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Sustainability of Product Market Collusion under Credit Market Imperfections

Sugata Marjit
Arijit Mukherjee
Lei Yang

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Abstract

We study the implications of credit constraints for the sustainability of product market collusion in a bank-financed oligopoly in which firms face an imperfect credit market. We consider two situations, without and with credit rationing, i.e., with a binding credit limit. When there is credit rationing, a moderately higher cost of external financing may affect the degree of collusion, but a substantial increase keeps it unaffected relative to the no-constraint case. A permanent adverse demand shock in this setup does not affect the possibility of collusion, but may aggravate financing constraints and eventually lead to collusion. We consider both Cournot and Bertrand models, and the results are qualitatively the same.

JEL-Codes: D210, D430, G210.

Keywords: collusion, credit market, debt-equity.

*Sugata Marjit**
Centre for Studies in Social Sciences, Calcutta
R 1 B.P. Township
India – Kolkata - 700094
marjit@gmail.com

Arijit Mukherjee
Nottingham University Business School
United Kingdom - NG8 1BB Nottingham
arijit.mukherjee@nottingham.ac.uk

Lei Yang
Hong Kong Polytechnic University
Kowloon / Hong Kong
liveyang@polyu.edu.hk

*corresponding author

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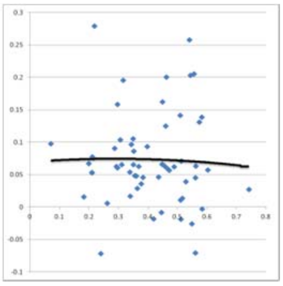
1. Introduction

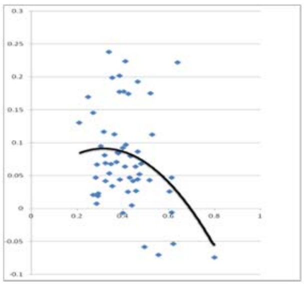
Financial crises in recent years have renewed research interest in their causes and consequences. The Asian crisis of the 1990s and the most recent crisis originating in the United Sates have affected large numbers of businesses. Lines of credit are essential inputs in business processes, with working capital and the day-to-day availability of credit of the utmost importance. The choice of capital structure by a firm in an oligopoly was discussed as far back as the 1980s by Brander and Lewis (1986). The nature of competitive strategies in the product market can determine a firm's choice between debt and equity capital. This line of inquiry was later extended to a repeated oligopolistic structure by Maksimovic (1988).

We consider a case in which firms have to depend on bank financing because their internal capital is inadequate to achieve their desired level of production. Thus, firms do not have any choice in terms of capital structure once they have determined their optimal level of production. If they cannot obtain sufficient credit to meet that level, they become capacity-constrained. This characterization of the financing process echoes concerns that the credit market is essentially imperfect and that the internal cash flow of a firm is very important because borrowing is costly relative to the opportunity cost of self-owned capital or credit. We draw here on the well-known work of Glenn Hubbard (1990) and others. Bernanke and Gertler (1989) also demonstrate that credit is a critical element in explaining the macroeconomic implications of business cycles.

Our theoretical study is motivated by the empirical evidence on the correlation between product market collusion and credit constraints in the Indian manufacturing sector shown in Figure 1. The horizontal axis represents the degree of credit constraints at the industry level measured by the ratio of outstanding bank loans to invested capital. A higher ratio implies a higher degree of credit constraints. The vertical axis denotes the price-cost margin measured by the ratio of total profit to total input cost. We use this ratio to measure the price-cost margin by implicitly assuming that the unit cost of production is constant. The price-cost margin is higher when firms collude implicitly and charge a higher price. Therefore, it can be used to measure the level of collusion at the industry level. Figure 1 illustrates the relationship between the ratio of outstanding loans to invested capital and the total profit to total input cost ratio for 63 three-digit industries for the periods between 1998-1999 and 2007-2008.* The trend is remarkably consistent except for 2003-2004 and 2004-2005. We dropped a number of extreme observations for each period and fitted a trend line of degree 3.



1998-1999



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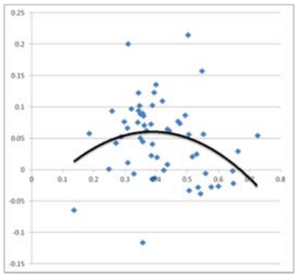

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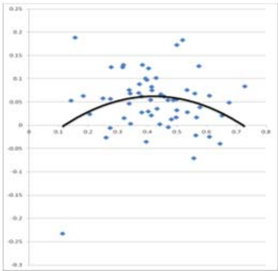
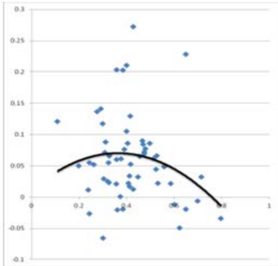
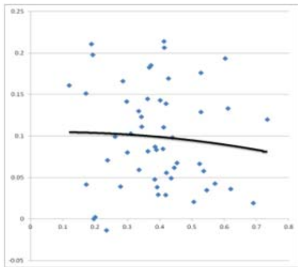


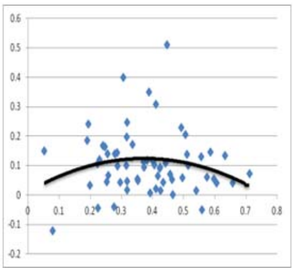
2001-2002



2002-2003



2005-2006



2006-2007

Figure 1 Relationship between the ratios of outstanding loans to invested capital and total profit to total input cost for 63 three-digit industries, 1998-1999 and 2007-2008

We are interested in the relationship between the sustainability of collusion and the level of credit in an oligopoly model. First, we focus on a case in which firms are credit-constrained but the credit limit granted by banks is greater than the amount required by production levels, which implies that the credit cap is not binding. Second, we consider the case in which the cap does bind. It is natural to use an oligopolistic structure to elucidate the consequences of credit constraints for the strategic decisions of firms. Unfortunately, models that consider these decisions in the face of credit constraints are rare. To the best of our knowledge, the non-cooperative and collusive strategies of firms under credit constraints have been discussed only by Bagliano and Dalmazzo (1999) and Bevia, Corchon, and Yasuda (2014) in the context of firm bankruptcies. Our paper differs from these studies in that we focus on firms' collusive strategies in the face of credit constraints without uncertainty. We do not consider the possibility of bankruptcy, but point toward the rather interesting result that severe constraints sometimes do not affect the degree of collusion, whereas moderate constraints do. We also find that if we follow Cournot or Bertrand models, permanent adverse demand shocks do not affect collusion unless we explicitly bring in the role of internal financing.

