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Asymmetric information, option to wait to invest and the optimal level of investment

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Abstract

This paper analyzes equilibrium rationing on credit markets in the case of gains from waiting to acquire information about the future profitability of investment. We compare the competitive outcome with the socially optimal level of investment. We show that the opportunity to postpone investment changes the nature of the inefficiencies of the competitive outcome fundamentally. Without the option to wait, high risk firms tend to invest and the outcome is characterized by a situation of underinvestment. If firms can wait high risk firms benefit the most from waiting. In this case low risk firms tend to invest immediately and a situation of overinvestment will result, since from the banks' point of view firms do not delay enough. © 2001 Elsevier Science B.V. All rights reserved.

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JEL classification: D81; D92; E22

1. Introduction

Asymmetric information may lead to equilibrium rationing of external funds available for real investment (see, e.g. Stiglitz and Weiss, 1982). More recent literature shows that due to costly reversibility there might be an opportunity cost of investing immediately rather than waiting (see, e.g. Dixit and Pindyck, 1994).

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The novelty of this paper is that it combines both the implications of asymmetric information in the credit market and the option to wait. We examine whether the optimal level of real investment from a social point of view corresponds with the competitive outcome for two models with asymmetric information: in the first model we assume that there is no option to wait, while in the second one there is. The possibility to delay investment changes the nature of the inefficiencies of the competitive outcome fundamentally. The competitive outcome is characterized by underinvestment if there is no possibility to delay. However, in case the investment decision can be postponed, there are too many high risk firms investing immediately. We analyze how taxing can prevent this form of dynamic misallocation.

The next section presents the basic model, in which no option value of waiting is taken into account. Section 3 extends the base model by taking into account that investing firms have an option value to wait. We consider the extreme case where investment is completely irreversible and waiting resolves uncertainty. Section 4 summarizes and concludes.

2. The model without an option to wait

We present the base model in the spirit of Stiglitz and Weiss (1982). The model resembles the models of Gale (1990, 1991), De Meza and Webb (1987, 1988) and especially Mankiw (1986). Mankiw examines the allocation of credit in a market in which borrowers have more information about their own riskiness than lenders. He illustrates, by analyzing a one-period model for the market for scholarships, that the allocation of credit may be inefficient and may be improved by government intervention. We consider a two-period setting and apply the model to the market for bank loans. The model consists of different types of firms, a representative commercial bank and a government.

2.1. The decision rules for firms and the bank

The model includes a continuum of risk neutral firms. Each firm decides whether it will invest (I) in a project or deposit its initial wealth (W) on a savings account on which a safe rate of interest ρ is paid by a bank. There is one project available per firm, so that firms and projects are interchangeable. There is only one decision moment, namely at $t = 0$. If a firm invests, its initial wealth is assumed to be too low for its given investment plan so that the firm has to raise outside finance by an amount $L = I - W$. We assume in line with De Meza and Webb (1988, p. 17) and Gale (1990, p. 180) that the costs of issuing equity and bonds are prohibitively high, so the firm needs bank loans L . The state of the world in the first period is known, but in the following periods there is a good and a bad state. Hence, we assume that there is only uncertainty in the *future*. This assumption is

in line with the work by Pindyck (1982) and Abel (1983) who argue that firms face much more uncertainty over future events than over the current period. If the firm invests, the payoff in the first period equals F_0 . In the second and following periods, the expected project return in the good state equals R_i and zero in the bad state (the subscript i refers to firm of type i). The project return will remain at this level forever. It is assumed that the size of the project (I), initial wealth (W) and the payoff in the first period (F_0) are the same for all firms. In line with Stiglitz and Weiss (1982) it is assumed that the expected return of projects (A) is equal. The heterogeneity of firms is taken into account by assuming that firms differ with respect to return in case the project is successful and with respect to the probability of success (q_i). q_i is the riskiness parameter, which is privately observed. An increase in q_i means less risk in the sense of mean preserving spread. We assume that q_i is uniformly distributed between q_0 and q_H with $0 < q_0 \leq q_i \leq q_H < 1$. The assumption of equal expected returns for all projects i implies:

$$F_0 + q_i \sum_{t=1}^{\infty} \frac{R_i}{(1 + \rho)^t} = F_0 + \frac{q_i R_i}{\rho} = A \tag{1}$$

