Trade Credit and Credit Rationing

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Asymmetric information between banks and firms can preclude financing of valuable projects. Trade credit can alleviate this problem by incorporating in the lending relation the private information held by suppliers about their customers. Incentive compatibility conditions prevent collusion between two of the agents (e.g., the buyer and the seller) against the third (e.g., the bank). Consistent with the empirical findings of Petersen and Rajan (1995), firms without relationships with banks resort more to trade credit, and sellers with greater ability to generate cash flows provide more trade credit. Finally small firms react to monetary contractions by using trade credit, consistent with the empirical results of Nilsen (1994).

As noted by Mian and Smith (1992, 1994) credit extended by a seller who allows delayed payment for his products, or "trade credit," represents a substantial fraction of corporate liabilities, especially for middle–

Many thanks for helpful comments to the referee and the editor, Rick Green, and to seminar and conference participants at EDHEC, HEC, Toulouse University, Université Libre de Bruxelles, the René Roy Economic Theory Seminar, the CEPR Conference on Industrial Organization and Finance at San Sebastian, the JFI-ABN–AMRO Symposium on Financial Intermediation, the ENTER Jamboree in Mannheim, and the Western Finance Association Meetings in Aspen, especially Ron Anderson, Sudipto Bhattacharya, Luis Cabral, Bernard Caillaud, Matthias Dewatripont, Robert Garibobo, Kathleen Hagerty, Bruno Jullien, Jean Jacques Laffont, Guy Laroque, David Martimort, Maureen O'Hara, Raghu Rajan, Anjan Thakor, and Jean Tirole. A previous version of this article was circulated and presented under the title, "Why do firms use trade credit? A signalling model." Our initial approach of the topic studied in this article greatly benefited from discussions with Pascale Viala. Address correspondence to Bruno Biais, IDEI, Université de Toulouse, Place Anatole France, 31000 Toulouse, France; e-mail: biais@cict.fr.

The Review of Financial Studies Winter 1997 Vol. 10, No. 4, pp. 903–937

market companies. For example, Mian and Smith (1994) report that "for the 3,550 non financial Nasdaq firms covered by COMPUSTAT, accounts payable were 26% of corporate liabilities, at the end of 1992." Why do those companies rely on their suppliers to obtain financing, rather than specialized financial intermediaries such as banks or financial markets?

There are a number of empirical findings suggesting that firms suffering from credit rationing use trade credit. Petersen and Rajan (1994a, b, 1995) find that firms which are less likely to be bank credit constrained tend to rely less on trade credit.[1] Nilsen (1994) finds that during monetary contractions, small firms, which Gertler and Gilchrist (1993) suggest are likely to be particularly bank credit rationed, react by borrowing more from their suppliers. Also, trade credit tends to be used less in economies where relationships between banks and firms are strong, such as Germany [see Breig (1994)], or where financial markets play an information transmission and monitoring role, such as the United States, and more in economies where financial markets are less developed and bank firm relationships are more distant, such as France.

These empirical findings raise a puzzle. Why is trade credit available when bank credit is rationed? Suppliers are themselves more likely to be credit constrained and to have high cost of funds than banks. Hence when banks cannot lend, suppliers should not be able to lend either.

One answer to this puzzle is that lending through trade credit serves a nonfinancial role. The use of trade credit to price discriminate has been analyzed theoretically by Brennan, Maksimovic, and Zechner (1988), and both theoretically and empirically by Petersen and Rajan (1995). Also Long, Malitz, and Ravid (1994) show that trade credit can serve as a warranty for product quality. Another answer to this puzzle is that suppliers have some comparative advantage in lending. For example, it is reasonable to assume that suppliers place more value on the collateral of their customer than the bank would [see Mian and Smith (1992)]. One should notice however that trade credit is heavily used in France, while under the French bankruptcy law trade creditors usually get practically nothing in the case of bankruptcy [see Biais and Malécot (1996)]. Alternatively it is plausible that sellers have private information that the bank does not have. [This point is also made by Mian and Smith (1992).]

The present article starts from the assumption that suppliers have private information about their customers, and shows that trade credit

[1] Similarly, in the case of France, Biais, Hillion, and Malécot (1995) find empirically that small firms, which are more likely to be credit rationed, tend to rely more on trade credit.

can facilitate aggregation of the supplier's information with the bank's information and thus alleviate an information asymmetry which otherwise would preclude financing of positive net present value (NPV) projects.

The main features of the model are as follows. Consider the market for an input good. There are different types of buyers. Some are "good." The projects for which they need the input have positive NPV. Other buyers (the "bad") have negative NPV projects. The buyers privately know their own type, while the bank and the supplier only have different signals about it. When bank credit is the only source of financing, if the proportion of negative NPV buyers is large and if the information of the bank is not precise, all buyers, including the "good," are denied credit. This prevents them from buying the input and investing in positive NPV projects. We will hereafter refer to this credit market breakdown due to asymmetric information as credit rationing.[2]

In contrast, when trade credit can be used and if sellers have sufficient expected future cash flow to pledge as collateral, there exists a separating equilibrium where sellers extend trade credit to their customers only if they have received a good signal, and where the positive information contained in the availability of trade credit induces the bank to also lend, if it also has received a good signal. In this context, trade credit plays an important role because it is a credible way for the seller to convey its private information to the bank. If the seller is willing to extend trade credit, and thus to bear the default risk of the buyer, it must be that it has good information about the latter. On observing this, the bank updates positively its beliefs about the buyer, and therefore agrees to lend. In other words, trade credit enables the private information of the seller to be used in the lending relationship, and this additional information can alleviate credit rationing due to adverse selection.

To carry out this analysis, we solve for the Bayesian Nash equilibrium of the three-agent game played by the bank, the seller, and the buyer. There is a double-sided information asymmetry, since the bank does not know the signal of the seller, and the seller does not know the signal of the bank. This raises the possibility of collusion between two agents against the third. For example, consider the case where the seller would collude with the buyer. In this case, the seller would extend trade credit to the bad–type buyer, thus sending a deceivingly reassuring signal to the bank to induce it to grant excessively

[2] Although this definition of the term is slightly different from the original definition of Stiglitz and Weiss (1981), it is in the spirit of their analysis to the extent that it relates credit market breakdown to asymmetric information.

cheap credit. The seller and the buyer would then use side payments, under the cover of their business relationship, to share the surplus thus extracted from the bank. For trade credit to play an information transmission role, such collusion must be ruled out. This is the case in equilibrium under the incentive compatibility condition that the amount of trade credit be sufficiently large with respect to the bank loan that the cost of collusion for the seller, which is increasing in the amount of trade credit, be lower than the surplus extracted from the bank, which is increasing in the bank loan. Thus one contribution of our article is to import the study of collusion and collusion–proofness [initiated by the seminal work of Tirole (1986, 1992)] into the analysis of financial contracting.

Our theoretical analysis of the link between information-motivated trade credit and information-motivated bank credit rationing provides an interpretation for a number of stylized facts:

- In our model, consistent with the empirical results of Petersen and Rajan (1995), firms which do not suffer from credit rationing do not use trade credit, while firms for which asymmetric information generates credit rationing react by using trade credit. Also, consistent with the empirical evidence in Nilsen (1994), we find that when the interest rates increase (because the monetary policy is tightened), small firms react by using trade credit to avoid credit rationing.
- Corporation managers often claim that if they had not extended trade credit they would not have been able to sell. Consistently with this remark, in our model, when the buyer does not have cash and is bank credit constrained, in absence of trade credit it could not buy the good from the seller. Yet by extending trade credit the seller enables the buyer to raise the funds necessary to purchase the good.
- Our model also includes an analysis of the way sellers refinance receivables using bank credit. We show that such refinancing (and, by the same token, the extension of trade credit) is possible only if the seller has sufficient expected cash flows to pledge as collateral against its bank borrowings. This is consistent with the empirical findings of Petersen and Rajan (1995) that more profitable sellers extend more trade credit. Note that our analysis of refinancing contrasts with Freixas (1993). In both articles the banks and the seller are assumed to have private signals about the buyer. Unlike in the present article, in Freixas (1993) the seller and the bank have equal access to outside financing at the same cost. Hence refinancing is unnecessary.
- Finally note that in our analysis, consistent with empirical obser-

vations, trade credit is used in spite of the high interest rates implicit in delayed payment prices. In our model some buyers borrow both from the bank and their supplier. The rate at which they borrow from the latter is larger than the bank rate. It might seem paradoxical that firms would use simultaneously two sources of financing, one being more expensive than the other. But if they did not use trade credit, then the information from the seller could not be conveyed, and the relatively low bank rate would not be granted. Thus we offer an interpretation for the fact that trade credit is used even though it is costly.[3]

In the next section we present the model. In Section 2, the equilibria are analyzed. In Section 3, our results, and in particular their empirical content, are discussed. Concluding comments are in the final section. Proofs are in the Appendix.

