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ON DEBT-FINANCING AND INVESTMENT TIMING*

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This paper studies the relationship between debt-financing and the timing of investment, under asymmetric information. In particular we show that an option to delay raises the average profitability of firms who choose to invest immediately, thereby reducing the market interest rate on debt. Moreover, the option to delay is shown to be welfare improving. (JEL: D81, D92, G33)

Introduction

It is well known that financial sources may affect investment decisions (see, e.g., Hart, 1995, and Hubbard, 1998). However, the literature on investment irreversibility almost always assumes equity-financing. Among the few exceptions, Vercammen (2000) shows that, under default risk, an option to delay induces firms to defer investment. By delaying investment, in fact, firms can reduce their debt, and, consequently, their default risk.

Lensink and Sterken (2001) make a step further by studying debt-financing under asymmetric information. They show that, if the firm is liquidity-constrained, the option to delay changes the sign of the distortion. Without the option, in fact, underinvestment takes place. When the option is available, the converse is true. However, they cannot prove whether such an option is welfare improving or not.

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Lensink and Sterken's (2001) results are obtained by assuming a continuum of firms, who face firm-specific shocks. Following Stiglitz and Weiss (1981), in fact, they assume that firms' projects have the same expected return but are characterised by different probabilities of success. Moreover, they use the simplifying assumption that the project return is zero in the bad state.

In this paper, we aim to study the effects of an option to delay under an industry-specific shock. This is relevant since, by assuming idiosyncratic risk, Lensink and Sterken (2001) do not take into account one of most important causes of irreversibility, i.e., industry comovement. When a firm can resell its capital, but the potential buyers operating in the same industry are subject to the same adverse market conditions, this comovement obliges the firm to sell the capital at a considerably lower price than an insider would otherwise be willing to pay. Moreover, we assume that, if default takes place, the firm's value is not necessarily zero. Although capital cannot be sold to insiders, the bank can expropriate the firm's assets by partially compensating for its loss.

In our model, firms differ for their initial gross profit and face the same shock. Thus, they have a different expected return. Moreover, we assume that, in the bad state, firms' gross profits are less than the risk-free return. This entails a 'pure' loss, but represents a collateral for the bank. Given these assumptions, we show that the option to delay raises the average profitability of firms investing at time 0, thereby reducing the debt interest rate. Moreover, this option is shown to be welfare improving.

2. *The model*

In this section we introduce a simple discrete-time model describing the relationship between debt-financed firms and a competitive bank.

2.1 The firm's problem

Let us assume a continuum of risk-neutral firms, who decide whether to invest in one sector. Firms differ for their initial gross profit Π_i, which is characterised by a density function $f(\Pi)$ for $\Pi \in [\underline{\Pi}, \overline{\Pi}]$. Since they are unable to self finance the project, they borrow the capital from a bank.[1] They pay interests at the end of each period at an interest rate ρ_0, which is set by the bank. For simplicity we assume that no renegotiation of the interest rate is allowed.

Firms face a bivariate industry shock. Given the firm-specific gross profit Π_i at time 0, all firms' profits will change at time 1. With probability q they will rise to $(1 + u)\Pi_i$ and with probability $(1 - q)$ they will drop to $(1 - d)\Pi_i$. Parameters $u > 0$ and $1 > d \geq 0$ measure the upward and downward profit moves. At time 1, uncertainty vanishes and the gross profit will remain at the new level forever. For simplicity we assume that

$$(1+u)\underline{\Pi} > \frac{r}{1+r} I > (1-d)\overline{\Pi}.$$

Namely, whatever its type, if a good news is received, the firm survives. If, instead, a bad news is received, the firm is unable to pay the interest and defaults. Given the above inequality, all firms face the same default risk. In the bad state, their assets are expropriated by the bank. Though capital cannot be sold to insiders, the bank can manage the firm thereby partially compensating for the loss.[2]

The initial profit level of firm i is firm i's private information. Following Stiglitz and Weiss (1981) and Lensink and Sterken (2001), we concentrate on a pooling equilibrium. Namely, we assume that neither firms can send signals of profitability nor banks can discriminate among firms. This rules out any separating equilibrium.