Issues related to fixed and working capital in an imperfect product market and their implications for macroeconomic outcomes have been explored by Das (2004). More recently, Dellas and Fernandes (2014) investigated financial structures and imperfect markets within a macro framework, deriving many interesting implications.

One of their results that is similar to this paper is that a markup behaves non-monotonically with the degree of financial constraint. However, their model does not consider the possibility of collusion in a repeated game, as we do in this paper. We argue that during financial distress, as is likely to occur when the credit limit becomes strictly binding even for a collusive level of output, there is no change in the degree of collusion relative to the no-constraint case. Moderate credit constraints, in contrast, do increase the possibility of collusion.

In a different context, Marjit, Ghosh, and Biswas (2007) analyzed the role of working capital, and hence line of credit, and trade policy reforms in a setup in which firms choose to outsource production to unorganized extra-legal entities. Bandopadhyay, Marjit, and Yang (2014) considered the outsourcing context amid financial crisis. The way in which we model the use of working capital bears a relation to those papers, but our focus is entirely different. Credit constraints may affect the pattern of joint ventures and can lead to buy-outs and joint venture breakdowns. Marjit and Raychaudhuri (2004) discussed these issues without explicitly modeling the credit market aspect of the problem.

Our paper is also related to the well-cited work of Rotemberg and Saloner (1985), who discussed the existence of counter-cyclical markups in a dynamic model of oligopoly. They explained that during a boom it is difficult to sustain collusion, and hence markups falter because of the increased possibility of deviations from a tacit collusive agreement. Here, we argue that if firms are hit very hard by financial constraints and believe that the shock is permanent, those constraints might not influence the degree of collusion. In fact, we find that the degree of collusion in that scenario is exactly the same as the case of no such constraints in both the linear Cournot model and general Bertrand model. Rotemberg and Saloner's (1985) concern is with the size of the market, whereas ours is with the availability of financing.

Our model also captures situations in which firms have very little capital or are extremely well endowed. As long as credit is available at a price, these two extreme situations may imply a similar degree of collusion. In brief, we introduce the credit side of product market collusion as a complement to Rotemberg and Saloner (1986).

The remainder of the paper is organized as follows. In Section 2, we describe the basic setup. In Section 3, we develop the model without credit constraints. Section 4 analyzes the scenario with credit constraints but a non-binding credit limit. Section 5 discusses the case with physical limits on credit availability. Section 6 describes the Bertrand game, and Section 7 concludes the paper.

2. The Basic Setup

Credit market imperfection is often characterized by moral hazard or adverse selection-type problems (Stiglitz and Weiss, 1981). Banks are worried about possible defaults by borrowers, and such complexities give collateral or internal finance a very important role to play. The maximum borrowing limit set by the bank depends on the level of assets owned by the borrower.

Consider an industry with firms that have their own equity, internal financing, or assets denoted by k, which is symmetric across firms. We follow Aghion and Banerjee (2005) in constructing a simple model that relates the credit limit to k. Assume that banks can raise capital at interest rate $\tilde{r}$ and lend at interest rate $\tilde{R}$, where $\tilde{R}$ is the sum of $\tilde{r}$ and some intermediation cost that is the same for all banks, and therefore for the representative bank, in a competitive setting. However, each bank has to worry about the potential default of borrowers. Banks have to decide on loan amount L ensuring the following condition.

$$F(L+k)-kr-pLR-\tau(L+k)\leq F(L+k)-kr-LR,$$

$$\text{or } \quad L \leq \frac{\tau k}{(1-p)R-\tau} \equiv \overline{L}, \qquad (1),$$

where $r=1+\tilde{r}$, $R=1+\tilde{R}$, $F(L+k)$ is firm revenue depending on $L+k$, p is the probability of getting caught in the case of default, and τ is the expected fine or monetary value of punishment that is assumed to be proportional to the total investment, *(L+k)*. The left-hand side of (1) shows the borrower's net profit in the case of default, and the right-hand side shows its profit in the case of repayment. Equation (2) shows that the maximum amount of credit offered by the bank is $\overline{L} = \dfrac{\tau k}{(1-p)R - \tau}$.

Therefore, the maximum capital at the disposal of the firm is

$$\overline{B} = k + \overline{L} = \frac{(1-p)k\,\mathrm{R}}{(1-p)R-\tau}. \qquad (2)$$

Assume that there are two symmetric firms with workers producing a homogeneous good. Further assume that both firms require α workers to produce one unit of the good and that the wage per worker is w, which is normalized to 1 for simplicity. Hence, the per-unit cost of production is α. If a firm produces q units of the good, it incurs a product cost of αq, which it needs to finance from *(L+k)*. The firm needs to borrow money if αq is greater than *k*; otherwise, it can finance production from its own assets. Suppose that the inverse demand function is given by

$$P = a - q, \qquad (3)$$

where *P* is the price and *q* is the total output. Let q_1 and q_2 denote the output of firms 1 and 2, respectively. The production of each firm has to be financed with k and L. We assume that the two firms compete for infinitely repeated periods.

Consider the following game. We assume that the firms consider a tacit collusion agreement: each firm produces half the monopoly output as long as its competitor produced that amount in the previous period. However, if a firm deviates from the monopoly output in one period, the firms then behave like Cournot duopolists from the next period onwards. Let q_{id} , q_{im} , and q_{ic} denote firm i's (i = 1, 2) Cournot output, collusive output, and output under a deviation from collusion, respectively, and its corresponding profits are π_{id} , π_{im} , and π_{ic} .

3. Basic Model without Credit Constraints

We first consider the basic Cournot model without credit constraints:

$$\frac{\overline{\beta}}{\alpha} > \frac{k}{\alpha} > q_{ic} > q_{id} > q_{im} . \qquad (4)$$

Equation (4) implies that not only do both firms have sufficient k to obtain a high credit limit from banks, but also that their individual k is high enough that neither needs to borrow from a bank. We begin with such a benchmark to track how the incentive to collude in a repeated game responds to firms' credit constraints. Note that the no credit constraint case in our analysis is equivalent to Rotemberg and Saloner (1985).