1. Model

1.1 Agents

We consider three types of agents: banks, buyers, and sellers. The three types of agents are risk neutral and rational. For simplicity we assume that the banks and the sellers are competitive and earn zero expected profits. The cost of funds for the banks is r which is equal to 1 plus the interest rate at which the bank can borrow. The buyers and the suppliers can apply for loans from the banks. Credit granting (or rationing) and interest rates for the buyer and the seller are endogenous.

To operate the buyer needs to invest one unit of input in its production process at the beginning of the period. If undertaken, this investement generates a random cash flow at the end of the period. At the beginning of the period the buyer has no cash and needs to borrow to purchase the input.

The sellers can produce this unit of input at a unit cost. They also do not have cash. They can cover their production cost either by receiving cash payment, or, if they obtain only delayed payment, by borrowing from the bank. In addition to its interaction with one buyer (modeled in the article), the seller is also assumed to have another exogenous source of income, which, at the end of the period, generates cash flow

[3] This is related to the pecking order analyzed in Petersen and Rajan (1994a) whereby firms first use relatively cheap sources of financing, such as retained earnings or bank credit, and then resort to the more expensive trade credit when these cheaper sources of financing are no longer available. The similarity is that in our model trade credit is used when bank credit alone cannot be used. The difference is that in our model the causality link also goes the other way: the availability of trade credit facilitates the access to bank credit.

A with probability δ, or 0 with probability $1 - \delta$. This cash flow can be pledged as collateral against the seller's bank borrowings, needed to finance trade credit. Should the buyer default on trade credit, then the seller would have to use this cash flow A to repay the bank.

1.2 Information and cash flows

There are two types of buyer. The good type has access to a positive NPV project, generating cash flow H with certainty. The bad type only has access to a negative NPV project, generating H with probability p, where $pH/r < 1$. The buyer knows its type, while the bank does not have perfect information on it. For example, the buyer could be a start-up venture, without relationships with banks.[4] The proportion of good types is π, while the proportion of bad types is $1 - \pi$.

The bank and the seller have private information about the buyer's type. If the buyer is bad then the signal of the seller, denoted θ, takes the value 1 with probability μ and 0 with probability $1-\mu$. If the buyer is good then the signal of the seller always takes the value 1. Hence, conditionally on the signal of the seller being good, the probability that the buyer is good is

$$\Pr(good \mid \theta = 1) = \frac{\pi}{\pi + (1 - \pi)\mu},$$

while, conditional on the signal of the seller being bad, the probability of the buyer being bad is 1. This assumption is analogous in our simple discrete model to the monotone likelihood property. Indeed the ratio of the probability of a good signal to the probability of a bad signal is larger for the good type than for the bad type.

The larger μ is, the larger is the probability that the bad buyer can receive a good signal, and the lower the precision of the seller's information. That only the bad buyers can be misclassified as good, ($\Pr(\theta = 1 \mid \text{bad}) = \mu > 0$) while the good cannot be misclassified as bad ($\Pr(\theta = 0 \mid \text{good}) = 0$), is assumed for simplicity only. Qualitatively identical results would be obtained if the good buyers could also be misclassified, as long as the seller's signal would be informative.

The information structure of the bank is similar to that of the seller. If the buyer is bad, the signal of the bank, denoted γ, takes the value 1 with probability λ and 0 with probability $1 - \lambda$. If the buyer is good then the signal of the bank always takes the value 1. Hence, conditional on the signal of the bank being good, the probability that

[4] Rajan (1992) and Petersen and Rajan (1994a) show that relationships with banks facilitate the access to credit.

the buyer is good is

$$\Pr(good \mid \gamma = 1) = \frac{\pi}{\pi + (1-\pi)\lambda},$$

while, conditional on the signal of the seller being bad, the probability of the buyer being bad is 1.

We assume that conditional on the buyer's type the signals of the bank and the seller are independent. Also the random cash flow obtained by the seller from his other activities (0 or A) is independent of the buyer's type.

1.3 Bank credit rationing

Consider the situation where there is no trade credit. If it obtains bank financing, the buyer purchases the input. Because of Bertrand competition, the cash price paid by the buyer for the input is equal to the constant unit production cost: 1. The bank uses its own signal (γ) to decide whether to extend trade credit. It is not willing to lend when its signal is bad, because in this case the buyer is known to have a negative NPV project. If the bank has observed a good signal ($\gamma = 1$), its break-even rate is

$$r_p = r\frac{\pi + (1-\pi)\lambda}{\pi + (1-\pi)\lambda p}. \tag{1}$$

This rate is larger than the bank's cost of funds, because there is a chance that the buyer is bad and will default. The break-even rate for the bank (conditional on its own signal) is too large to be covered by the cash flow of the good buyer if

$$H < r\frac{\pi + (1-\pi)\lambda}{\pi + (1-\pi)\lambda p}. \tag{2}$$

When Equation (2) holds, the average buyer has negative NPV. This is the case when there are many "lemons" in the population (i.e., π is low) or if the default risk of the buyer is large (i.e., p is low), or if the bank has imprecise information (λ is high). This type of situation could arise in industries which are globally not very profitable, but contain a few efficient firms that are difficult to identify.

If Equation (2) holds, the good buyer fails to obtain financing, although it has a positive NPV project, because of asymmetric information and the presence of the negative NPV bad buyers. Hereafter we will assume that this is the case, so that when only bank information and bank credit can be used there is credit rationing. This raises the issue whether trade credit can be used to alleviate credit rationing.

1.4 Trade credit

Instead of requiring cash payment for the unit of input it supplies, the seller can accept delayed payment, at the end of the period, for a fraction α of the purchase. We refer to this as trade credit.

Extending trade credit leads the seller to incur some additional administrative costs. Mian and Smith (1992, 1994) provide a comprehensive economic analysis of these costs. In particular they show that the seller must devote some time and energy to assessing the credit risk of the buyer and structuring the delayed payment contract. The seller must also incur some costs to collect the payment from the buyer. To represent these costs in a simple way, we assume that, when \$1 is payed by the buyer to the supplier as a result of trade credit, the seller's net cash inflow is only $k <$ \$1. Admittedly banks also incur costs when lending. But these costs are likely to be lower than for the seller, reflecting the specialization of the bank in credit evaluation and collection. For simplicity we normalize them to zero. That the supplier incurs larger transaction costs than the bank, when extending credit, will lead to trade credit being more expensive than bank credit for the buyer. In the analysis below we will show that in spite of this cost differential buyers prefer to rely (at least partially) on trade credit.

Because the seller does not have cash initially to cover the unit production cost, if it extends trade credit for a fraction of the purchase (α), it must borrow this amount from the bank. To obtain this loan, it can pledge its cash flow from other activities (A) as collateral to be used to repay the bank should the buyer default and fail to pay the seller. Denote as r_S the rate at which the bank lends to the seller. The cash flows for the buyer and the seller are summarized in Table 1.

Our modeling of bankruptcy cases is drastically simplified. We abstract from bankruptcy costs. Debtors meet their obligations by paying out any cash they have, but there is limited liability. In addition, since the buyer obtains either H or 0, we need not take into account the seniority of the bank and the trade creditor's loans. It could be interesting to extend our analysis to take into account more realistic features of the bankruptcy process. This is left for further research.[5]

1.5 The extensive form of the game

The extensive form of the game is as follows:

1. Nature decides the type of the buyer and the realization of the signals.

[5] Wilner (1994) studies the impact of features of the bankruptcy law on the interest rate implicit in trade credit.

Table 1
Cash flows for the buyer and the seller at time 1 and time 2

Time 0 cash flows for the buyer:
At time 0, the buyer has no cash available.
A fraction $(1 - \alpha)$ of the purchase is paid cash.
To finance this purchase, the buyer borrows $1 - \alpha$ from the bank at rate r_B.
A fraction α of the purchase is made on credit, against payment P_{TC} at time 1.
Time 0 cash flows for the seller:
The seller must borrow α from the bank to finance the trade credit it extends.
The rate at which the bank lends to the seller is r_S.
Time 1 cash flows for the buyer:
At time 1 the "good" buyer obtains cash flow H, while the "bad" buyer obtains cash flow H with probability p and 0 with the complementary probability.
If the cash flow H is generated, then the buyer repays the bank $((1 - \alpha)r_B)$, and the seller repays (αP_{TC}). Else the buyer goes bankrupt.
Time 1 cash flows for the seller:
Since we have assumed collection costs (k), when the seller is paid by the buyer, it only obtains in net $k\alpha P_{TC}$.
In addition, with probability δ, the seller generates cash A (independent of the buyer's project), and with the complementary probability the seller generates 0.
If the seller has cash flow available it repays the bank up to (αr_S).
If the seller cannot fully meet the obligation to repay αr_S, it goes bankrupt.

