have already been exhausted. High growth firms, which need as much finance as possible, together with firms experiencing liquidity problems, get a higher proportion of credit from their suppliers. This seems a reasonable strategy, given that using trade credit beyond the date that qualifies for an early payment discount is a relatively expensive form of finance. Finally, the proportion of trade credit with respect to other forms of finance seems to be highly dependent on the levels of collateral. Higher levels of collateral mean a lower proportion of trade credit. This is consistent with the hypothesis of firms exhausting other available forms of credit before using trade credit as a source of finance. These results are consistent with the theoretical model developed in the first part of the article and challenge some of the results of other theoretical models.

Appendix

Eliminating wealth as a state variable

To obtain an expression for value function (1) that is independent of the customer's wealth, one has to first find the values of I_t^S, ϖ_{t+1}^h, and ϖ_{t+1}^h that are linear in the initial wealth of the customer, ϖ_t. Then, substituting into (1), the expression can be simplified.

Under the conjecture that customers invest all available funds $I_t^S = \varpi_t + \beta\theta I_t^S + I_t^S d_s$; that is, investment equals the wealth of the customer plus the maximum borrowing capacity from banks $\beta\theta I_t^S$ plus the inputs financed by the supplier at the beginning of the period $I_t^S d_s$. This means that, $I_t^S = \varpi_t \frac{1}{1-\beta\theta-d_s}$; that is, the wealth of the customer times the necessary downpayment per investment unit. Also, the levels of final wealth, depending on having a high or low return, are respectively: $\varpi_{t+1}^h = Y_h I_t^s - \theta I_t^s - p_{sh} I_t^s - cI_t^S = (R_h - p_m)I_t^s$ and $\varpi_{t+1}^l = Y_l I_t^s - \theta I_t^s - p_{sl} I_t^s - cI_t^S = (R_l - p_s)I_t^s$. That is, the return from previous period production minus the repayment to banks, the repayment to trade creditors, and consumption. Therefore, $\varpi_{t+1}^h = \frac{(R_h - p_m)\varpi_t}{1-\beta\theta-d_s}$ and $\varpi_{t+1}^l = \frac{(R_l - p_s)\varpi_t}{1-\beta\theta-d_s}$. Substituting into Expression (1) generates a value function that does not depend on ϖ_t. The same substitutions in Expression (2) lead to Expression (4).

Proof of Proposition 1

The customer has two basic strategies when using the startup technology: one is to invest all possible funds in the project and the other is to invest minimum funds in the project (i.e., almost zero) and invest all funds only when using the mature technology. All other strategies are linear combinations of these two. So, by proving that investing all funds dominates investing almost zero, I will prove that it dominates all other strategies. To do so, I use the "unimprovability principle" that says that a strategy is optimal if there is no "one-shot" deviation that improves the strategy. I compare the strategy of investing all possible funds with the "one-shot deviation" strategy of investing minimum funds in the first startup period and then investing all possible funds in any other period (even if the prototype strategy is used again). If this "one-shot deviation" is not an improvement, then the "unimprovability principle" guarantees that deviating in any further period is suboptimal too. The value function of investing an infinitesimal amount for only one period is

$$S_\epsilon = \frac{\delta}{\beta}[\gamma M + (1-\gamma)S]. \tag{12}$$

I want to show that there exists a value $\delta^* \epsilon (0,\beta)$, such that for every $\delta < \delta^*$ it is optimal to invest all available funds, even when using the prototype technology.