In the absence of any option to delay, the timing of decisions is as follows. Firms decide whether investing at time 0 or never. Contemporaneously the bank sets the interest rate ρ_0 ensuring nil profits. At the end of time 0, firms may start earning profits, net of the interest rate. If default takes place, firms are expropriated by the bank.

Let us now focus on the firms' decision. Without any option, their problem is

$$\max\left\{NPV^F_{0_i}, 0\right\}, \ \forall i \tag{1}$$

where, given the risk-free interest rate r,

$$NPV^F_{0_i} = \Pi_i - \rho_0 \frac{I}{1+r} + q \cdot \sum_{t=1}^{\infty} \frac{1}{(1+r)^t}\left[(1+u)\,\Pi_i - \rho_0 \frac{I}{1+r}\right] + (1-q)\cdot 0, \tag{2}$$

is the present value of future profits, net of the investment cost. It is worth noting that the profit in the bad state is not taken into account because the owner is expropriated.

According to problem (1) if $NPV^F_{0_i} > 0$, then investment is undertaken. Setting $NPV^F_{0_i} = 0$ and solving for Π_i one obtains the firm's trigger point above which investment is profitable

$$\Pi^* \equiv \frac{r+q}{r+(1+u)q} \frac{\rho_0}{1+r} I. \tag{3}$$

[1] *This assumption is fairly realistic for start-ups, who cannot rely on reputation and are only seldom equity-financed.*

[2] *Due to irreversibility, the present value of gross profits in the bad state, $\frac{(1-d)\Pi_i}{r}$, is greater than revenues arising from reselling the installed capital.*

As can be seen, the trigger point depends on ρ_0. Since all the firms investing at time 0 pay the same interest rate, they will have the same trigger point.

When firm *i* can postpone investment, it faces a trade-off. If it invests at time 0, it earns Π_i. If, instead, it waits until time 1, it loses Π_i, but its benefit is twofold. First, it gathers information. Second, the default risk vanishes. Therefore, the debt interest rate drops to *r*. The firm's problem is now

$$\max\left\{NPV_{0_i}^F, NPV_{1_i}^F\right\}, \forall i \tag{4}$$

where

$$NPV_{1_i}^F = q \cdot \sum_{t=1}^{\infty} \frac{1}{(1+r)^t}\left[(1+u)\,\Pi_i - r\frac{I}{1+r}\right] \tag{5}$$

is the net present value of the firm's profit when investing at time 1. As can be seen $NPV_{1_i}^F$ takes into account only good news, since a rational firm would not invest in the bad state.[3]

Using equations (2), (5), setting $NPV_{0_i}^F = NPV_{1_i}^F$ and solving for Π_i yields the common trigger point above which immediate investment is profitable

$$\Pi^{**} \equiv \left(\rho_0 + q \cdot \frac{\rho_0 - r}{r}\right)\frac{I}{1+r}. \tag{6}$$

The term $q \cdot \frac{\rho_0 - r}{r}$ measures the expected loss in terms of interest rate, faced by those firms who decided to invest at time 0. A comparison between (3) and (6) shows that $\Pi^{**} > \Pi^*$, for any ρ_0. With an option to delay, in fact, the firm must take into account both the opportunity cost, represented by the exercise of the option, and the higher interest rate paid when investing at time 0.

2.2 The bank

The bank lends before observing the firm-specific payoff Π_i^*. However, it knows the density function $f(\Pi)$ and the parameters *q*, *d* and *u*. Thus, it can compute the firms' trigger point. Without the option to delay, therefore, its net present value is

$$\begin{aligned} NPV_0^B(\Pi^*) = \int_{\Pi^*}^{\overline{\Pi}} \Big\{&\rho_0\tfrac{I}{1+r} + q\textstyle\sum_{t=1}^{\infty}\tfrac{\rho_0}{(1+r)^t}\tfrac{I}{1+r} + \\ &+(1-q)\textstyle\sum_{t=1}^{\infty}\tfrac{(1-d)}{(1+r)^t}\Pi - \textstyle\sum_{t=0}^{\infty}\tfrac{r}{(1+r)^t}\tfrac{I}{1+r}\Big\} f(\Pi)d\Pi. \end{aligned} \tag{7}$$