The firm will undertake the investment project if the expected return from the project exceeds the opportunity cost. If the lending rate for a firm equals r , and if it is assumed that the risk over project returns is fully diversifiable (with a complete spanning of financial markets) so that the firm discounts cash flows with the safe rate of interest ρ , the firm invests if:

$$F_0 - rL + q_i(R_i - rL) \sum_{t=1}^{\infty} \frac{1}{(1 + \rho)^t} \geq \sum_{t=0}^{\infty} \frac{\rho W}{(1 + \rho)^t} \tag{2}$$

Using Eq. (1) this expression can be rewritten in terms of a net present value at time $t = 0$:

$$NPV_{0,i}^f = (F_0 - rL) + \frac{q_i}{\rho}(R_i - rL) - (1 + \rho)W \geq 0 \tag{3}$$

This expression gives the first period return, the expected return in later periods, and the opportunity costs of investing in the safe asset, respectively. The risk level for the marginal firm (q_s), which is the firm for which the decision rule holds as an equality, reads (using Eq. (1)):

$$q_s = \frac{\rho}{rL} (A - (1 + \rho)W) - \rho \tag{4}$$

Eq. (3) shows that, for a given lending rate r , the less risky the project (the higher the q_i) is the lower net profits are. Since $dq_s/dr = -(q_s + \rho)/r < 0$, the *reservation* lending rate, i.e. the cutoff lending rate above which firms decide not to invest, is higher for the high risk firms. Hence, an increase in the lending rate will drive out the low risk firms or, for a given lending rate, the risky projects will be executed first. Hence, the expected payoffs for firms decrease in q . Therefore,

the marginal firm is the firm within the group of investing firms with the lowest risk level.

Asymmetric information enters the model by assuming that the bank, unlike firms, is not able to observe the risk level of individual firms. The bank only has knowledge about the distribution of q_i . On the other hand, both the bank and firms (and also the government) know the expected return of the various projects. Since the bank cannot observe q_i , it cannot discriminate among firms and hence offers the same debt contract to all firms. This implies that the lending rate will be determined by the entire group of investing firms, and a pooling equilibrium under asymmetric information results.

The bank's net return to lending equals the return on the lending minus the opportunity costs of the loan, which is given by the safe rate of return on the savings account. Note that these safe returns equal ρL . The return on lending consists of the certain interest payments in the first period and the interest payments times the probability of a good state in the future periods. Hence, the net return for the bank on project i is:

$$NPV_{0,i}^b = rL + q_i \sum_{t=1}^{\infty} \frac{rL}{(1+\rho)^t} - (1+\rho)L = rL \left(1 + \frac{q_i}{\rho}\right) - (1+\rho)L \quad (5)$$

It is assumed that the representative commercial bank faces perfect competition in the banking market.¹ Hence, bank returns are zero for the average probability of repayment (P), so:

$$r = \frac{\rho(1+\rho)}{P+\rho} \quad (6)$$

The average probability of repayment equals:

$$P = \frac{q_0 + q_s}{2} \quad (7)$$

Note that bank returns are positive for the marginal firm ($NPV_{0,s}^b > 0$) since bank returns are increasing in q_i . Eqs. (4), (6) and (7) determine a pooling equilibrium.

¹The model assumes that a bank exists. It abstracts from the possibility that endogenous intermediary coalitions emerge which evaluate loan projects ex ante, by which incentives of firms are structured in such a way that a Pareto-optimal allocation is brought about. For this type of model, see, e.g. Boyd and Prescott (1986) and Williamson (1988). More in general, our model does not consider possible monitoring activities of banks which may improve the efficiency of the decentralized outcomes with asymmetric information (see, e.g. Diamond, 1984 and Ramakrishnan and Thakor, 1984).

