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Economics of Governance

Technology choice bias and limited liability*

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Abstract. The effect of limited liability on debt contracts has been analysed as creating the possibility of credit rationing and hence inefficiently low levels of investment. In this paper we instead focus on restrictions on the use of debt finance to avoid moral hazard problems but which add inefficiency by removing management discretion in the investment process. Essentially, the trade-off is between "rules" and "discretion", and can lead to the wrong choice of technology being adopted. It is shown that this inefficient technology can persist in a steady-state competitive equilibrium. The role of venture capitalists is to reduce this inefficiency both by providing equity rather than debt finance and by involvement in the firm's management. The latter involvement can counteract other possible agency problems associated with the dilution of the firm's equity share.

Key words: Technology, moral hazard, venture capitalists

JEL Classification: L1, G2

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1. Introduction

Firms that are given discretion may be more affected by the existence of down-side bankruptcy "insurance" than those whose decisions are more strictly controlled. Hence the moral hazard problem which often underlies credit rationing models[1] may lead lenders to choose to enforce side conditions to loans which remove much of the firm's discretion. On the one hand this can solve the inefficiency caused by limited liability. On the other hand it may leave the firm with a sub-optimal technology. This is because it has not been allowed to select what it knows to be the best technology in case it falls into temptation and chooses a more risky variant. The choice of "rules" over "discretion" by the lenders may inhibit innovation and efficiency, while removing the need for credit rationing. An interesting view[2] of the instruments used in contracting between firm and finance provider is that there are three: control rights, cash-flow rights and investment timing. In our analysis, the last is not included, but control rights can involve removing discretion over the choice of investment or its use from the firm and allocating them to the financier.

One way forward is to vary the standard debt contract to include an equity share element, thus changing the cash-flow rights. This moves the objectives of lender and borrower more into line, but may lead to other moral hazard problems. Venture capital firms and "business angels" will often proceed in this way. Thus one way of viewing the contribution of this paper is as an explanation for the growth and development of these institutions, which have become important contributors to start-up firms' financial structure at various stages of their early development. [3] "Venture capitalists" sometimes take on a dual role within firms: both as a provider of capital at risk, and as a provider of expertise, advice and management. Both roles are responses to the problems of using loan finance. Monitoring may be one way of removing discretion from the firm, but more expert monitoring may reduce the loss of positive benefits from firm autonomy. We will also show how contracts based on equity finance are largely immune to the moral hazard issue we

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[1] See Stiglitz and Weiss (1981) made the key point that raising the amount having to be repaid for a loan would affect riskier projects less since these would be more likely to benefit from the insurance of bankruptcy. Hence an adverse selection problem would be made worse by increasing the cost of loans, and it may be a competitive equilibrium to randomly ration the number of loans rather than to ration them by raising their price. Further analysis is given by Clemenz (1986). De Meza and Webb (1987) contrast this under supply of investment finance, compared with the full-information outcome, with the over-supply induced by pooling of different qualities of investment project. De Meza and Webb (2000) offer a model that has features of both arguments. The role of "rules" to limit discretion of borrowers is not normally considered in the literature, although it is recognised that control can be exercised by concentrated equity holders or by banks (see Stiglitz, 1985), and this is a theme taken up by Grossman and Hart (1988) who emphasise voting structure. Allen and Gale (1994) Ch 11 review many of these contributions.

[2] See Kaplan and Stromberg (2000). Hart (2001) also considers the effect of reducing firm's discretion, but within a day-to-day management framework, rather than the technology choice issue that we focus on here.

[3] McNally (1997) considers the growing role of corporate venture capitalists in the UK. In a sample of 23 technology based firms, mostly starting in the 1980s, non-financial institutions provided more than half of the external equity finance (McNally (1997) Table 6.1). See also Hellman and Puri (2000) who show evidence of the positive effect of venture capitalist participation in developing start-up firms in Silicon Valley.

consider, and that active monitoring and management contributions of lenders assist in making the firm's plans for investment credible. Venture capitalists are defined by these two roles, although both roles are not always adopted. Arguably, no other kind of institution can replicate these roles fully, and so other institutions may not be appropriate principals with which start-up firms can discuss a contractual relationship.

Our analysis will thus concentrate first on the case where firms do not have access to external equity finance, and then contrast this with the advantages and disadvantages of the case where equity finance from a particular source (a Venture Capitalist) is possible. As is generally the case with start-up firms, the firm is assumed not to have access to more general equity finance (e.g. a stock market).

We adopt a multi-stage decision-making model where we have the following sequence of events:

Stage 1: lenders choose terms and conditions for the loan proposals they announce;

Stage 2: the firm chooses its preferred proposal from those offered, and carries out its project, maximising its expected profit under those terms and conditions;

Stage 3: some firms are successful and others are not: those that are successful complete the credit contract, while those that fail proceed to go bankrupt and renege on repayment.

In the next section we present the analysis for both a one-period model and a multi-period model. In the multi-period version of the model we assume that successful firms can continue in the industry, and can do so either by taking out a further loan contract or by using their own internal funding (gained from previous surpluses). The key point here is that a sub-optimal technology may be the best that is available to firms that have to seek external loan finance, and this means that other firms (in our model continuing firms) will enjoy positive expected rents. In equilibrium two technologies will be observed in tandem. New, entering, firms have zero expected value due to competition to enter from the large pool of candidate new firms, and also to the lender adopting "rules" that prevent their opportunistic behaviour. In Sect. 3 some applications of the model are sketched. These are all of the "rules versus discretion" kind. One of the applications demonstrates that the model, though couched in terms of a moral hazard issue, could also be stated in terms of an adverse selection problem. Section 4 discusses institutional responses to the inefficient equilibrium. In particular, to resolve the issues, the role of both equity shares and costly monitoring is examined as a justification for the emergence of venture capitalists.