Under perfect competition the bank's profits are zero. Thus, setting $NPV_0^B(\Pi^*) = 0$ and solving for ρ_0. one obtains

$$\rho_0(\Pi^*) = \frac{1+r}{q+r}r\left[1 - \frac{(1-q)(1-d)E(\Pi \mid \Pi \geqslant \Pi^*)}{rI}\right] \tag{8}$$

where $E(\Pi \mid \Pi \geqslant \Pi^*) = \frac{\int_{\Pi^*}^{\overline{\Pi}} \Pi f(\Pi)d\Pi}{1-F(\Pi^*)}$ is the expected conditional payoff for the sub-set of firms with $\Pi_i \in [\Pi^*, \overline{\Pi}]$, namely for the firms which invest.[4]

When firms hold an option to delay, the bank's net present value is

$$\begin{aligned} NPV_0^B(\Pi^{**}) = \int_{\Pi^{**}}^{\overline{\Pi}} \Big\{&\rho_0\tfrac{I}{1+r} + q\textstyle\sum_{t=1}^{\infty}\tfrac{\rho_0}{(1+r)^t}\tfrac{I}{1+r} + \\ &+(1-q)\textstyle\sum_{t=1}^{\infty}\tfrac{(1-d)\Pi}{(1+r)^t} - \textstyle\sum_{t=0}^{\infty}\tfrac{r}{(1+r)^t}\tfrac{I}{1+r}\Big\} f(\Pi)d\Pi + \\ &+q\int_{\underline{\Pi}}^{\Pi^{**}}\Big[\textstyle\sum_{t=1}^{\infty}\tfrac{r-r}{(1+r)^t}\tfrac{I}{1+r}\Big] f(\Pi)d\Pi. \end{aligned} \tag{9}$$

The term $q\int_{\underline{\Pi}}^{\Pi^{**}}\sum_{t=1}^{\infty}\frac{r-r}{(1+r)^t}\frac{I}{1+r}f(\Pi)d\Pi$ measures the present discounted value of interest revenues earned by the bank if the firm invests at time 1. Since the default risk has vanished, however, this term is zero. Now, setting $NPV_0^B(\Pi^{**}) = 0$ and solving for ρ_0 yields

$$\rho_0(\Pi^{**}) = \frac{1+r}{q+r}r\left[1 - \frac{(1-q)(1-d)E(\Pi \mid \Pi \geqslant \Pi^{**})}{rI}\right], \tag{10}$$

where $E(\Pi \mid \Pi \geqslant \Pi^{**}) = \frac{\int_{\Pi^{**}}^{\overline{\Pi}} \Pi f(\Pi)d\Pi}{1-F(\Pi^{**})}$. As can be seen, the sub-set of firms investing at time 0 differs from the one obtained without the option to delay, namely $[\Pi^{**}, \overline{\Pi}] \subset [\Pi^*, \overline{\Pi}]$.

So far we have shown how firms compute their trigger points, for a given interest rate, and how the bank sets the interest rate for a given trigger point. Given the above results we can find a pooling equilibrium where the trigger point and the interest rate are computed simultaneously. The following Proposition holds:

Proposition 1: The introduction of an option to delay reduces the interest rate paid by those

[3] *For details on the firm's problem under equity-financing see Dixit and Pindyck (1994).*

[4] *It can be shown that, given $\frac{r}{1+r}I > (1-d)\underline{\Pi}$, inequality $\rho(\Pi^*) > r$ holds.*

firms who decide to invest at time 0, i.e. $\rho_0(\Pi^{**}) < \rho_0(\Pi^*)$.