2.2. Social optimum

From a social point of view all projects with positive social return should be undertaken. The social return ($S_{0,i}$) of a project i is equal to the sum of $NPV_{0,i}^f$ and bank returns $NPV_{0,i}^b$: $S_{0,i} = A - (1 + \rho)L$, which is independent of the riskiness of the project and assumed to be positive. In order to characterize the competitive outcome it suffices to consider bank returns for the marginal firm. Since bank returns, and hence also social returns, are positive at the margin, some low risk applicants will not participate although they should from a social point of view. Hence, in general the competitive outcome will be characterized by underinvestment.

3. The model with an option to wait

In the previous section investment is modeled as a decision to be taken now or never. However, in practice investment will be at least partially irreversible, which implies that it might be profitable to wait to obtain more information on the state of the world.

3.1. Decision rules for firms and the bank with waiting

In our model firms decide whether to invest immediately or to wait for one more period. The firms that invest immediately need outside finance from the bank. Firms decide to invest immediately based on the option value, which is calculated by subtracting the net return from investing immediately (given by Eq. (3)) from the net return of investing when the firm waits. It can be shown that the net return from investing in case the firm waits equals:

$$NPV_{w,i}^f = 0 + \frac{q_i}{\rho}(R_i - \rho L) - q_i W \quad (8)$$

In line with Eq. (3) the first term refers to the first period return (which equals 0), the second term to the return in later periods and the third term to the opportunity costs of investing in the safe asset. The option value is defined by:

$$V_i = NPV_{w,i}^f - NPV_{0,i}^f = -(F_0 - rL) + \frac{q_i L}{\rho}(r - \rho) + W(1 - q_i) + \rho W \quad (9)$$

The return from waiting and the option value can be interpreted as follows. First, if the firm waits there is no return on the first period investment. The foregone gains of waiting then equal $-(F_0 - rL)$. Second, if the firm waits, the lending rate on loans starting in period 1 equals the risk free rate, since the returns for the bank are guaranteed under the assumption that waiting resolves uncertainty. This benefit of waiting, with an expected value of $(q_i L / \rho)(r - \rho)$, will be higher for firms with a

higher probability of success and increases with the amount of the loan. Third, since waiting resolves uncertainty, a firm will only invest in the good state. This implies that the expected value of funds used for the investment only equals $q_i W$. The gain from waiting then equals $W(1 - q_i)$, which will be higher the lower the probability of success. Hence, depending on the parameters of the model, an increase in q_i has a positive or negative effect on the option value. Therefore, it is ambiguous whether the high or low risk firms will wait to invest, as will be shown below. Finally, if the firms waits for one period, the opportunity costs of safe funds for the first period (ρW) are not lost.

If $V_i < 0$ the firm decides to invest immediately. By comparing Eqs. (3) and (9), and after some manipulation, it can be easily seen that the hurdle for investment, i.e. the minimum required return a firm expects to get from investing immediately, is higher in case the option value is considered. This is a standard result of investment irreversibility (see Dixit and Pindyck, 1994). The option to delay investment makes firms more reluctant to invest since there is an additional cost of immediate investment: immediate investment implies that the option to invest no longer exists.

The risk level of the marginal firm is found by setting the option value V_i equal to zero:

$$q_s = \frac{\rho(F_0 - rL) - (1 + \rho)W}{L(r - \rho) - \rho W} \quad (10)$$

Since the sign of $dq_s/dr = [L(\rho + q_s)]/(\rho I - rL)$ is ambiguous, it is not clear whether the high or low risk firms will wait. If $rL < \rho I$, that is if the loan repayment is smaller than the safe return on the project, $dq_s/dr > 0$. If the size of the repayment on the loan is relatively low, the low risk firms have a higher reservation rate than the high risk firms. This implies that an increase in the lending rate will drive out the high risk investors so that, in contrast to the analysis in the previous section, the low risk projects will be executed immediately while the high risk firms will wait. Waiting resolves uncertainty, so that entrepreneurs only invest if the project is profitable, which implies that high risk firms, who have a high probability of having a bad return, will benefit the most from waiting. If the amount of borrowing is high ($rL > \rho I$), $dq_s/dr < 0$, so an increase in the lending rate will drive out the low risk investors, similar to the analysis in the previous section. The low risk firms will wait. Because of adverse selection, low risk firms obtain poor loan terms if they invest immediately.