2. The bank and the seller privately observe their signals.
3. The bank and the seller make simultaneous and contingent offers:
    - The bank offers a loan to finance $1 - \alpha$ of the purchase at rate r_B, contingent on its signal and on the seller supplying trade credit for the remaining fraction of the purchase.
    - The seller offers trade credit for a fraction α of the purchase, sold at the delayed payment price P_{TC}, contingent on its signal and on the bank financing the complementary fraction of the purchase.
4. If the seller and the bank extend credit, for α and $1 - \alpha$, respectively, the project is undertaken.
5. Finally, at period 2, if cash flows are generated, loans are paid back.

The assumption that the bank and the seller make simultaneous offers, contingent on each other's offers, attempts to capture in a simple way the following stylized facts.[6] On the one hand, when providing loans, banks can, and in practice do, examine in detail whether the suppliers of the firm accept to provide trade credit and for what amount. On the other hand, since the amount lent by the supplier is not sufficient to fully finance the project, if the bank refused to pro-

[6] Note that we would have obtained identical results if we had made the alternative assumption that the seller moved first and made a trade credit offer contingent on the bank providing the complementary loan.

vide complementary financing, the project could not be undertaken and trade credit would not be used.

2. Separating Equilibria

In this section we analyze separating Bayesian Nash equilibria, where the buyer obtains trade credit and bank credit and can undertake the project if and only if both signals (θ and γ) are positive. Two remarks are in order about these separating equilibria:

Bad buyers with two good signals obtain financing. In that sense there is not full separation, since bad types with two good signals are pooled with good types. In spite of this partial pooling, for simplicity we will refer to the equilibrium we analyze as "separating" rather than semiseparating. Note that in the context of the present model, it is not possible to construct strongly separating equilibria, ruling out financing of bad types even when they have two good signals. Indeed, since there is limited liability and since the payoff of the buyer who does not get financing is 0, bad types with good signals would always find it attractive to imitate good types.

If there exists a separating equilibrium, credit rationing is alleviated since good buyers have access to financing. This is due to our assumption that good buyers always obtain good signals. In a variation of our model where good buyers could obtain a bad signal (θ or $\gamma = 0$), similar separating equilibria would obtain, except that good buyers with bad signals would be credit rationed. Note also that in the current version of the model, good buyers pay large interest rates since they are pooled with bad buyers who have obtained good signals.

2.1 Equilibrium conditions

2.1.1 Participation constraints. The following lemma summarizes the conditions on the bank rate to the buyer (r_B), the bank rate to the seller (r_S), the delayed payment price offered by the seller to the buyer (P_{TC}), and the percentage of trade credit (α) such that the bank and the seller make zero expected profits.

Lemma 1. *In the separating equilibria where (i) the seller offers trade credit only to buyers for which it has a good signal and (ii) the bank extends bank credit only if it has a good signal and the equilibrium amount of trade credit (α) is available, the bank rate is*

$$r_B = \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} r. \tag{3}$$

The price of the good sold on credit is

$$P_{TC} = \frac{1}{k} \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} r. \tag{4}$$

The interest rate at which the bank lends to the seller is r_S such that

$$r_S = \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} r - \frac{(1-\pi)\lambda\mu(1-p)}{\pi + (1-\pi)\lambda\mu p} \delta \min[r_S, A/\alpha]. \tag{5}$$

The interpretation of the lemma is as follows:

In the separating equilibrium, the signals of the bank and the seller are fully revealed, under the incentive compatibility conditions analyzed in the next subsection, and only the buyers for which both the bank's and the seller's signals are good obtain financing. Hence, since the bank is assumed to be competitive, it quotes an interest rate such that it expects to break even *conditional on both signals being good*. This rate is r_B in Equation (3).

As expected, the trade credit price, P_{TC}, is increasing in the credit collection cost borne by the seller.

Should the buyer default, and the seller generate cash flow A, then the seller would have to use this cash flow to repay the bank. Pledging this cash flow A as collateral enables the seller to borrow at a lower rate than the buyer, as can be seen by comparing Equations (3) and (5). The min operator in the last term of the right-hand side of Equation (5) reflects the use of the collateral A to repay up to αr_S.

Note that the formula for r_S in Equation (5) is only implicit because it depends on whether the seller goes bankrupt when the buyer defaults. Explicit solutions are provided below.

2.1.2 No collusion constraints. In this three-agent game there is scope for potential collusion between two of the agents against the third. For example, the supplier could be tempted to extend trade credit to the bad buyer, even if this exposed him to a large credit risk, because, contingent on the supplier extending trade credit, the bank would provide complementary financing (if it had observed a positive signal $\gamma = 1$) at an excessively low rate: r_B (because it would falsely believe that $\theta = 1$). The value thus extracted from the bank could then be shared between the seller and the buyer, and thus compensate the seller for risk taking. This surplus sharing could take place under the cover of the business relationship existing between the seller and the buyer (inflated price, services that the seller would pretend to perform for the buyer, etc.).

Symmetrically the buyer and the bank could be tempted to collude at the expense of the seller. Side payments from buyer to bank could similarly be covered by financial services the bank would pretend to provide to the buyer. Hence, in addition to the participation constraints, the contract must be such that the supplier and the buyer or the bank and the buyer have no incentive to collude against the third party.

Let T_B be the bribe from the buyer to the bank in case of collusion. The bank would be willing to collude if

$$p[(1-\alpha)r_B + T_B] > (1-\alpha)r,$$

where the left-hand side is the expected bribe and repayment if the bank colludes, while the right-hand side is the bank's cost of funds. Thus collusion is attractive for the bank if the bribe is large enough:

$$T_B > (1-\alpha)\left(\frac{r}{p} - r_B\right). \tag{6}$$

Collusion between the bank and the buyer is feasible if the cash flow (H) is large enough to pay this bribe:

$$\alpha P_{TC} + (1-\alpha)r_B + T_B < H. \tag{7}$$

Equations (6) and (7) imply that collusion between the bank and the buyer is *not* feasible if

$$\alpha P_{TC} + (1-\alpha)\frac{r}{p} \geq H. \tag{8}$$

[Note that the inequality in Equation (8) is weak. In interpreting this inequality, hereafter in the article we will work under the assumption that when agents are indifferent between colluding and not colluding, they choose not to collude.]

Substituting the price of the good from Lemma 1, the condition under which there is no collusion with the bank can be rewritten as

$$\alpha\left[\frac{r}{p} - \frac{1}{k}\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}r\right] \leq \frac{r}{p} - H. \tag{9}$$

The interpretation of Equation (9) is as follows: The right-hand side is the loss in economic value due to the investment in the negative NPV of the bad project. The left-hand side is the surplus extracted by the coalition of the bank and the buyer from the seller, which is equal to the amount lent by the seller (α) times the difference between the fair interest rate (r/p) and the interest rate implicit in the trade–credit price. Equation (9) states that there is no collusion if the loss in economic value due to collusion is larger than the surplus extracted from the seller. For this to be true it must be that the amount lent by the seller (α) is not too large.

If the collection cost for the seller is very large (i.e., if k was very low), or if the pooled information of the bank and the seller is very imprecise ($\lambda\mu$ very large), then collusion between the bank and the buyer would be trivially excluded because the left-hand side of Equation (9) would be negative. This could happen if the supplier was a small firm for which the cost of managing trade credit would be high, or if the supplier had a distant relationship with its customer and consequently imprecise information. To focus on the more interesting case where collusion with the bank is an issue, we henceforth assume that

$$\frac{1}{p} > \frac{1}{k}\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}. \tag{10}$$

Under Equation (10), the condition under which there is no collusion with the bank is

$$\alpha \leq \frac{\frac{r}{p} - H}{\frac{r}{p} - \frac{1}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}r}. \tag{11}$$

Note that if Equation (11) holds, then $\alpha < 1$ if

$$(1/k)\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} < H/r. \tag{12}$$

Equation (12) means that the delayed payment price (P_{TC}) should not exceed cash flow H. It holds if the information that both signals were good is precise ($\lambda\mu$ is low) and the transaction cost incurred by the supplier when extending trade credit is low (k is close to one). We will hereafter assume that this inequality holds to avoid complicating the analysis.[7]

Using symmetric arguments, we show in the Appendix that the condition under which there is no collusion between the seller and the buyer is

$$\alpha \geq \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} - \delta\frac{1-p}{p}[A/r - \max[0, A/r - \alpha r_S/r]]}{r_S/r - (2-1/k)\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}. \tag{13}$$

The condition for no collusion with the bank required that α not be too large. Symmetrically the condition for no collusion with the

[7] We have checked that in cases where it does not hold, there can exist separating equilibria with trade credit financing, and they have similar qualitative properties.

seller requires that α be large enough. This is because if α is large (and consequently $1 - \alpha$ is low), then the seller has a lot to lose and not much to gain from extending trade credit to the bad buyer.