When $\delta = \beta$, then $S_\epsilon = [\gamma M + (1-\gamma)S] > S$. Evaluating $\frac{S_\epsilon}{S}$ using (3) and (12) and the fact that $d_s = p_{sh} = p_{sl}$; the expression is $\frac{S_\epsilon}{S} = \frac{1-\beta\theta}{\beta}\frac{\gamma M+(1-\gamma)S}{c+[\gamma(R_h-p_{sh})M+(1-\gamma)(R_l-p_{sl})S]}$. Given that both M and S tend to zero as δ goes down toward zero, it is easy to see that $S > S_\epsilon$ as δ tends to zero. In fact, one can solve for the value δ^* that makes $S_\epsilon = S$, which is $\delta^* = \beta\frac{S}{S+\gamma(M-S)}$. For $\delta < \delta^*$, investing as much as possible in the prototype technology is the optimal strategy. Given that $\frac{S}{S+\gamma(M-S)}\epsilon(0,1)$, and $M > S$, and that both M and S are positive and increasing in δ, it can be seen that $\delta^*\epsilon(0,\beta)$. Moreover, the equilibrium function for $S_\epsilon - S = 0$ is a continuous quadratic function in δ, so there is a single value for δ in the interval $(0,\beta)$ such that $\delta^* = \beta\frac{S}{S+\gamma(N-S)}$. This is because there are two solutions for δ^* such that $S_\epsilon - S = 0$, but given that $S_\epsilon > S$ if $\delta = \beta$ and $S_\epsilon < S$ when δ tends to 0, then only one of the solutions lies between 0 and β. This means that there is a unique $\delta^*\epsilon(0,\beta)$. So it is also true that if $\delta > \delta^*$, investing as little as possible in the startup technology is the optimal strategy.

With respect to the mature stage, the bargaining game between supplier and customer leaves the customer indifferent between the mature stage and the startup stage. Therefore, from the point of view of the customer, there is also an incentive to invest as much as possible.

Proof that forgiving part of p_{hm} is suboptimal

The value function for the supplier just before being repaid is $p_{hm} + (R_h - p_{hm})m$, but m equals zero, given that d_m transfers all the future surplus to the customer. Any forgiveness of part of p_{hm} can, in fact, be written as an increase in d_m keeping p_{hm} constant. The derivative of m with respect to d_m, keeping the continuation m constant (i.e., a one-shot change in d_m) is $-\frac{1}{(1-\beta\theta-d_m)}$ that is negative as long as $d_m < 1 - \beta\theta$, any d_m larger that $1 - \beta\theta$ would mean infinite investment from the point of view of the customer, but Assumption 4 makes that a negative NPV option from the point of view of the supplier. So, any increase in d_m would make m negative, thus reducing the supplier value function.

Proof of the dominance of "supplier insurance" and "bank insurance" over precautionary saving

The relevant value function for the customer in the mature stage is

$$M^{ps} = \frac{1}{1-\beta\theta-d_m^{ps}+\beta L}\delta(c + \{\alpha[R_h - p_{mh}^{ps} + (1-\upsilon)L]M^{ps} + (1-\alpha)[R_l - p_{ml}^{ps} + (1-\upsilon)L]S^{ps}\}). \tag{13}$$

I use the superscript ps to denote precautionary saving. When using the startup technology, the value function remains the same. Using precautionary saving is equivalent to, paying a premium βLI at the beginning of the period and getting it back with probability $(1-\upsilon)$. In expected terms, this is equivalent to paying a premium υL and saving $(1-\upsilon)L$ for one period. Bank insurance entails paying υL and no saving. Proposition 1 and Assumption 6 make saving suboptimal even in the startup stage, so it is also suboptimal in the mature stage. Thus, bank insurance dominates precautionary saving.

Proof of Proposition 4

The expressions below (marked by the superscript b) show the value function in the mature stage if the customer decides to use bank insurance.

$$M^b = \frac{1}{1-\beta\theta-d_m^b+\beta\upsilon L}\delta\{c + [\alpha(R_h - p_{mh}^b)M^b + (1-\alpha)(R_l - p_{ml}^b)S^b]\}. \tag{14}$$

The leverage factor of the customer's firm has gone down only by υL, which is the expected value of the shock. The relevant value functions for the supplier are in the case of bank insurance is

$$m^b = \frac{1}{1-\beta\theta-d_m^b}(-d_m^b+\beta\{\alpha[(R_h-p_{mh}^b)m+p_{mh}^b]+(1-\alpha)(R_l-p_{ml}^b)s+p_{ml}\}]. \quad (15)$$

The solutions for p_{mh}^b and d_m^b for this case, taking into account that $M(R_h-p_{mh}^b)=SR_h$, $n=0$, and Equations (5) and (3) are

$$d_m = \beta\alpha p_{mh}$$
$$p_{mh} = \frac{R_h}{1-\beta\theta+\delta(R_h-R_l)(\alpha-\gamma)}[d_m+\delta(\alpha-\gamma)(R_h-R_l)].$$

So $d_m^b = d+\beta\upsilon L$ and $p_{mh}^b = p_{mh}$. This implies that, in pure cost terms, both types of insurance are equivalent.

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