After uncertainty is resolved the bank can only charge the risk free rate, so that bank returns after waiting are 0. Therefore, the change in returns for banks due to waiting by firms equals:

$$\Delta NPV_i^b = -NPV_{0,i}^b = L(1 + \rho) - rL \left(1 + \frac{q_i}{\rho}\right) \quad (11)$$

The bank is indifferent between waiting or immediately investing if $\Delta NPV_i^b = 0$, in which case the risk level of firms equals:

$$q^{ind} = \frac{(1 + \rho)\rho}{r} - \rho \quad (12)$$

For low risk firms ($q_i > q^{ind}$) the bank prefers immediate investing, for high risk firms ($q_i < q^{ind}$) the bank prefers that the firm waits. For the average immediately investing firm bank returns are zero and hence the bank is indifferent between waiting or investing immediately.

If high risk firms wait, so that the marginal firm investing immediately is the firm with the highest risk level, the average risk level of firm's investing immediately becomes:

$$p = \frac{q_s + q_H}{2} \quad (13)$$

The Eqs. (6), (10) and (13) then simultaneously determine a pooling equilibrium for the early investors. The marginal firm takes more risk than the firm with the average risk level, so that bank returns are negative for the marginal firm ($NPV_{0,s}^b < 0$). This implies that the bank would have gained had the marginal firm waited for one period ($\Delta NPV_s^b > 0$). Otherwise, when low risk firms wait and hence the marginal firm of the group of firms investing immediately is the firm with the lowest risk level, the pooling equilibrium for early investors is determined by Eqs. (6), (10) and (7). In this case, bank returns are positive for the marginal firm.

3.2. Government and social optimum

The social value of waiting (VS) equals the sum of the value of waiting for firms (Eq. (9)) plus the change in bank profit due to waiting by firms (Eq. (11)). This gives:

$$VS_i = -F_0 + I(1 + \rho - q_i) \quad (14)$$

From a social point of view all projects with a $VS_i < 0$ should be undertaken immediately. The marginal social project is determined by:

$$q_A = -\frac{F_0}{I} + (1 + \rho) \quad (15)$$

Since $\partial VS / \partial q_i = -I < 0$, the relatively safe firms (for which $q_i \geq q_A$) should invest immediately. If high risk firms wait (for the case with the smaller loans) and hence $\partial V_i / \partial q_i < 0$, all projects with $q_i > q_s$ will be undertaken immediately. Since waiting resolves uncertainty, the only distortion stems from adverse selection in the first period. Therefore, the competitive outcome again can be characterized by considering bank profits in the first period. Since in this case bank profits are

negative for the marginal firm ($NPV_{0,s}^b < 0$ and hence $\Delta NPV_s^b > 0$) the value of waiting to society for the marginal firm is positive ($VS_s > 0$). This implies that too many risky firms are investing immediately. Hence, in contrast to the analysis presented in the previous section, the competitive outcome is characterized by overinvestment.² Alternatively, if the loan size is such that $rL > \rho I$ and $\partial V_i / \partial q_i > 0$ and hence the relatively safe firms wait, all projects for which $q_i < q_s$ will be undertaken immediately. Since bank profits are now positive for the marginal firm, the value of waiting to society is negative at the margin. This implies that from a social point of view too few safe firms are investing immediately, which is comparable to the analysis in the previous section. However, it should be noted that since $\partial VS / \partial q_i < 0$ and $\partial V_i / \partial q_i > 0$, the value to society from waiting is positive for the undertaken projects with the highest risk level ($q_i = q_0$). Hence, the competitive outcome is also characterized by too many risky firms investing immediately, which again is in contrast with the analysis for which the option to wait is not taken into account.

3.3. Taxation

Since our analysis shows that the market equilibrium possibly does not lead to an optimal outcome from a social point of view, it is natural to consider whether taxation can have efficiency-enhancing effects. Normally models almost always assume efficient allocation of resources if there are no tax distortions. For instance, if we assume symmetric information about q , taxation would have no first-order effects on efficiency. In this case capital taxation will lead to underinvestment. Here we concentrate on the case with overinvestment due to waiting ($rL < \rho I$).