The results obtained in this subsection are summarized in the next lemma.

Lemma 2. *In the separating equilibria where the seller and the bank extend credit only if both have observed good signals, there is no collusion between the bank and the buyer if the amount of trade credit is not too large and Equation (11) holds. Further, there is no collusion between the buyer and the seller if the amount of trade credit is sufficiently large and Equation (13) holds.*

Note that there is a tension between the two no-collusion constraints. No collusion with the seller requires that the amount of trade credit (α) be large enough, so that the seller would find it very costly to collude with the bad buyer, while no collusion with the buyer requires that the amount of bank debt ($1-\alpha$) be large enough so that the bank would find it very costly to collude with the bad buyer. Because of this tension, there can be cases where separating equilibria fail to exist. The next subsections delineate parameter values for which the two no-collusion conditions are consistent so that separating equilibria exist.

Consider the case where the two no collusion conditions are consistent, that is, where the upper bound in Equation (11) is above the lower bound in Equation (13). These upper and lower bounds define an interval of values of α which, jointly with the participation constraints summarized in Lemma 1, characterize a continuum of separating equilibria. Since trade credit is costly, because it compels the seller to incur collection costs (reflected in $k < 1$), the most efficient equilibrium is the equilibrium involving the lowest possible amount of trade credit. In this equilibrium the amount of trade credit is such that the constraint under which there is no collusion with the seller holds as an equality. In fact, inefficient equilibria with a larger amount of trade credit can be ruled out by the Cho and Kreps (1987) intuitive criterion. The intuition is the following: Suppose the players focus on an equilibrium value of α larger than the lower bound. To eliminate this inefficient equilibrium consider the out-of-equilibrium beliefs where the bank would interpret a deviation to α equal to the lower bound as stemming from the good type. For this out-of-equilibrium belief, the good type prefers to use this deviation over his equilibrium strategy. The bad type does not mimick this deviation since this lower bound satisfies the no-collusion condition. Consequently we will hereafter focus on this equilibrium.

Note also that the equation reflecting the condition under which there is no collusion between the seller and the bank is still in implicit form, since the equation for r_S is implicit (see Lemma 1). In the next subsections we solve these equations explicitly, and thus characterize precisely (i) for what parameter configurations equilibrium exists and (ii) the equilibrium values of the interest rates, prices, and amounts lent. Preliminary comparative statics results can already be obtained from Lemma 2, by focusing on the role of H and k.

Corollary 1. *The larger the cash flow generated by the buyer in case of success (H), or the lower the credit management cost for the seller ($1/k$), the more demanding the no collusion constraints, and consequently the larger the amount of trade credit.*

The corollary follows immediately from Equation (13) and the selection of the efficient signaling equilibrium by the intuitive criterion. The interpretation of Corollary 1 is the following. When H is large, the buyer can offer large bribes so that the stake of the seller in collusion is larger. This makes collusion more difficult to deter.[8] In contrast, when credit management is costly for the seller, trade credit is more inefficient, which reduces the value of collusion. This makes collusion easier to deter.

An empirical implication of Corollary 1 is that the proportion of purchases relying on trade credit (i.e., in our notation, α) should be larger for more profitable firms (i.e., in our notation, for which H is larger). This is consistent with the empirical results of Petersen and Rajan (1995, Table V).[9]

Another empirical implication of Corollary 1 is that trade credit should be lower when the credit management costs of the seller are higher.[10] To the extent that credit management involves some fixed costs, it involves, at least for moderate levels of operations, economies of scale. Hence credit management costs are expected to be larger for small firms. Small firms are therefore expected to extend less trade credit. This is consistent with the empirical findings of Petersen and Rajan (1995, Table III).

[8] Note however that if H is large enough then Equation (2) would not hold, and there would not be credit rationing, even in the absence of trade credit.

[9] Petersen and Rajan (1995) offer another interpretation for this finding: on observing evidence suggesting that the buyer's profitability is large, the seller infers that the buyer is creditworthy and consequently offers trade credit. Our model is also consistent with this line of interpretation to the extent that the seller's private signal (θ) contains private information about the buyer's profitability.

[10] Surely one does not need an asymmetric information model to yield this prediction. We believe it is interesting, however, that this reasonable hypothesis also emerges in our analysis of information aggregation through trade credit. Note that in this analysis, credit management costs play an important role in facilitating the credibility of information transmission.

2.2 Equilibria where $\alpha r_S < A$

We now solve explicitly for the equilibrium in the case where the cash flow generated by the seller from another project (A) is sufficiently large to repay the seller's bank debt when the buyer defaults, that is, $\alpha r_S < A$.

In this case the bank loan to the supplier is repaid if (i) the buyer generates the cash flow H, or (ii) the buyer is bad but the seller generates the cash flow A. The probability of (i) or (ii), given that the bank and the supplier have received good signals is

$$\frac{\pi + (1-\pi)\lambda\mu(p + (1-p)\delta)}{\pi + (1-\pi)\lambda\mu}.$$

Hence the rate at which the bank lends to the buyer is[11]

$$r_S = \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu(p + (1-p)\delta)} r. \tag{14}$$

Substituting Equation (14) and $\alpha r_S < A$ in Equation (13), the condition under which the seller does not collude with the buyer can be rewritten as

$$\alpha \geq \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}{(1 + \frac{1-p}{p}\delta)\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)} - (2 - \frac{1}{k})\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}} \stackrel{d}{=} \underline{\alpha}. \tag{15}$$

As mentioned above, no collusion between the seller and the buyer requires that the amount of trade credit (α) be large enough so that it would be too costly for the seller to offer it to the bad buyer. Also as mentioned above, since trade credit is costly ($k < 1$), we focus on the equilibrium involving the lowest possible amount of trade credit. Hence in this subsection we examine existence and properties of equilibria where the amount of trade credit equals $\underline{\alpha}$.

Comparing Equations (15) and (11), checking that the condition $\alpha r_s < A$ holds, and verifying that the participation constraint of the buyer is satisfied, the following proposition obtains:

Proposition 1. *There exist two functions Φ and Ψ (given in the proof in the Appendix) such that if*

$$\frac{r_b}{r} = \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} \leq \frac{H}{r} \leq Min[\Phi(\delta), \Psi(\delta)] \tag{16}$$

then there exists a separating equilibrium, with trade credit equal to $\underline{\alpha}$ [as defined in Equation (15)]. In this equilibrium the interest rates

[11] Equation (14) can also be obtained from Lemma 1 by substituting $A > \alpha r_S$.

quoted by the bank to the buyer and the seller and the delayed payment price are as given in Equations (3), (14), and (4), respectively.

The inequality on the left-hand side of Equation (16) reflects the feasibility condition that when the buyer succeeds at time 1, its repayments to the seller and the bank can be no larger than the cash flow generated (H). Trade credit is feasible in the equilibrium as long as the project has positive NPV *at the bank break-even rate*, that is, as long as $H > r_B$. Thus the seller's credit management costs (reflected in $k < 1$) do not jeopardize the feasibility of trade credit. This is because the amount of trade credit adjusts to these costs. As shown in Corollary 1, when the seller's credit management cost is very high (i.e., when k is very low), the amount of trade credit (α) is very low.

The inequality on the right-hand side of Equation (16) reflects the no collusion constraint (through Ψ) and the condition under which the seller does not go bankrupt as long as it generates the cash flow A (through Φ). Note that these conditions are satisfied only if H/r is not too large. If H is large, there is a lot of cash flow available to pay bribes when the buyer succeeds. Hence the no–collusion condition is more demanding.

The following corollaries describe how the characteristics of the equilibrium vary as the parameters of the game change.

Corollary 2. *The larger the probability (δ) that the seller generates cash flow from its other source of income, the lower the amount of trade credit ($\underline{\alpha}$), the higher the right-hand side of Equation (16), and consequently the less demanding the condition under which the separating equilibrium exists.*

When the probability (δ) to generate cash flow A is large, there is a lot to lose for the seller by pledging this cash flow as collateral to lend to the bad buyer. Consequently, the larger δ is, the less willing the seller is to collude, the less demanding the no–collusion needs to be, and the lower the amount of trade credit needed to deter collusion.

That the two no-collusion conditions can be more easily satisfied, and thus trade credit be granted in equilibrium when δ is large, is consistent with the remark made by Petersen and Rajan (1995, p. 13) that "firms with a greater ability ... to generate capital internally use part of their capital to finance their customers."

That the amount of trade credit ($\underline{\alpha}$) is decreasing in δ is consistent with the result in Petersen and Rajan (1995) that net income is negatively correlated with accounts receivable.[12] As noted by Petersen and Rajan (1995), this negative correlation may seem surprising at

[12] See Petersen and Rajan (1995), Table III, column 1.

first glance. Our theoretical analysis, however, provides an economic interpretation of this apparently surprising result, and its consistency with the other empirical results of Petersen and Rajan (1995).