Proof: Using (8) and (10) it is straightforward to ascertain that the sign of $[\rho_0(\Pi^{**}) - \rho_0(\Pi^*)]$ depends on the difference $[E(\Pi \mid \Pi \geqslant \Pi^*) - E(\Pi \mid \Pi \geqslant \Pi^{**})]$. Since the conditional expected value increases with an increase in the lower bound, the following relation holds

$$\rho_0(\Pi^{**}) - \rho_0(\Pi^*) \propto [\Pi^* - \Pi^{**}]\,. \tag{11}$$

To show that inequality $\rho_0(\Pi^{**}) < \rho_0(\Pi^*)$ holds, assume *ab absurdo* that $\Pi^{**} < \Pi^*$. Using the relation (11), we would obtain $\rho_0(\Pi^{**}) > \rho_0(\Pi^*)$. If, however, we compare equations (3) and (6), it is easy to ascertain that, for a given interest rate ρ_0, inequality $\Pi^{**} > \Pi^*$ holds. *A fortiori*, this inequality holds if $\rho_0(\Pi^{**}) > \rho_0(\Pi^*)$. This contradicts the assumption $\Pi^{**} < \Pi^*$. Since $\Pi^{**} > \Pi^*$, therefore, the inequality $\rho_0(\Pi^{**}) < \rho_0(\Pi^*)$ always holds.■

The intuition behind the above result is straightforward: the existence of an option to delay induces the firms with an intermediate payoff, i.e., with $\Pi \in (\Pi^*, \Pi^{**})$, to postpone investment. This implies that the average profitability of the firms investing at time 0 is higher. Thus, the interest rate, ensuring null profits to the bank, is lower.

Given the above Proposition, we have thus obtained inequalities $\Pi^{**} > \Pi^*$ and $\rho_0(\Pi^{**}) < \rho_0(\Pi^*)$, which hold if the gross profit in the bad state is positive, i.e., $d < 1$. If, following Lensink and Sterken (2001), we assumed $d = 1$, instead, equalities $\Pi^{**} = \Pi^*$ and $\rho_0(\Pi^{**}) = \rho_0(\Pi^*)$ would hold. Thus the firm-bank relationship would be unaffected by the option.

3. *The welfare analysis*

Let us now define welfare as the summation of the firms' and the banks' present values. Under perfect competition, however, NPV_0^B is zero.

Thus social welfare boils down to the former term. Given Proposition 1 we can prove the following

Proposition 2: The introduction of an option to delay is welfare improving.

Proof: To prove the above Proposition let us substitute (8) and (10) into (2). For any given Π we have

$$NPV_0^F(\rho_0(\Pi^*)) = \left(\frac{r+q(1+u)}{r}\right)\Pi - \frac{\rho_0(\Pi^*)}{r}\frac{q+r}{1+r}I, \tag{12}$$

$$NPV_0^F(\rho_0(\Pi^{**})) = \left(\frac{r+q(1+u)}{r}\right)\Pi - \frac{\rho_0(\Pi^{**})}{r}\frac{q+r}{1+r}I. \tag{13}$$

Since $\rho_0(\Pi^{**}) < \rho_0(\Pi^*)$, the inequality $NPV^F_0\,(\rho_0(\Pi^{**})) > NPV^F_0\,(\rho_0(\Pi^*))$ holds $\forall \Pi > 0$. Using (12), we can compute the welfare function in the absence of any option to delay

$$W_{nd} \equiv \int_{\Pi^*}^{\overline{\Pi}} NPV_0^F(\rho_0(\Pi^*))f(\Pi)d\Pi. \tag{14}$$

With the option to delay, instead, the present value of firms investing at time 1 must be taken into account. Thus, using (5) and (13) we have

$$W_d \equiv \int_{\Pi^{**}}^{\overline{\Pi}} NPV_0^F(\rho_0(\Pi^{**}))f(\Pi)d\Pi + + \int_{\underline{\Pi}}^{\Pi^{**}} NPV_1^F f(\Pi)d\Pi. \tag{15}$$