Taxing does not affect the social optimum, since tax payments are received by the government. But taxing might lead to a shift in the marginal firm that invests. So in case of overinvestment due to the option value of waiting an increase in q_s leads to a welfare improvement. To that extent it is important to know what types of tax policy can lead to a $dq_s/d\tau > 0$, where τ is a tax rate to be defined later. A natural candidate is a capital return tax on the uncertain returns R_i . However, since this does not affect the option value of waiting nor the income of the bank it is not effective. We therefore consider two other forms of tax policy. We can tax the certain first period return F_0 of the firm. Secondly we can tax the interest income of the bank.

²Note that De Meza and Webb (1987), by using a model similar to that of Stiglitz and Weiss, also show that the equilibrium may be characterized by over-investment. However, their result stems from the assumption with respect to the heterogeneity of projects, whereas our result stems from the introduction of irreversible investment and the possibility to delay. We, in line with the original Stiglitz and Weiss (1982) model, assume that the expected returns of different projects are the same, while the probability of success and the return in the good state differ. De Meza and Webb, on the other hand, assume that expected returns of projects differ.

Using Eqs. (6) and (13) and adjusting (10) for the tax $(1 - \tau)F_0$, we can derive:

$$\frac{dq_s}{d\tau} = \frac{(q_s + q_H + 2\rho) F_0}{(1 - \tau) F_0 + (2q_s + q_H + 2\rho) I - (1 + \rho)(W + 2)} \quad (16)$$

The sign of this expression is ambiguous. So taxing the first period return does not lead with certainty to a reduction of the overinvestment problem. It might be so that an increase of the tax rate leads to an increase of the lending rate, which lowers q_s .

Secondly, we can tax the interest income of banks $(1 - \tau)rL$. This leads to an adjustment of the lending rate:

$$r = \frac{\rho(1 + \rho)}{(1 - \tau)(P + \rho)} \quad (17)$$

Using Eqs. (13), (10), and (17) we get:

$$\frac{dq_s}{d\tau} = \frac{(q_s + q_H + 2\rho)(q_s I + F_0 - (1 + \rho) W)}{(1 - \tau)[q_s I + F_0 - (1 + \rho) W + (2\rho + q_s + q_H) I] + 2(1 + \rho) L} \quad (18)$$

Next we show that $dq_s/d\tau > 0$. The numerator of (18) is positive since $q_s I + F_0 - (1 + \rho) W = (1 + \frac{1}{\rho}) rL > 0$. Using the same identity and

$$(1 - \tau)(2\rho + q_s + q_H) I = \frac{2\rho(1 + \rho)}{r} I \quad (19)$$

we can rewrite the denominator as:

$$(1 - \tau)(\rho + 1) \frac{rL}{\rho} + \frac{2\rho(1 + \rho)}{r} I - 2(1 + \rho) L \quad (20)$$

The sign of this expression is given by:

$$(1 - \tau) \frac{r^2}{\rho} L + 2(\rho I - rL) \quad (21)$$

which is clearly positive for $rL < \rho I$. This implies that taxing interest repayments will increase the market interest rate r , which leads unambiguously to a higher q_s .

4. Summary and conclusions

This paper compares the competitive level of investment with the optimal level of investment from a social point of view. The innovation of the paper is that it considers an option value to wait. We start by deriving the optimal level of investment in a standard model with asymmetric information, where the option value to wait is not taken into account. For this case the competitive outcome is characterized by underinvestment. Next, we introduce an option to wait for firms.

We show that this changes the nature of the inefficiencies of the competitive outcome fundamentally. Most importantly, the optimal outcome from a social point of view depends on the risk level of firms when an option value is taken into account, whereas the socially optimal outcome is not affected by the risk level when firms can not wait to invest. This implies that there are also some high risk firms that invest immediately, although for the social optimum they should not. The option to wait may lead to a situation of overinvestment. This will be the case when the loan repayment is smaller than the safe return on the project. Finally, we show that taxing returns on investment is not a viable instrument to improve the market equilibrium. In order to improve the market equilibrium from a social point of view, the government may consider taxing interest income of banks when there is overinvestment.

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