We now turn to the comparative statics analysis of a change in precision of the signals. Observe first that $\underline{\alpha}$ is a function of μ and λ only through their product $\mu\lambda$, which is inversely related to the precision of the pooled information. For tractability the corollary is stated for the simpler case where $\delta = 1$.

Corollary 3. *For* $\delta = 1$*, the minimum incentive compatible amount of trade credit* ($\underline{\alpha}$) *increases with the precision of the pooled information of the bank and the seller.*

If the pooled information of the seller and the bank is very precise, then the signal conveyed by the extension of trade credit is very strong. Hence, on observing that trade credit has been extended, the bank is willing to quote a rather low rate. This makes collusion between the seller and the buyer attractive. A symmetric argument applies for collusion between the bank and the buyer. To put it differently, in our model, to the extent that tight or long-term relationships lead to precise information, they are conducive of collusion. Hence, in the presence of such relationships, stronger signals (i.e., larger values of α) are needed.

An empirical implication of Corollary 3 is that the amount of trade credit ($\underline{\alpha}$) should be increasing in the tightness of the relationship between the buyer and the seller. Petersen and Rajan (1995) argue that such relationships should be more distant when suppliers are numerous. In contrast with our empirical implication, they find that the ratio of purchases made on credit to asset is increasing in the number of creditors. They interpret this result as reflecting the greater risk-bearing capacity and diversification potential achieved when there are multiple suppliers. Another proxy for the tightness of the relationship with suppliers could be the length of this relationship. In this context, Corollary 3 predicts that the amount of trade credit should be increasing with the length of the buyer–supplier relationship.

Using results from a survey of credit managers, Kiholm Smith and Schnuker (1994) investigate empirically the decision made by sellers to integrate the management of trade credit or to subcontract it to factors. In the latter case, the factor bears (a large part of) the risk of default of the buyer, while in the former case, the selling firm bears the default risk. In our model α measures the extent to which the seller is exposed to the risk of default of the buyer. In that sense α (or some increasing function of it) is larger when the seller integrates credit management than when it delegates it to the factor. Kiholm Smith and Schnuker (1994) find that sellers who respond that "to be effective, salespeople have to take a lot of time to get to know their accounts" tend to integrate the credit management decision rather than to subcontract it to factor. This is consistent with Corollary 3, since sellers "who take a lot of time to know their accounts" are likely to have private information about their customers.

Corollary 4. *The equilibrium amount of trade credit* ($\underline{\alpha}$) *is decreasing in the cost of funds of the bank* (r).

The intuitive interpretation of the corollary is the following: as r increases, the amount of cash available to bribe the seller or the bank decreases. As a result, collusion is less attractive. Consequently the amount of trade credit necessary to rule out collusion is lower.

2.3 Equilibria where $\alpha r_S > A$

Second we consider the case where the cash flow generated by the seller from another project (A) is not sufficiently large to repay the seller's bank debt when the buyer defaults, that is, where $\alpha r_S > A$.

In this case, the bank loan to the supplier is repaid fully only if the buyer generates the cash flow H. Substituting $A > \alpha r_S$ in the equation for r_S in Lemma 1, the interest rate at which the bank lends to the seller is

$$r_S = \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} r - \frac{(1-\pi)\lambda\mu(1-p)}{\pi + (1-\pi)\lambda\mu p}\delta\frac{A}{\alpha}. \tag{17}$$

The rate at which the bank lends to the seller is equal to the rate at which the bank lends to the buyer (since if the buyer defaults then the seller defaults too), minus a discount reflecting the cash flow A pledged as collateral.

Checking under what conditions the participation and incentive compatibility constraints are verified, along with the inequality $\alpha r_s > A$, we obtain our second proposition:

Proposition 2. *There exists a function* Γ *(given in the proof in the Appendix) such that if:*

$$\Phi(\delta) \leq \Gamma(\delta),$$

and if

$$\frac{H}{r} \in [\Phi(\delta), \Gamma(\delta)], \tag{18}$$

then there exists a separating equilibrium, with trade credit equal to

$$\frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} - \delta A \frac{1-p}{p}\frac{\pi}{\pi+(1-\pi)\lambda\mu p}}{\frac{1-k}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}} \stackrel{d}{=} \underline{\alpha}'.$$

In this equilibrium, the seller goes bankrupt if the buyer defaults. The interest rates quoted by the bank to the buyer and the seller and the delayed payment price are as given in Equations (3), (17), and (4), respectively.

Some properties of the equilibrium described in Proposition 2 are presented in the next corollary.

Corollary 5. *In the equilibrium described in Proposition 2, the larger the probability (δ) that the seller generates cash flow from its other source of income and the larger this cash flow (A), the lower the amount of trade credit ($\underline{\alpha}'$), and the less demanding the conditions under which the two no-collusion conditions are consistent.*

The interpretation of the role of the probability (δ) is the same as for Corollary 2. The role of cash flow A is similar: the larger the cash flow pledged by the seller as collateral, the less incentive the seller has to collude with the bad buyer.

Finally, note that generically the equilibrium described in Proposition 1 and the equilibrium described in Proposition 2 do not coexist, since the latter requires $H/r \geq \Phi(\delta)$ while the former requires $H/r \leq \Phi(\delta)$.

2.4 Are there other equilibria than those analyzed above?

In the above analysis we focused on separating equilibria, where only buyers with two good signals ($\theta = 1, \gamma = 1$) obtain trade credit and can finance their project. Could there exist semipooling equilibria, whereby only the information of the bank or that of the seller would be used in the credit granting decision?

First, note that if $\theta = 1$ and $\theta = 0$ are pooled, the information of the seller is not used in the lending relationship. Consequently the cost of financing cannot be below

$$\frac{\pi + (1-\pi)\lambda}{\pi + (1-\pi)\lambda p} r.$$

This is the rate r_p defined in Equation (1) corresponding to the situation where there is no trade credit. Hence our assumption [stated in Equation (2)] that there is credit rationing if trade credit is not available rules out the semipooling equilibrium where $\theta = 1$ and $\theta = 0$ are pooled.

Second, consider the case where $\gamma = 1$ and $\gamma = 0$ are pooled, so that the credit granting decision relies only on the information of the seller. If the latter is precise enough there could exist a semipooling equilibrium where buyers with $\theta = 1$ would obtain financing. The conditions under which such an equilibrium exist reflect two countervailing forces. On the one hand, since the information of the bank is not used in the lending decision, equilibrium is no longer constrained by the condition that there is no collusion with the bank. On the other hand, since the information of the bank is not used, bad buyers (with $\gamma = 0$) are financed, which implies that the default rate, and consequently the rate at which the buyer can borrow from the bank, is higher than in the separating equilibrium.

These semipooling equilibria exhibit one unpalatable feature, however. As explained in Section 2.5, at the third stage of the game, the seller makes a trade credit offer (α) to the buyer, contingent on the bank providing the complementary financing ($1 - \alpha$). For $\gamma = 0$ and $\gamma = 1$ to be pooled, it is necessary that the seller's offer be contingent on the availability of bank credit, *but not on the rate of the bank loan*. Indeed, on observing $\gamma = 0$, the bank cannot quote a rate below r/p. Now, if the seller observed this large rate, it would no longer be willing to extend trade credit. Because it is not plausible to assume that the bank rate is not observable, for the sake of brevity, we do not report the results we obtained about these equilibria.[13]

3. Discussion

3.1 Relation between the model and empirical studies

Petersen and Rajan (1995) find that firms with good relationships with their bank(s) tend to use less trade credit. More precisely, a linear regression of the use of trade credit on a measure of bank relationships yields a negative and significant sign [see Petersen and Rajan (1995), Table VI].

To provide an interpretation of this result in the framework of our simple model, consider the following extension of our setup. In addition to the good and bad buyers, assume there are some buyers that are publicly known (by the banks) to be good. Such firms may be larger or older or easier to evaluate and have been able to establish relationships with banks. There is a continuum of risk-neutral and competitive banks, a continuum of mass 1 of sellers, and a continuum of mass 1 of buyers. There is a mass ν of buyers that are publicly known (by the banks) to be good, a mass $(1 - \nu)\pi$ of good buyers, and a mass $(1 - \nu)(1 - \pi)$ of bad buyers. Each seller is matched with a buyer.

Consider the case analyzed above whereby (i) in absence of trade credit neither the good nor the bad buyer can obtain financing, while

[13] We have shown however, that if one is willing to assume that the seller does not observe the bank rate, then for some parameter values semipooling equilibria do exist. The proof is available upon request.