Because the firms are symmetric, without loss of generality, we consider the problem for firm 1. If firm 1 maximizes as a Cournot duopolist, its net profit from production in the benchmark case is

$$\pi_1 = (a - q_1 - q_2)q_1 - \alpha q_1 r . \qquad (5)$$

From the standard solution in the Cournot model, we have

$$\pi_{id} = \frac{(a - \alpha r)^2}{9}. \qquad (6)$$

If the two firms collude with each other, each earns half the monopoly profit. Hence, we have

$$\pi_{im} = \frac{(a-\alpha r)^2}{8}. \qquad (7)$$

If firm 1 deviates from collusion, its profit becomes

$$\pi_1 = (a - q_1 - \frac{a - \alpha r}{4})q_1 - \alpha r q_1. \qquad (8)$$

From the first-order condition, we have

$$\pi_{ic} = \frac{9(a - \alpha r)^2}{64}. \qquad (9)$$

We follow the simplest procedure for modeling collusion, that is, the trigger strategy equilibrium in an infinitely repeated game a la Friedman (1971) and as posited in Gibbons (1992). We abstract from finer refinements, as in Abreau (1988), because our focus is on credit availability's effect on collusion rather than on collusion per se.

Let δ_1 denote the critical value of the trigger strategy equilibrium under no credit constraints. We thus have

$$\delta_1 = \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} = \frac{9}{17}, \qquad (10)$$

which implies that collusion is sustained for $\delta > \delta_1$.

4. Credit Constraints without a Binding Credit Limit

In this section, we discuss the scenario of binding credit constraints but a non-binding credit limit. Consider that when credit constraints are binding, i.e., $\alpha q_{im} > k$, the implication is that $\alpha q_{ic} > k$ and $\alpha q_{id} > k$ because $\frac{\overline{B}}{\alpha} > \frac{k}{\alpha} > q_{ic} > q_{id} > q_{im}$.

Constraint severity is characterized by firms' inability to produce the optimum amount of goods without credit. If they cannot produce the monopoly output, it follows that they surely cannot produce the Cournot or deviation output. Hence, in this case bank financing is necessary, but firms can obtain the required loan only if they pay $R > r$.

In this case, the net profit of firm 1 under Cournot competition is

$$\begin{aligned} \pi_1 &= (a - q_1 - q_2)q_1 - (\alpha q_1 - k)R - kr \\ &= (a - q_1 - q_2)q_1 - \alpha q_1 R + k(R - r) \end{aligned}, \qquad (11)$$

which gives the equilibrium outputs and profits of the firms respectively as

$$q_{1d} = q_{2d} = \frac{a - \alpha R}{3} \qquad (12)$$

and

$$\pi_{1d} = \pi_{2d} = \frac{(a - \alpha R)^2}{9} + k(R - r). \qquad (13)$$

Note that the equilibrium output in (11) assumes that the firms are not credit-constrained, i.e., the maximum capital available to them, $\overline{B}$, is greater than the equilibrium output shown in (12). However, if $\overline{B}$ is less than the equilibrium output shown in (12), the equilibrium output of the firms is $\frac{\overline{B}}{\alpha}$. Hence, the equilibrium Cournot outputs of the firms should satisfy

$$q_{id} = Min[\frac{a-\alpha R}{3}, \frac{\overline{B}}{\alpha}]. \quad (14)$$

We assume that a similar condition also holds for collusive output q_{im} and deviation output q_{ic}.

Similarly, each firm's profit under collusion is given by

$$\pi_{im} = \frac{(a-\alpha R)^2}{8} + k(R-r). \quad (15)$$

When the deviation output faces credit constraints, there are two possibilities: (1) collusive output also faces such constraints or (2) it does not.

For the first case, the profit under deviation is given by

$$\pi_{ic} = \frac{9(a-\alpha R)^2}{64} + k(R-r). \quad (16)$$

For the second case, the firm's profit is given by the following expression if it deviates from collusion.

$$\pi_1 = (a - q_1 - \frac{a-\alpha r}{4})q_1 - (\alpha q_1 - k)R - kr. \quad (17)$$

From the first-order condition, we have

$$q_{1c} = \frac{a - \alpha R - \frac{a-\alpha r}{4}}{2}. \quad (18)$$

The corresponding profit is

$$\pi_{ic} = (\frac{a - \alpha R - \frac{a - \alpha r}{4}}{2})^2 + k(R - r) . \qquad (19)$$

Let δ_2 denote the critical value for the trigger strategy equilibrium under full credit constraints, where the collusive output, Cournot output, and cheating output are also under credit constraints. From equations (13), (15), and (16), we have

$$\delta_2 = \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} = \frac{9}{17} = \delta_1 \qquad (20)$$

which leads to the following lemma.

Lemma 1: *Collusion is equally sustainable under no credit constraints and under complete credit constraints without a binding credit limit.*

The intuition is as follows. The degree of collusion depends on the differences between payoffs under different strategies. Because firms with k amount of internal financing will always earn $k(R-r)$ as a premium regardless of their strategy, it does not feature anywhere in the determination of delta. Moreover, in the linear example, the ratios between the differences in various payoffs are constant independent of the marginal cost, i.e. r or R, and hence we have the foregoing result.

Note that a permanent demand shock, whether positive or negative (such that the firms are not bankrupt and manage to earn some profits), does not affect δ. However, if an adverse demand shock today affects k tomorrow, the collusion possibilities may be affected. Hence, the critical role here is that of internal financing.

We now characterize the relationship between k and δ as firms move from a high to low k regime while the credit limit remains non-binding.[2] We first study the effect on the delta as we move from an unconstrained to a constrained situation. It is possible that for some reason the level of internal equity falls and the constraint becomes binding. It is obvious that the cheating output would be the first affected because it requires the largest amount of credit. The other two payoffs would not be affected, and the cheating output would fall.

We define $\bar{k} = \frac{(a - \alpha R - \frac{a - \alpha r}{4})\alpha}{2}$, $\tilde{k} = \frac{(a - \alpha R)\alpha}{3}$, and $\underline{k} = \frac{(a - \alpha R)\alpha}{4}$, which means that the credit constraint is not binding for $k \geq \bar{k}$. As discussed in Section 3, δ is equal to $\frac{9}{17}$ for $k \geq \bar{k}$. We consider reducing k slightly from $\bar{k}$ ($\tilde{k} \leq k < \bar{k}$). In this case, the credit constraint is not binding under collusion or Cournot competition, but it is under cheating. Hence, the firm's profit under cheating is given by

[2] We assume that R is higher than r by a very small margin. This assumption is made to minimize technical details that are not essential for our results. In principle, if R is much higher than r, then there is a range of k where the firm does not need to borrow from the bank and produces at $\frac{k}{\alpha}$ because the optimal output without a credit constraint is greater than $\frac{k}{\alpha}$, whereas the optimal output with a credit constraint is less than $\frac{k}{\alpha}$.