Using (14) and (15) let us compute the difference

$$W_d - W_{nd} = \int_{\Pi^{**}}^{\overline{\Pi}} NPV_0^F(\rho_0(\Pi^{**}))f(\Pi)d\Pi + \int_{\underline{\Pi}}^{\Pi^{**}} NPV_1^F f(\Pi)d\Pi - \int_{\Pi^*}^{\overline{\Pi}} NPV_0^F(\rho_0(\Pi^*))f(\Pi)d\Pi \tag{16}$$

Since $\Pi^{**} > \Pi^*$, the difference (16) can be rewritten as

$$W_d - W_{nd} = \int_{\Pi^{**}}^{\overline{\Pi}} \left[NPV_0^F(\rho_0(\Pi^{**})) - NPV_0^F(\rho_0(\Pi^*))\right] f(\Pi)d\Pi + + \int_{\underline{\Pi}}^{\Pi^{**}} NPV_1^F f(\Pi)d\Pi - \int_{\Pi^*}^{\Pi^{**}} NPV_0^F(\rho_0(\Pi^*))f(\Pi)d\Pi. \tag{17}$$

Next, note that firms with $\Pi < \Pi^{**}$ prefer to postpone investment. In other words, they have $NPV_1^F > NPV_0^F(\rho_0(\Pi^{**}))$. Moreover, inequality $NPV_0^F\,(\rho_0(\Pi^{**})) > NPV_0^F\,(\rho_0(\Pi^*))$ holds $\forall\Pi$. Given the above inequalities we thus have $NPV_1^F > NPV_0^F(\rho_0(\Pi^*))$ for $\Pi < \Pi^{**}$. This implies that inequality

$$\int_{\Pi^*}^{\Pi^{**}} \left[NPV_1^F - NPV_0^F(\rho_0(\Pi^*))\right] f(\Pi)d\Pi > 0$$

holds. Next, rewrite (17) as

(18)

$$W_d - W_{nd} = \int_{\Pi^{**}}^{\overline{\Pi}} \left[NPV_0^F(\rho_0(\Pi^{**})) - NPV_0^F(\rho_0(\Pi^*))\right] f(\Pi)d\Pi +$$
$$+ \int_{\Pi^*}^{\Pi^{**}} \left[NPV_1^F - NPV_0^F(\rho_0(\Pi^*))\right] f(\Pi)d\Pi + \int_{\underline{\Pi}}^{\Pi^*} NPV_1^F f(\Pi)d\Pi > 0,$$

Since the three terms in the RHS of (18) are positive, the difference $W_d - W_{nd}$ is always positive. The Proposition is thus proven.■

According to Proposition 1, the option to delay raises the quality of firms investing at time 0, thereby reducing the debt interest rate. As firms pay a lower interest rate and the bank benefits from better conditions, according to Proposition 2, a welfare improvement takes place.

4. Conclusion

In this article, we have studied the effects of debt-financing on investment timing. In particular, we have shown that the ownership of an option to delay raises the average profitability of firms investing immediately, thereby reducing the debt interest rate. Moreover, this option is shown to be welfare improving.

This paper must be considered as a benchmark for future research. In particular future developments should include moral hazard. It may happen, in fact, that firms can send an intentionally misleading signal to banks in order to exploit more favourable market conditions. Alternatively, they might devote to the business less effort than expected.

Moreover, recent empirical evidence shows that a higher cost of default stimulates firms to innovate in order to reduce the default risk in the future (see Aghion et al., 2002). This is an interesting puzzle for future research, since innovation entails the payment of sunk costs. Thus undertaking innovation means exercising the option to delay earlier thereby loosing flexibility.

Another promising direction for further research is represented by venture capital finance. As we know, in innovative industries, the use of convertibles has substantially replaced traditional debt-financing. This leads to a double moral-hazard problem (see, e.g., Kanniainen and Keuschnigg, 2001). The introduction of an option to delay entails the existence of a trade-off between the benefits from immediate investment and the loss of flexibility. If good news is received, the entrepreneur has to share its positive result with the venture capitalist. On the other hand, if default takes place, its cost is completely shifted to the venture capitalist. In turn, the balancing between good and bad news may affect the agency problem between the entrepreneur and the venture capitalist.

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