Table 2
Theoretical sample distribution

Probability	RELAT	Trade credit
ν	1	0
$(1-\nu)\frac{\pi}{\pi+(1-\pi)\lambda\mu}$	0	α
$(1-\nu)\frac{(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu}$	0	α

(ii) when trade credit can be used, there exists a separating equilibrium in which only buyers with two good signals ($\theta = \gamma = 1$) are financed with a mix of trade credit (in proportion α) and bank credit. In this case, the bad buyers for which either the bank's signal or the seller's signal was bad do not obtain any financing, and thus do not invest. Note also that since credit management is more costly for suppliers than for banks ($k < 1$), buyers which are publicly known to be good have no reason to bear the inefficiency cost associated with trade credit and thus finance their purchase with bank credit only.

Suppose the econometrician is able to observe if a firm has relationships with a bank, that is, if it is publicly known by the banks to be good. The variable *RELAT* takes the value 1 if the firm has bank relationships, and 0 otherwise. The econometrician also observes the fraction of the financing stemming from trade credit. Denote this variable *TRADECRED*. The sample to be analyzed econometrically consists of all firms that undertake the investment. Firms which cannot raise funds at all do not undertake the project and are not observed. Suppose the econometrician uses this sample to run the following linear regression:

$$TRADECRED = a + bRELAT + \epsilon. \tag{19}$$

The regression coefficient (computed using the theoretical distribution of the observations in Table 2) is negative (and equal to $-\alpha$).

Nilsen (1994) shows empirically that during periods of monetary contractions small firms have less access to bank loans and react by using trade credit. This can be interpreted in the context of the simple economy described Section 2.4. Suppose that initially the interest rate is low (equal to $r-\eta$) and at this rate all types obtain financing. Firms which are publicly known to be good obtain financing at rate r while the other firms obtain financing at the pooling rate,

$$(r-\eta)\frac{\pi + (1-\pi)\lambda}{\pi + (1-\pi)\lambda p},$$

which we assume is lower than H. Now consider an episode of monetary contraction whereby the bank's cost of funds is raised to $r > r-\eta$

and assume that at this new and higher rate Equation (2) holds. In this case, firms that the banks do not *know* to be good cannot rely on bank credit only. They must resort to trade credit, as in the separating equilibria described in Section 2.

3.2 Market power

So far we have assumed that the seller is competitive. We now analyze how relaxing this assumption alters our results. Suppose that the seller, instead of selling at its break-even price, sells at this price multiplied by a markup reflecting market power: $m \geq 1$. (For simplicity we do not model the imperfect competition game leading to this markup. Rather we take it as given, in a reduced-form approach.) In this case we obtain the following proposition:

Proposition 3. *Suppose the seller has market power, measured by the markup m such that*

$$1 < m < \frac{k}{p}\frac{\pi + (1-\pi)\lambda\mu p}{\pi + (1-\pi)\lambda\mu}.$$

If there exists a separating equilibrium where only buyers with two good signals are financed and $A > \alpha r_s$, the no–collusion bounds are as follows: the fraction of trade credit must be lower than

$$\bar{\alpha}(m) = \frac{\frac{r}{p} - H}{\frac{r}{p} - \frac{m}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}r},$$

to rule out collusion with the bank, and larger than

$$\underline{\alpha}(m) = \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}{\left(m\frac{1-k}{k} - 1\right)\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} + \left(1 + \frac{1-p}{p}\delta\right)\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}},$$

to rule out collusion with the seller. Further, the lower bound $\underline{\alpha}(m)$ is decreasing with the amount of market power m, while the upper bound $\bar{\alpha}(m)$ is increasing with m.

The larger the market power of the seller, the less cash is left available to bribe the bank, and the less demanding the condition under which there is no collusion with the bank. The intuition for the impact of market power on collusion with the seller is more intricate. On the one hand, as m increases, the feasibility of collusion is reduced since there is less cash left available to bribe the seller. On the other hand, as m increases, the attractiveness of collusion for the seller increases, since he has more stake in the project — because of the high price P_{TC} he would get should the project succeed. Because of these two countervailing forces, the effect of market power on the condition under which there is no collusion with the seller could be ambiguous. However, the reduction in the feasibility of collusion is stronger than the increase in its attractiveness because the latter is muted by the transaction cost associated to trade credit ($k < 1$).

Proposition 3 implies that, as the market power of the seller increases, the condition under which there exists a separating equilibrium is less demanding. In that sense, when suppliers have more market power, buyers have better access to credit. An empirical implication of this result is that, during episodes of tight monetary policy and high interest rates, industries with oligopolistic suppliers should be better able to accomodate the shock by relying on the use of trade credit.

3.3 Trade credit, draft discounting, and factoring

In our model the seller borrows from the bank to lend to the buyer. Both the future payment from the buyer and the seller's other cash flows are pledged as collateral to this loan. A slightly different financing scheme would lead to substantially the same result. Suppose that instead of borrowing from the bank, the seller discounts its customer's draft at the bank. In this case, as in the case we analyze, the seller in fact borrows from the bank and retains the credit risk from its customer's default.

Another institutional arrangement related to trade credit is factoring. In this case, the seller subcontracts trade credit management to the factor. As discussed by Mian and Smith (1992, 1994) such delegation can be efficient to the extent that the factor is in a better position to exploit scale economies in credit management. As mentioned above, one major difference between factoring and integrated trade credit management is that in the former the seller can transfer to the factor the default risk of the buyer. This is the case in particular when receivables are securitized [as discussed in Mian and Smith (1994, pp. 83–84)]. In practice, there are limits to this transfer of risk. Even when receivables are securitized, the seller must retain a fraction of the default risk. As Mian and Smith (1994, p. 84) put it: "This retention of risk by the original trade creditor is generally accomplished by requiring the firm to retain a significant residual claim on the pool." Mian and Smith (1994) (informally) interpret this requirement in terms of asymmetric information. It is indeed very similar to the requirement in our equilibria that α be larger than a lower bound (presented in Lemma 2).

4. Conclusion

This article shows that trade credit can alleviate bank credit rationing due to asymmetric information between banks and firms. Our theoretical results are consistent with empirical studies documenting that firms which are likely to be credit constrained (such as small firms during monetary contractions, or firms without relationships with banks) resort more to costly trade credit.

Avenues of further research include an analysis of the macroeconomic implications of trade credit. For example, one could study further how the interaction between information-motivated bank credit rationing and trade credit varies with the business cycle, how this affects the conduct of monetary policy, and how trade credit, by generating chain bankruptcies, can have a feedback effect on the business cycle.

Appendix

Proof of Lemma 1. Conditionally on $\gamma = \theta = 1$, the probability that the buyer can repay the bank loan is

$$\frac{\pi + (1-\pi)\lambda\mu p}{\pi + (1-\pi)\lambda\mu}.$$

Hence, conditionally on $\theta = \gamma = 1$, the break–even lending rate for the bank is

$$r_B = \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} r. \tag{20}$$

Conditionally on $\gamma = \theta = 1$, the probability that the buyer will pay the seller is :

$$\frac{\pi + (1-\pi)\lambda\mu p}{\pi + (1-\pi)\lambda\mu}.$$

If the buyer was bad and fails, then the seller must use his other source of income A to repay the bank. Hence the break-even trade credit price is P_{TC} such that

$$\begin{aligned}&\frac{\pi + (1-\pi)\lambda\mu p}{\pi + (1-\pi)\lambda\mu}[\alpha(kP_{TC} - r_S) + \delta A]\\ &\quad + \frac{(1-\pi)\lambda\mu(1-p)}{\pi + (1-\pi)\lambda\mu}\delta \max[0, A - \alpha r_S] = \delta A,\end{aligned}$$

where the left-hand side is the expected profit of the supplier if it sells on credit, and the right-hand side is its profit if it does not sell. The max operator in the last term of the left-hand side reflects that if the buyer fails, and the seller has generated cash A, this cash must be used to repay the bank up to αr_S. If $\alpha r_S > A$ then the seller goes bankrupt. Rearranging, the break-even trade credit price is

$$P_{TC} = \frac{1}{k}\left[r_S + \frac{(1-\pi)\lambda\mu(1-p)}{\pi+(1-\pi)\lambda\mu p}\delta\left(\frac{A}{\alpha} - \max\left[0, \frac{A}{\alpha} - r_S\right]\right)\right]. \quad (21)$$

Finally, the break-even rate of the bank loan to the supplier is

$$\alpha r = \frac{\pi+(1-\pi)\lambda\mu p}{\pi+(1-\pi)\lambda\mu}\alpha r_S + \frac{(1-\pi)\lambda\mu(1-p)}{\pi+(1-\pi)\lambda\mu}\delta \min[\alpha r_S, A]. \quad (22)$$

The min operator on the right-hand side of Equation (22) plays a similar role as the max in Equation (21). Rearranging, the break-even rate at which the bank can lend to the seller is

$$r_S = \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} r - \frac{(1-\pi)\lambda\mu(1-p)}{\pi+(1-\pi)\lambda\mu p}\delta \min[r_S, A/\alpha]. \quad (23)$$