$$\pi_{ic} = (\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 + k(R-r) \ .$$

To compare the collusive profit in the presence and absence of credit constraints, we take the derivatives of π_{ic} with respect to R. We thus have

$$\frac{\partial \pi_{ic}}{\partial R} = k - \alpha[(a-\alpha R) - \frac{a-\alpha r}{4}] = k - 2\alpha q_{ic} \ . \qquad (21)$$

As $k < \alpha q_{ic}$, we have

$$\frac{\partial \pi_{ic}}{\partial R} = k - 2\alpha q_{ic} < 0 \ . \qquad (22)$$

We also have

$$\pi_{ic}(R=r) = \frac{9(a-\alpha r)^2}{64} \ .$$

Thus, we have $\pi_{ic} = (\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 + k(R-r) < \frac{9(a-\alpha r)^2}{64}$ for $\tilde{k} \le k < \bar{k}$, which implies that the cheating profit is lower in the presence than absence of credit constraints even if there is a premium for a greater amount of internal financing ($k(R-r)$). In this case,

$$\delta_3 = \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} = \frac{(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 + k(R-r) - \frac{(a-\alpha r)^2}{8}}{(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 + k(R-r) - \frac{(a-\alpha r)^2}{9}} \ . \qquad (23)$$

It can be shown that $\frac{d\delta_3}{d\pi_{ic}} > 0$ in this case. Thus, δ is lower than $\frac{9}{17}$ for $\tilde{k} \le k < \bar{k}$. Accordingly, collusion is more sustainable under partial credit constraints.

It can also be shown that $\frac{d\delta_3}{dk} = \frac{(R-r)(a-\alpha r)^2}{72[(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 + k(R-r) - \frac{(a-\alpha r)^2}{9}]^2} > 0$

in this scenario. Also, $\frac{d^2\delta_3}{dk^2} < 0$.

As k drops further, the credit constraint also becomes binding under Cournot competition ($\underline{k} < k < \tilde{k}$), in which case the profit under such competition is

$$\pi_{id} = \frac{(a-\alpha R)^2}{9} + k(R-r).$$

The corresponding critical value for the trigger strategy equilibrium is

$$\delta_4 = \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} = \frac{(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 + k(R-r) - \frac{(a-\alpha r)^2}{8}}{(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 - \frac{(a-\alpha R)^2}{9}}. \qquad (24)$$

To compare the collusive profit in the presence and absence of credit constraints, we take the derivatives of π_{im} with respect to R. We have

$$\frac{\partial \pi_{im}}{\partial R} = -\alpha q_{im} + k.$$

If the monopolist needs to borrow, then we have $k < \alpha q_{im}$. Hence, we also have $\frac{\partial \pi_{im}}{\partial R} < 0$, which implies that the collusive profit decreases when R increases. We also have

$$\pi_{im}(R = r) = \frac{(a-\alpha r)^2}{8}.$$

Hence, we have $\frac{(a-\alpha R)^2}{8} + k(R-r) < \frac{(a-\alpha r)^2}{8}$ when $R > r$, which implies that the collusive profit is lower in the presence than absence of credit constraints even if there is a premium for having a greater amount of internal financing ($k(R-r)$). It can also be shown that $(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 < \frac{9(a-\alpha R)^2}{64}$.

Thus, we have

$$\delta_4 = \frac{\pi_{ic}-\pi_{im}}{\pi_{ic}-\pi_{id}}$$

$$= \frac{(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 + k(R-r) - \frac{(a-\alpha r)^2}{8}}{(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 - \frac{(a-\alpha R)^2}{9}} < \frac{\frac{9(a-\alpha R)^2}{64} - \frac{(a-\alpha R)^2}{8}}{\frac{9(a-\alpha R)^2}{64} - \frac{(a-\alpha R)^2}{9}} = \frac{9}{17}. \quad (25)$$

Hence, δ is lower than $\frac{9}{17}$ for $\underline{k} < k < \tilde{k}$, and collusion is more sustainable in this case. It can also be shown that $\frac{d\delta_4}{dk} = \frac{R-r}{(\frac{a-\alpha R-\frac{a-\alpha r}{4}}{2})^2 - \frac{(a-\alpha R)^2}{9}} > 0$ and $\frac{d^2\delta_4}{dk^2} = 0$.

When k is further reduced such that $k < \underline{k}$, credit constraints are binding for all three strategies, and δ is equal to $\frac{9}{17}$.

We illustrate the relationship between δ and k in different circumstances in Figure 2, where the horizontal axis represents k and the vertical axis represents δ.

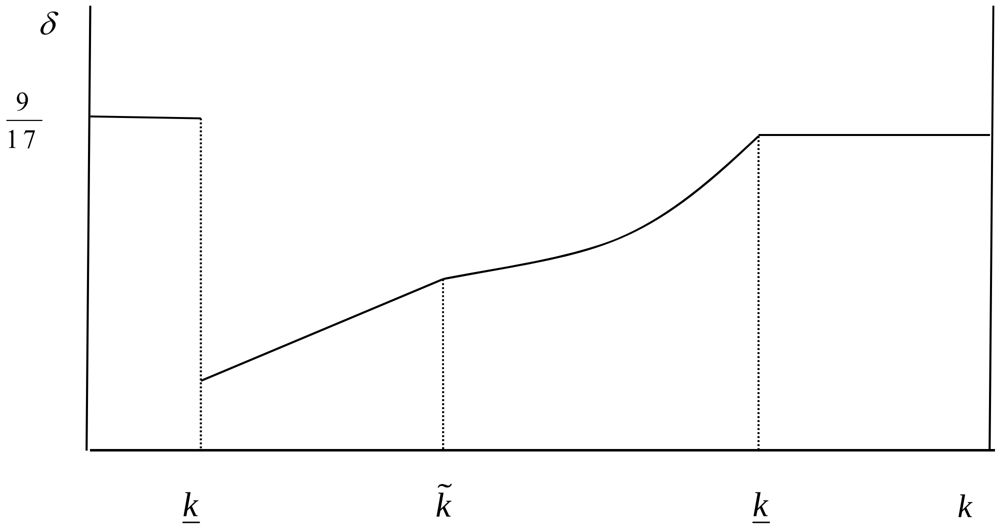


Figure 2 Relationship between δ and k without a binding credit limit under Cournot Competition

We thus have the following Proposition 1.

Proposition 1: *If the credit limit is non-binding, the response of δ to the debt/equity ratio is non-monotonic. However, for a sufficiently high k, the collusion possibility increases with a reduction in k.*

Proof: See the discussion above. QED

We show in the appendix that a similar qualitative result holds even under a general demand function.