Substituting Equation (23) in Equation (21), the trade credit price is

$$\begin{aligned} P_{TC} \;=\; & \frac{1}{k}\left[\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} r + \frac{(1-\pi)\lambda\mu(1-p)}{\pi+(1-\pi)\lambda\mu p}\right. \\ & \left. \times\ \delta\left(\frac{A}{\alpha} - \min[r_S, A/\alpha] - \max\left[0, \frac{A}{\alpha} - r_S\right]\right)\right]. \end{aligned}$$

Now

$$\left(\frac{A}{\alpha} - \min[r_S, A/\alpha] - \max\left[0, \frac{A}{\alpha} - r_S\right]\right) = 0. \quad (24)$$

Hence the break-even delayed payment price is

$$P_{TC} = \frac{1}{k}\frac{\pi(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} r. \quad (25)$$

Note that A does not appear in Equation (25). This is because, as reflected in Equation (24), the discount on the bank interest rate to the supplier due to the collateralization of A and the premium required by the seller from the buyer to compensate for the cost of this collateralization offset each other. ■

Intermediary computations to obtain Equation (13)

Let T_s be the bribe from the buyer to the bank in case of collusion. Collusion would be attractive for the seller if

$$\delta A < p[\alpha(kP_{TC} - r_S) + T_s + \delta A] + (1-p)\delta \max[0, A - \alpha r_S].$$

That is if

$$T_s > \frac{1-p}{p}\delta[A - \max[0, A - \alpha r_S]] - \alpha(kP_{TC} - r_S). \tag{26}$$

Now, collusion between the buyer and the seller is not feasible if

$$\alpha P_{TC} + (1-\alpha) r_B + T_s > H. \tag{27}$$

Substituting Equation (26) in Equation (27), collusion between the buyer and the seller is not feasible if

$$\alpha r_S + (1-\alpha) r_B + \alpha P_{TC}(1-k) + \delta \frac{1-p}{p}[A - \max[0, A - \alpha r_S]] \geq H. \tag{28}$$

Substituting r_B and P_{TC} from Lemma 1, and rearranging, the condition under which there is no collusion with the seller is

$$\alpha \geq \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} - \delta\frac{1-p}{p}[A/r - \max[0, A/r - \alpha r_S/r]]}{r_S/r - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} + \frac{1-k}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}. \tag{29}$$

■

Proof of Proposition 1. Before proving the proposition we establish two preliminary lemmas.

Lemma 3. *The condition under which there is no collusion with the seller is consistent with the condition under which there is no collusion with the bank if*

$$\frac{H}{r} \leq \Psi(\delta), \tag{30}$$

where

$$\Psi(\delta) \stackrel{d}{=} \frac{\pi+(1-\pi)\lambda\mu p}{\pi+(1-\pi)\lambda\mu p} \frac{\frac{\pi+(1-\pi)\lambda\mu}{k} + (\frac{\pi}{p} + (1-\pi)\lambda\mu(1+\frac{1-p}{k}))\delta}{(\pi+(1-\pi)\lambda\mu p) + (\pi+(1-\pi)\lambda\mu(2-p))\delta}. \tag{31}$$

Proof of Lemma 3. From Lemma 2, no collusion with the bank requires

$$\alpha \leq \frac{\frac{r}{p} - H}{\frac{r}{p} - \frac{1}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} r}, \tag{32}$$

while, from Equation (15), no collusion with the seller requires

$$\alpha > \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}{(1+\frac{1-p}{p}\delta)\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)} - (2-\frac{1}{k})\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}.$$

The denominator of this equation can be rewritten

$$\frac{\begin{array}{c}[\pi + (1-\pi)\lambda\mu][(p+(1-p)\delta)(\pi+(1-\pi)\lambda\mu p) \\ -(2-1/k)p(\pi+(1-\pi)\lambda\mu(p+(1-p)\delta))]\end{array}}{p[\pi+(1-\pi)\lambda\mu p][\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)]}.$$

Rearranging terms, this is equal to

$$\frac{[\pi+(1-\pi)\lambda\mu][\frac{1-p}{p}\delta\pi + \frac{1-k}{k}(\pi+(1-\pi)\lambda\mu(p+(1-p)\delta))]}{[\pi+(1-\pi)\lambda\mu p][\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)]}. \quad (33)$$

Hence there is no collusion between the buyer and the seller if

$$\alpha \geq \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}{\begin{array}{c}\frac{\pi+(1-\pi)\lambda\mu}{[\pi+(1-\pi)\lambda\mu p][\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)]} \\ \times[\frac{1-p}{p}\delta\pi + \frac{1-k}{k}(\pi+(1-\pi)\lambda\mu(p+(1-p)\delta))]\end{array}}. \quad (34)$$

Equations (32) and (34) are consistent if

$$\frac{\frac{1}{p} - H/r}{\frac{1}{p} - \frac{1}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}} \geq \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}{\begin{array}{c}\frac{\pi+(1-\pi)\lambda\mu}{[\pi+(1-\pi)\lambda\mu p][\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)]} \\ \times[\frac{1-p}{p}\delta\pi + \frac{1-k}{k}(\pi+(1-\pi)\lambda\mu(p+(1-p)\delta))]\end{array}}. \quad (35)$$

Rearranging terms, Equation (35) can be rewritten as

$$\begin{aligned}\frac{H}{r}&\left[\frac{\pi(1-p)/p}{\pi+(1-\pi)\lambda\mu p} + \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}\frac{\delta\pi(1-p)/p}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}\right] \\ &\leq \frac{1}{p}\left[\frac{\pi+(1-\pi)\lambda\mu}{(\pi+(1-\pi)\lambda\mu(p+(1-p)\delta))(\pi+(1-\pi)\lambda\mu p)}\right. \\ &\qquad \left.\times\left[\frac{1-p}{p}\pi\delta + \frac{1-k}{k}(\pi+(1-\pi)\lambda\mu(p+(1-p)\delta))\right]\right] \\ &\quad + \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}\left[1/p - 1/k\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}\right]. \qquad (36)\end{aligned}$$

After some manipulations the left-hand side of Equation (36) can be rewritten as

$$H/r\frac{1-p}{p}\frac{\pi}{\pi+(1-\pi)\lambda\mu p}\frac{(\pi+(1-\pi)\lambda\mu p)+(\pi+(1-\pi)\lambda\mu(2-p))\delta}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}, \tag{37}$$

while the right-hand side can be rewritten as

$$\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}\left[\frac{1}{p}\frac{\pi}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}\frac{1-p}{p}\delta + \frac{1}{k}\frac{1-p}{p}\frac{\pi}{\pi+(1-\pi)\lambda\mu p}\right]. \tag{38}$$

Combining Equations (37) (38), the condition under which the two no collusion constraints are consistent is

$$\begin{aligned} H/r&\frac{(\pi+(1-\pi)\lambda\mu p)+(\pi+(1-\pi)\lambda\mu(2-p))\delta}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)} \\ &\leq [\pi+(1-\pi)\lambda\mu]\left[\frac{1}{p}\frac{1}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}\delta + \frac{1}{k}\frac{1}{\pi+(1-\pi)\lambda\mu p}\right], \end{aligned}$$

which after some manipulations yields

$$H/r \leq \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}\frac{\frac{\pi+(1-\pi)\lambda\mu p}{k}+(\frac{\pi}{p}+(1-\pi)\lambda\mu(1+\frac{1-p}{k}))\delta}{(\pi+(1-\pi)\lambda\mu p)+(\pi+(1-\pi)\lambda\mu(2-p))\delta}. \quad \blacksquare$$

Lemma 4. *The condition*

$$\alpha r_S \leq A, \tag{39}$$

holds if

$$\frac{H}{r} \leq \Phi(\delta), \tag{40}$$

where

$$\begin{aligned} \Phi(\delta) \stackrel{d}{=} &\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} + \frac{1-k}{k}\frac{A}{r} \\ &+ \left(\frac{\frac{1-p}{p}\pi}{\pi+(1-\pi)\lambda\mu p} + \frac{1-k}{k}\frac{(1-\pi)\lambda\mu(1-p)}{\pi+(1-\pi)\lambda\mu p}\right)\frac{A}{r}\delta. \end{aligned} \tag{41}$$

Proof of Lemma 4. Substituting Equations (15) and (14) in $\alpha r_s \leq A$, we can determine under which condition on parameter values it is indeed the case that the seller does not go bankrupt, even if the buyer fails, when A is generated:

$$\frac{\left[\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)} r\right]\left[\frac{H}{r}-\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}\right]}{(1+\frac{1-p}{p}\delta)\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}-(2-\frac{1}{k})\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}} \leq A. \tag{42}$$

From Equation (33), Equation (42) can be rewritten as

$$\begin{aligned} A/r \geq & \left[\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}\right] \\ & \times \frac{\frac{H}{r}-\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}{\frac{[\pi+(1-\pi)\lambda\mu][\frac{1-p}{p}\delta\pi+\frac{1-k}{k}\{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)\}]}{[\pi+(1-\pi)\lambda\mu p][\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)]}}. \end{aligned} \tag{43}$$

Simplifying by $\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}$, this is

$$A/r \geq \frac{\frac{H}{r}-\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}}{\frac{[\frac{1-p}{p}\delta\pi+\frac{1-k}{k}\{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)\}]}{[\pi+(1-\pi)\lambda\mu p]}}. \tag{44}$$

Rearranging, this is equivalent to

$$\begin{aligned} H/r \leq & \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}+\frac{1-k}{k}\frac{A}{r} \\ & + \left(\frac{\frac{1-p}{p}\pi}{\pi+(1-\pi)\lambda\mu p}+\frac{1-k}{k}\frac{(1-\pi)\lambda\mu(1-p)}{\pi+(1-\pi)\lambda\mu p}\right)\frac{A}{r}\delta. \end{aligned}$$

The right-hand side is $\Phi(\delta)$, as defined in Equation 41. ■

Using Lemmas 1, 2, 3, and 4 we can now establish the proposition. Since the interest rates quoted by the bank to the buyer and the seller, and the delayed payment price stated in Proposition 1 are as given in Lemma 1 they satisfy the participation constraints.