5. Binding Credit Limit

Thus far we have assumed that the credit limit is sufficient and that firms can borrow as much as they wish at R. We now relax this assumption and consider the scenario of a binding credit limit. Suppose that $\overline{L}$ is low because k is too low and/or that p and τ are low or R is fairly high, such that $\frac{\overline{B}(k)}{\alpha}$ could be lower than the output level. When the credit limit is binding, $\frac{\overline{B}(k)}{\alpha}$ is the output level.

Note that when k decreases, the corresponding credit limit is also reduced. Accordingly, π_{im} and π_{ic} decrease with a reduction in k. However, π_{id} is likely to increase with a reduction in k because firms can commit to a lower output level and increase their non-cooperative payoff as long as the output with a binding credit limit is greater than the collusive output. This supposition is consistent with the conventional wisdom that the Cournot payoff is dominated by profits at lower levels of output with a lower bound on the monopoly output.

First, consider the case in which the credit limit is not binding for any output. It is as if we were at the same k as that determined in Figure 2, and firms can expand their output by borrowing more. Suddenly, k drops and the credit limit becomes binding.

Define $\bar{k}'$ such that $\bar{B}(\bar{k}') = \bar{k}' \dfrac{(1-p)\mathrm{R}}{(1-p)R-\tau} = \dfrac{(a-\alpha R-\frac{a-\alpha r}{4})\alpha}{2}$. Therefore, we obtain $\bar{k}' = \dfrac{(a-\alpha R-\frac{a-\alpha r}{4})\alpha[(1-p)R-\tau]}{2(1-p)\mathrm{R}}$, which implies that the credit limit is not binding for all three levels of output for $k > \bar{k}'$. In this case, the relationship between δ and k is the same as in Figure 2.

For $\tilde{k} < k < \bar{k}'$, the credit limit is binding for the cheating output. From equation (17), we have

$$\pi_1 = (a - q_1 - \frac{a - \alpha r}{4})q_1 - (\alpha q_1 - k)R - kr \quad .$$

Hence, $\dfrac{d\pi_1}{dq_1} = a - \alpha R - 2q_1 - \dfrac{a-\alpha r}{4}$. As $\dfrac{\bar{B}(k)}{\alpha} < \dfrac{a-\alpha R-\frac{a-\alpha r}{4}}{2}$, we have $\dfrac{d\pi_1}{dq_1}(q_1 = \dfrac{\bar{B}(k)}{\alpha}) > 0$. Therefore, the cheating profit with a binding limit is lower than that without. The corresponding critical value for the trigger strategy equilibrium is given by

$$\delta_3' = \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} = \frac{(a - \frac{\bar{B}}{\alpha} - \frac{a-\alpha r}{4})\frac{\bar{B}}{\alpha} - \bar{B}R + k(R-r) - \frac{(a-\alpha r)^2}{8}}{(a - \frac{\bar{B}}{\alpha} - \frac{a-\alpha r}{4})\frac{\bar{B}}{\alpha} - \bar{B}R + k(R-r) - \frac{(a-\alpha r)^2}{9}} \; . \qquad (26)$$

As $\dfrac{d\delta}{d\pi_{ic}} > 0$, we find that $\delta_3' < \delta_3$, which implies that a binding credit limit increases the possibility of collusion. It can also be shown that $\dfrac{d\delta_3'}{dk} > 0$.

Define $\tilde{k}'$ such that $\bar{B}(\tilde{k}')=\tilde{k}'\frac{(1-p)R}{(1-p)R-\tau}=\frac{(a-\alpha R)\alpha}{3}$. Hence, we have $\tilde{k}'=\frac{(a-\alpha R)\alpha[(1-p)R-\tau]}{3(1-p)R}$. For $\tilde{k}' < k < \tilde{k}$, the credit limit is binding for the cheating output, whereas the Cournot output faces credit constraints without a binding credit limit. The critical value for the trigger strategy equilibrium is

$$\delta_4' = \frac{\pi_{ic}-\pi_{im}}{\pi_{ic}-\pi_{id}} = \frac{(a-\frac{\bar{B}}{\alpha}-\frac{a-\alpha r}{4})\frac{\bar{B}}{\alpha}-\bar{B}R+k(R-r)-\frac{(a-\alpha r)^2}{8}}{(a-\frac{\bar{B}}{\alpha}-\frac{a-\alpha r}{4})\frac{\bar{B}}{\alpha}-\bar{B}R-\frac{(a-\alpha R)^2}{9}}. \quad (27)$$

Comparing δ_4' and δ_4, we find that $\delta_4' < \delta_4$, as $\frac{d\delta}{d\pi_{ic}} > 0$, and the cheating profit with a binding limit is lower than that without.

When k drops further, q_{id} also becomes binding. For $\underline{k} < k < \tilde{k}'$, the credit limit is also binding for the Cournot output. In this case, π_{im} is not affected, yet the credit limit is binding for both the cheating and Cournot output. The profit under Cournot competition is

$$\pi_{id} = (a - 2\frac{\bar{B}}{\alpha})\frac{\bar{B}}{\alpha}.$$

Because the collusive output is not affected, we have $q_{im} < \frac{\bar{B}}{\alpha} < \frac{a-\alpha R}{3}$. Therefore, π_{id} increases when the credit limit becomes binding. Hence, the critical value for the trigger strategy equilibrium is given by

$$\delta_5' = \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} = \frac{(a - \frac{\overline{B}}{\alpha} - \frac{a - \alpha r}{4})\frac{\overline{B}}{\alpha} - \overline{B}R + k(R - r) - \frac{(a - \alpha r)^2}{8}}{(a - \frac{\overline{B}}{\alpha} - \frac{a - \alpha r}{4})\frac{\overline{B}}{\alpha} - (a - 2\frac{\overline{B}}{\alpha})\frac{\overline{B}}{\alpha}} . \tag{28}$$

In this case, the cheating profit with a binding credit limit is lower than that without, whereas the Cournot profit is higher with than without such a limit. Also, we have $\frac{d\delta}{d\pi_{ic}} > 0$ and $\frac{d\delta}{d\pi_{id}} > 0$, and the relationship between δ_5' and δ_4 is thus undetermined.

Define $\underline{k}'$ such that $\overline{B}(\underline{k}') = \underline{k}' \frac{(1-p)\mathrm{R}}{(1-p)R - \tau} = \frac{(a - \alpha R)\alpha}{4}$. We thus have $\underline{k}' = \frac{(a - \alpha R)[\alpha(1-p)R - \tau]}{4(1-p)R}$. For $\underline{k}' < k < \underline{k}$, the credit limit is binding for both the cheating and Cournot output, whereas the collusive output faces credit constraints without a binding credit limit. The critical value for the trigger strategy equilibrium is

$$\delta_6' = \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} = \frac{(a - \frac{\overline{B}}{\alpha} - \frac{a - \alpha R}{4})\frac{\overline{B}}{\alpha} - \overline{B}R - \frac{(a - \alpha R)^2}{8}}{(a - \frac{\overline{B}}{\alpha} - \frac{a - \alpha R}{4})\frac{\overline{B}}{\alpha} - (a - 2\frac{\overline{B}}{\alpha})\frac{\overline{B}}{\alpha}} . \tag{29}$$

Similarly, the cheating profit with a binding credit limit is lower than that without, whereas the reverse is the case for the Cournot profit. Hence, the relationship between δ_6' and $\frac{9}{17}$ is undetermined.

For $k < \underline{k}'$, the credit limit is binding even for the collusive output, which implies that the profits are the same under the three production strategies. Hence, none of the firms can increase its payoff by deviating from the collusive output, and δ approaches infinity.

We now extend Figure 2 to Figure 3 to demonstrate that a binding credit limit may increase the possibility of collusion. The dashed and solid lines in Figure 3 represent the movement of δ with respect to k when the credit limit is non-binding and binding, respectively.

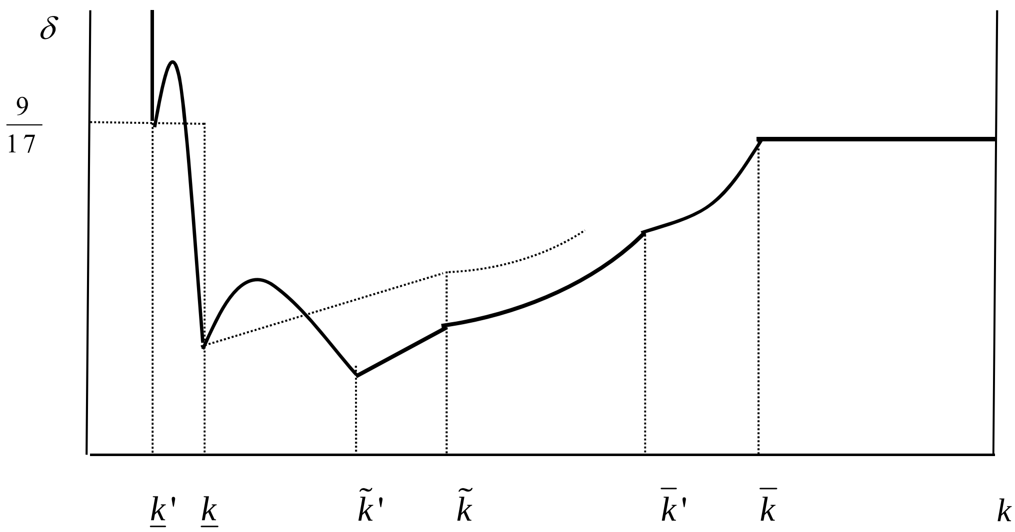


Figure 3 Relationship between δ and k with a binding credit limit under Cournot competition

We thus have the following proposition.

Proposition 2: *If the credit limit is binding, the response of* δ *to the debt/equity ratio is also non-monotonic. The possibility of collusion may increase under a binding credit limit compared to a non-binding credit limit.*

Proof: See the discussion above. QED

6. The Bertrand Model

In this section, we briefly describe a Bertrand price-setting game in the homogeneous good case under three possible scenarios: (a) the firms do not need to borrow; (b) the firms borrow but do not face a credit limit; and (c) the firms face a binding credit limit.

We first consider the scenario in which the firms do not need to borrow. Invoking the standard logic of the Bertrand game, we know that $\pi_{ic} = 2\pi_{im}$ because, with slight undercutting, the deviant can cover the entire market, earning almost the entire monopoly profit. $\pi_{id} = 0$ due to the limit pricing equilibrium.

Let δ_B denote the critical value for the trigger strategy equilibrium under Bertrand competition. Hence, we have

$$\delta_B = \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} = \frac{1}{2}. \qquad (30)$$

This is the case in which no credit is required.

Now consider the second case in which the firms borrow at $R > r$. Note that a firm earns $k(R-r)$ when it is forced to borrow.

$$\begin{aligned}\delta_B &= \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} \\ &= \frac{\frac{(a-\alpha R)^2}{4} + k(R-r) - \frac{(a-\alpha R)^2}{8} - k(R-r)}{\frac{(a-\alpha R)^2}{4} + k(R-r) - k(R-r)} . \qquad (31) \\ &= \frac{1}{2}\end{aligned}$$

Therefore, the degree of collusion remains the same in cases (a) and (b), which is exactly the same as Proposition 1.

When we transit from case (a) to (b), π_{im} is initially unaffected, and therefore π_{im} continues to be evaluated at r. However, π_{ic} is evaluated at R, and thus

$$\pi_{ic}(R) < \pi_{ic}(r) = \pi_{im}(r) .$$

In this case, the critical value for the trigger strategy equilibrium under Bertrand competition is

$$\begin{aligned}\delta_B &= \frac{\pi_{ic} - \pi_{im}}{\pi_{ic} - \pi_{id}} \\ &= \frac{\frac{(a-\alpha R)^2}{4} + k(R-r) - \frac{(a-\alpha r)^2}{8}}{\frac{(a-\alpha R)^2}{4}} < \frac{\frac{(a-\alpha R)^2}{4} - \frac{(a-\alpha R)^2}{8}}{\frac{(a-\alpha R)^2}{4}} = \frac{1}{2} . \qquad (32)\end{aligned}$$

Hence, δ_B is lower than $\frac{1}{2}$ in this case. We also have $\frac{d\delta_B}{dk} > 0$ and $\frac{d^2\delta_B}{dk^2} = 0$.

Define $\bar{\bar{k}} = \frac{(a-\alpha R)\alpha}{2}$ and $\underline{\underline{k}} = \frac{(a-\alpha R)\alpha}{4}$, which means that the credit constraint is not binding for $k > \bar{\bar{k}}$. Both the cheating and duopoly output face credit constraints for $k < \bar{\bar{k}}$. The collusive output also comes under credit constraints for $k < \underline{\underline{k}}$. Thus, the critical value for the trigger strategy equilibrium under Bertrand competition is equal to $\frac{1}{2}$ for $k > \bar{\bar{k}}$ and $k < \underline{\underline{k}}$, and is less than $\frac{1}{2}$ for $\underline{\underline{k}} < k < \bar{\bar{k}}$.