Since $\frac{H}{r} \leq \Psi(\delta)$, there is no collusion for these interest rates and credit.

Since $\frac{H}{r} \leq \Phi(\delta)$, it is indeed the case that $\alpha r_S \leq A$ so that the seller does not go bankrupt if it generates A.

Therefore to establish the proposition we only need to check that these equilibrium values are feasible, that is, that the interest rates and amounts of credit are such that

$$\alpha P_{TC}+(1-\alpha)r_B \leq H. \tag{45}$$

Substituting the values of r_B and P_{TC} from Lemma 1, this is equivalent to

$$H/r \geq \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}\left(1 + \alpha\left(\frac{1-k}{k}\right)\right).$$

Substituting $\underline{\alpha}$ from Equation (15) and simplifying, this inequality becomes

$$H/r - \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} \geq \frac{[H/r - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}]\frac{1-k}{k}}{\frac{1-k}{k} + \frac{\frac{1-p}{p}\pi\delta}{\pi+(1-\pi)\lambda\mu(p+(1-p)\delta)}},$$

which is equivalent to

$$H/r \geq \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}. \quad \blacksquare$$

Proof of Corollary 2. That $\underline{\alpha}$ is decreasing in δ is obvious from Equation (15).

That Φ is increasing in δ is obvious from Equation (41).

From Equation (31):

$$\Psi'(\delta) > 0 \Leftrightarrow$$

$$k\pi/p + (1-\pi)\lambda\mu(k + (1-p)) > \pi + (1-\pi)\lambda\mu(2-p) \Leftrightarrow$$

$$k/p > \frac{\pi + (1-\pi))\lambda\mu}{\pi + (1-\pi))\lambda\mu p}.$$

which is true by assumption [see Equation (10)]. ■

Proof of Corollary 3. Denote $v = \lambda\mu$. As v increases, the precision of the pooled information of the seller and the bank decreases. To establish the corollary we prove that $\underline{\alpha}$ is decreasing in v.

With $\delta = 1$

$$\underline{\alpha} = \frac{\frac{H}{r} - x}{\frac{1}{p} - \left(2 - \frac{1}{k}\right)x},$$

with

$$x = \frac{\pi + (1-\pi)v}{\pi + (1-\pi)vp}.$$

Observe that

$$\frac{\partial x}{\partial v} = \frac{\pi(1-\pi)(1-p)}{(\pi + (1-\pi)vp)^2} > 0.$$

Moreover, we have

$$\frac{\partial \underline{\alpha}}{\partial x} = \frac{\frac{H}{r}\left(2 - \frac{1}{k}\right) - \frac{1}{p}}{\left(\frac{1}{p} - \left(2 - \frac{1}{k}\right)x\right)^2}.$$

Because we assumed that $H/r < 1/p$ and $k > 1$, we obtain $\frac{\partial \underline{\alpha}}{\partial x} < 0$. We conclude that $\underline{\alpha}$ is decreasing in v. ■

Proof of Proposition 2. Substituting Equation (17) in Equation (13) the condition under which the seller does not collude with the buyer can be rewritten as

$$\alpha \geq \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} - \delta A \frac{1-p}{p}\frac{\pi}{\pi+(1-\pi)\lambda\mu p}}{\frac{1-k}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}} \stackrel{d}{=} \underline{\alpha}'. \tag{46}$$

Comparing Equation (46) and Equation (11), no collusion with the seller and no collusion with the bank are consistent if

$$\frac{\frac{1}{p} - \frac{H}{r}}{\frac{1}{p} - \frac{1}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}} \geq \frac{\frac{H}{r} - \frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p} - \delta A \frac{1-p}{p}\frac{\pi}{\pi+(1-\pi)\lambda\mu p}}{\frac{1-k}{k}\frac{\pi+(1-\pi)\lambda\mu}{\pi+(1-\pi)\lambda\mu p}} \stackrel{d}{=} \underline{\alpha}'. \tag{47}$$

Simplifying and rearranging terms, Equation (47) is

$$\begin{aligned} H/r\pi(1-p) \ \leq\ & \frac{1-k}{k}[\pi + (1-\pi)\lambda\mu] \\ & + \left(1 - p/k\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}\right)\frac{\pi + (1-\pi)\lambda\mu}{\pi(1-p)} \\ & + \left(1 - p/k\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}\right)\pi\frac{1-p}{p}\delta A/r. \end{aligned}$$

Consequently no collusion with the seller and no collusion with the bank are consistent if

$$\begin{aligned} H/r \ \leq\ & 1/k\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} + \left(1/p - 1/k\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}\right)\delta A/r \\ \stackrel{d}{=}\ & \Gamma(\delta). \end{aligned} \tag{48}$$

Interest rates, prices, and amounts of credit stated in Equations (3), (4), (25), and (47) are consistent with participation constraints and no-collusion constraints.

To conclude the proof we only need to check that under Equation

(18) this equilibrium is feasible, that is,

$$\alpha P_{TC} + (1-\alpha) r_B \leq H.$$

Following the same steps as in the proof of Proposition 1, the equilibrium is feasible if

$$\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} < \frac{H}{r}.$$

This holds under Equation (18) since $\Phi' > 0$ and

$$\Phi(0) \geq \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}. \qquad \blacksquare$$

Proof of Corollary 5. Straightforward from inspection of Equations (47) and (48).

Proof of Proposition 3. Following the same steps as in the case of competitive sellers, it is easy to prove the following:

(i) The seller quotes price m for cash payment and $P_{TC} = \frac{1}{k} \cdot r_B \cdot m$ for delayed payment.

(ii) The buyer must borrow $(1-\alpha) \cdot m$ from the bank. The break-even rate for the bank is r_B,

$$\frac{\pi + (1-\pi)\lambda\mu p}{\pi + (1-\pi)\lambda\mu} \cdot r_B(1-\alpha)m - (1-\alpha)m \cdot r = 0.$$

Hence

$$r_B = \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p} r.$$

(iii) Assuming that $A > \alpha r_s$, the rate quoted by the bank to the seller is

$$r_s = \frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu(p + (1-p)\delta)}.$$

Now consider the no-collusion conditions. Collusion would be attractive for the seller if

$$\delta A < p[\alpha(kmP_{TC} - r_s) + T_s + \delta A] + (1-p)\delta(A - \alpha r_s),$$

that is,

$$T_s > \alpha r_s \left(1 + \frac{1-p}{p}\delta\right) - \alpha kmP_{TC}.$$

Collusion would be feasible if

$$\alpha m P_{TC} + (1-\alpha) r_B + T_s < H,$$

that is,

$$T_s < H - \alpha m P_{TC} - (1-\alpha) r_B.$$

Hence there is no collusion with the seller if

$$H - \alpha \cdot m \cdot P_{TC} - (1-\alpha) r_B \leq \alpha r_s \left(1 + \frac{1-p}{p}\delta\right) - \alpha k m P_{TC}.$$

After some manipulations this is equivalent to $\alpha \geq \underline{\alpha}(m)$, where $\underline{\alpha}(m)$ is as defined in Proposition 3.

There is no collusion with the bank if

$$\alpha m P_{TC} + (1-\alpha)\frac{r}{p} \geq H.$$

Now

$$\frac{1}{p} > \frac{m}{k}\frac{\pi + (1-\pi)\lambda\mu}{\pi + (1-\pi)\lambda\mu p}.$$

Hence the no-collusion condition is

$$\alpha \leq \bar{\alpha}(m),$$

where $\bar{\alpha}(m)$ is as defined in Lemma 3. ■

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