Figure 4 illustrates the relationship between δ and k under a non-binding credit limit and Bertrand competition.

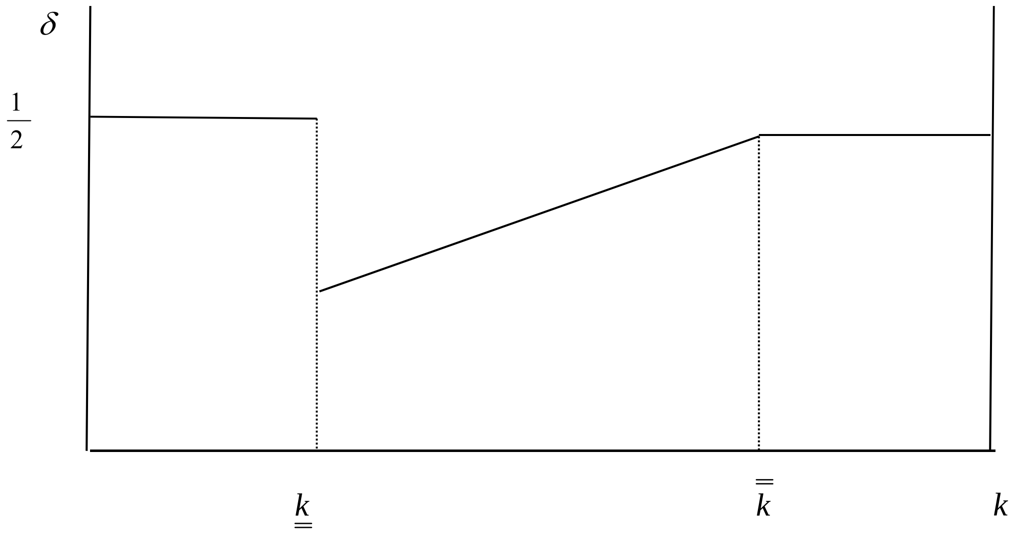


Figure 4 Relationship between δ and k without a binding credit limit under Bertrand competition

We next discuss case (c) in which there is a binding credit limit. Define $\bar{\bar{k}}'$ such that $\bar{\bar{k}}' = \frac{(a-\alpha R)\alpha[(1-p)R-\tau]}{2(1-p)R}$ and $\underline{\underline{k}}'$ such that $\underline{\underline{k}}' = \frac{(a-\alpha R)\alpha[(1-p)R-\tau]}{2(1-p)R}$.

Hence, the credit limit is binding for both cheating and duopoly output for $k < \bar{\bar{k}}'$ and for collusive output for $k < \underline{\underline{k}}'$.

For $k > \bar{\bar{k}}'$, the credit limit is non-binding for all three levels of output, and the relationship between δ and k is thus the same as in Figure 4.

For $\underline{\underline{k}} < k < \bar{\bar{k}}'$, both the cheating and duopoly output are binding, whereas the collusive output faces no credit constraints. A binding cheating output implies that even if the deviant undercuts, it may be unable to cover the entire market. Hence, π_{ic} is lower than in the case of no binding credit limit. The duopoly profit is still equal to 0, whereas π_{im} is unaffected. Accordingly, the critical value for the trigger strategy equilibrium is lower than that without a binding credit limit.

For $\underline{\underline{k}}' < k < \underline{\underline{k}}$, both the cheating and duopoly output are binding, whereas the collusive output faces credit constraints without a binding credit limit. Because π_{ic} with a binding credit limit is less than that without, δ_B is less than $\frac{1}{2}$.

For $k < \underline{\underline{k}}'$, credit is binding for all three outputs. Therefore, none of the firms can increase its payoff by deviating from the collusive output, and δ_B approaches infinity, which is the same as the conclusion under Cournot competition.

Figure 5 summarizes the result of the Bertrand game with a binding credit limit. There is little change in our conclusions under Cournot or Bertrand competition.

In the middle range of the initial k, the possibility of collusion increases. If firms can borrow, and the collusive and deviation payoffs are symmetrically affected, the degree of collusion remains invariant with changes in k. The possibility of collusion may be greater in the presence of a binding credit limit than in the scenario of non-binding credit limit.

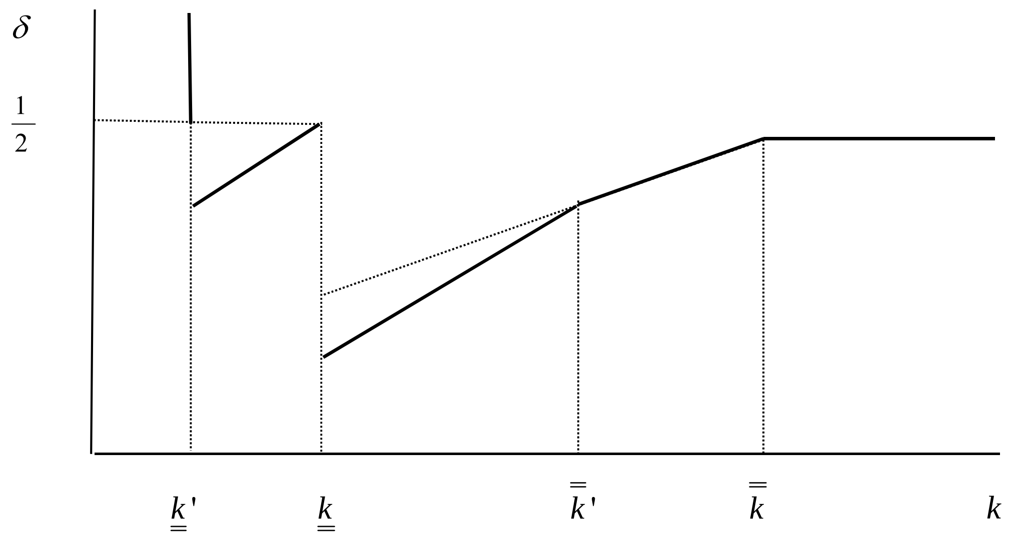


Figure 5 Relationship between δ and k with a binding credit limit under Bertrand competition

The above discussion is summarized in the following proposition.

Proposition 3: *The results derived under Bertrand competition are generally very similar to the results derived under Cournot competition. Under Bertrand competition, the response of* δ *to the debt/equity ratio is non-monotonic. The possibility of collusion may be greater under a binding credit limit than under a non-binding credit limit.*

7. Concluding Remarks

We have shown in this paper that the sustainable degree of collusion is non-monotonic with respect to the debt-equity ratio. However, a drastic fall in a firm's own equity increases the possibility of collusion. A larger debt-equity ratio has a greater chance of sustaining collusion provided that the non-cooperative payoff is not favorably affected. An adverse demand shock by itself may not affect collusion, but it does affect k, thus leading to collusion. Similarly, a positive demand shock relaxes the constraints and reduces the markup. Thus, financial factors may determine the counter-cyclical behavior of markups.

This paper investigates the behavior of finance-constrained firms in an oligopolistic setting, a rather neglected segment of the literature. A large number of entrepreneurs in the developing world face credit constraints due to a lack of wealth, assets, or cash flow. For them, bank financing is absolutely essential. The models presented herein should thus be studied in greater detail for firms with different levels of asset holdings.

For example, it could be demonstrated that in the presence of fixed costs and heterogeneous levels of k, a financial crisis would increase the price-cost margin through the exit of weaker firms independent of repeated firm interactions. However, such exits may be efficient if they promote the adoption of new technology. This supposition is related to a similar outcome in a completely different context, that analyzed by Bolton and Scharfstein (1990). Another useful extension would be to consider the effect of collusive banking on the sustainability of product market collusion when banks can charge differential interest rates even when firms do not face physical constraints. We will explore these issues in future work.

Appendix

A general demand function: We show in this Appendix that the non-monotonic relationship between credit constraint and the incentive to collude remains even under a general demand function. Assume that the inverse demand function is *p(q)* with $p' < 0$ and the firms compete like Cournot oligopolists.

Collusion is sustainable if $\delta \geq \frac{\pi_{ic}(r) - \pi_{im}(r)}{\pi_{ic}(r) - \pi_{id}(r)} \equiv \delta^*$, where $\pi_{im}(r)$, $\pi_{id}(r)$ and $\pi_{ic}(r)$ are the collusive profit, non-cooperative Cournot profit and cheating or deviating profit of the *i*th firm, *i = 1, 2*, and these profits are a function of the cost of capital, *r*. Considering that credit constraint affects the cost of capital, *r*, we get that

$$\frac{\partial \delta^*}{\partial r} = \frac{\left(\frac{\partial \pi_{ic}}{\partial r} - \frac{\partial \pi_{im}}{\partial r}\right)\left(\pi_{ic} - \pi_{id}\right) - \left(\frac{\partial \pi_{ic}}{\partial r} - \frac{\partial \pi_{id}}{\partial r}\right)\left(\pi_{ic} - \pi_{im}\right)}{\left(\pi_{ic} - \pi_{id}\right)^2}$$

$$= \frac{\frac{\partial \pi_{ic}}{\partial r}\left(\pi_{im} - \pi_{id}\right) + \frac{\partial \pi_{id}}{\partial r}\left(\pi_{ic} - \pi_{im}\right) - \frac{\partial \pi_{im}}{\partial r}\left(\pi_{ic} - \pi_{id}\right)}{\left(\pi_{ic} - \pi_{id}\right)^2} \quad . \qquad \text{(A1)}$$

First, consider the case where the *i* th firm, *i* = *1, 2*, faces a binding credit constraint only under cheating, i.e., the credit constraint affects only $\pi_{ic}(r)$. In this situation, if the credit constraint increases, which increases *r*, the expression (A1) becomes $\frac{\partial \delta^*}{\partial r} = \frac{\frac{\partial \pi_{ic}}{\partial r}\left(\pi_{im} - \pi_{id}\right)}{\left(\pi_{ic} - \pi_{id}\right)^2} < 0$, since $\left(\pi_{im} - \pi_{id}\right) > 0$, $\left(\pi_{ic} - \pi_{id}\right) > 0$ and $\frac{\partial \pi_{ic}}{\partial r} < 0$ (as, it is usual to consider that a higher cost of capital reduces $\pi_{ic}(r)$). Hence, a higher credit constraint increases the possibility of collusion.

Next, consider the case where the *i*th firm, *i* = *1, 2*, faces a binding credit constraint under cheating and non-cooperation, i.e., the credit constraint affects $\pi_{ic}(r)$ and $\pi_{id}(r)$. In this situation, if the credit constraint increases, the expression (A1) becomes $\frac{\partial \delta^*}{\partial r} = \frac{\frac{\partial \pi_{ic}}{\partial r}\left(\pi_{im} - \pi_{id}\right) + \frac{\partial \pi_{id}}{\partial r}\left(\pi_{ic} - \pi_{im}\right)}{\left(\pi_{ic} - \pi_{id}\right)^2}$. Since $\left(\pi_{im} - \pi_{id}\right) > 0$, $\left(\pi_{ic} - \pi_{im}\right) > 0$, $\left(\pi_{ic} - \pi_{id}\right) > 0$ and $\frac{\partial \pi_{ic}}{\partial r} < 0$, we get that $\frac{\partial \delta^*}{\partial r} < 0$ if $\frac{\partial \pi_{id}}{\partial r} < 0$ but $\frac{\partial \delta^*}{\partial r}$ can be positive only if $\frac{\partial \pi_{id}}{\partial r} > 0$. Hence, a higher credit constraint increases the possibility of collusion if $\frac{\partial \pi_{id}}{\partial r} < 0$ but it may decrease the possibility of collusion only if $\frac{\partial \pi_{id}}{\partial r} > 0$.

Finally, consider the case where the *i*th firm, *i* = *1, 2*, faces a binding credit constraint under cheating, non-cooperation and collusion, i.e., the credit constraint affects $\pi_{ic}(r)$, $\pi_{id}(r)$ and $\pi_{im}(r)$. In this situation, if the credit constraint increases, the relevant expression is (A1), i.e., $\frac{\partial \delta^*}{\partial r} = \frac{\frac{\partial \pi_{ic}}{\partial r}(\pi_{im} - \pi_{id}) + \frac{\partial \pi_{id}}{\partial r}(\pi_{ic} - \pi_{im}) - \frac{\partial \pi_{im}}{\partial r}(\pi_{ic} - \pi_{id})}{(\pi_{ic} - \pi_{id})^2}$. If $\frac{\partial \pi_{im}}{\partial r} < 0$, it increases the possibility of $\frac{\partial \delta^*}{\partial r} > 0$, i.e., increases the possibility of a lower incentive for collusion, compared to the situation where credit constraint is non-binding under collusion.

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