2. Analysis

One-period model

Consider a one-period world, where firms can adopt one of two technologies, a "good" technology G and a "bad" technology B.

Technology G. This can be used in 2 ways however: one efficient G_e and the other inefficient G_i. G_e is an efficient use which gives a probability of s of making a surplus of S and $1 - s$ of making a zero surplus. S can be considered a conditional expectation (conditional on the event "successful") from a distribution of outcomes with finite supports. We consider S as a benchmark and relate the expected surpluses from other technologies as variations from S. G_i is an inefficient use (the temptation variant of G) which gives a smaller probability of $h < s$ of making a larger surplus of $S + H(H > 0)$ and $1 - h$ of making zero. Again $S + H$ can be a conditional mean from a distribution with finite supports and these contain S just as the distribution from G_e contains $S + H$. More generally, the supports of the conditional distributions can be the same. The key point here is that the outcome does not prove which variant was adopted (although of course it can yield a clue). Use of G_e rather than G_i is assumed to be neither verifiable nor contractable.

Technology B. This is an inefficient technology which gives a probability of s of making a smaller surplus of $S - L$ and $1 - s$ of making a zero surplus, where $L > 0$. It is inefficient since it is dominated by G_e. However it is more efficient than G_i since we assume $s(S - L) > h(S + H)$.

The choice of G or B can be contracted between the firm and the lender. It is just the decision to go for G_e or G_i that cannot. The choice within G represents the firm's discretion that the lender can remove by insisting on the adoption of B instead. One interpretation of B is that it involves a close monitoring of the investment and its use, but this incurs a direct or indirect cost L. Another is that it involves a technology, that is distinct to that in G, is immune to moral-hazard temptations, but is more costly by the amount L. Let R denote the risk-free end of period repayment to finance either of these technologies (either G or B), and R would be the opportunity cost of a firm's internal funds for the investment (the investment cost is normalised to 1). Also, it is the amount a lender would have to pay at the end of the period to its depositors for the funds to lend out. We assume that the market for providing loans is competitive, so that expected profits of lenders are zero in equilibrium.

Our assumptions above imply $h(S + H) < s(S - L) < sS$ (lowest expected surplus with inefficient use of G but highest expected surplus with efficient use of G), so that we are considering a case of "mixed" asset substitution where social as well as private (to the firm) values of the projects differ.[4] We will also assume $h(S + H - D) > s(S - D)$ for $D \geq R/s$. Thus a debt contract permitting G and charging at least R/s for repayment, if the firm is successful, while repayment is zero if the firm is not successful (since the firm goes bankrupt), suffers from moral hazard: the firm does better to operate G as G_i than as G_e due to the bankruptcy protection. Debt contracts permitting G would then assume that G_i was to be used and have $D = R/h(> R/s)$ as the competitive repayment for contracts financing G. In the one-period world, we can show that only B would be used since finance would then require repayment of R/s and the B technology would be more profitable for the borrowing firm. An additional term F is introduced as the end of period value of an ex ante cost that is incurred by the firm whether it succeeds or

[4] See for instance Bigus (2002).

not. It may be the money equivalent of effort expended or an opportunity cost. We assume $F \geq 0$. Then we can state Proposition 1.

Proposition 1. If $h(S + H) < s(S - L) < sS$ (efficiency ordering assumption) and $h(S + H - D) > s(S - D)$ for $D \geq R/s$ (presence of moral hazard), then the only equilibrium is for technology B to be financed with a loan repayment of R/s.

Proof. define the firm's expected profits in each case:
Loan repayment for G of R/s implies that the firm prefers G_i to G_e:

$$\Pi_{Gi} = h(S + H - R/s) - F > \Pi_{Ge} = s(S - R/s) - F \tag{1a}$$

Loan repayment for G of R/h and loan repayment for B of R/s implies that the firm prefers B to G_i and G_e :

$$\begin{aligned} \Pi_B &= s(S - L - R/s) - F > \Pi'_{Gi} \\ &= h(S + H - R/h) - F > \Pi'_{Ge} = s(S - R/h) - F \end{aligned} \tag{1b}$$

Equation (1b) is based on the fact that the firm and lender can contract on B or G_i, but not on G_e since this is not incentive compatible (from 1a). Hence the debt repayment in Π'_{Gi} and Π'_{Ge} is R/h. Hence with a contract based on B, the debt repayment is R/s, whereas the contract based on G would have R/h as the competitive repayment.

Many period model

We now extend our analysis to a continuing world. Each investment in technology has a life of one period. At the end of the period the technology is of zero value (it falls to pieces). Then a repeat investment is necessary. The investment each period can be financed by borrowing in a competitive credit market or by using retained earnings or a mixture of the two. New entrants do not have retained earnings so they must use external credit. All those firms that have been unsuccessful in period t go bankrupt (if externally financed) or exit (if internally financed). They do not have further reserves to continue for further periods without re-entry.[5] Each active firm has one machine and technology (G or B) and produces one unit of output whether successful or not. s, h are independent probabilities across firms and periods, and S is an amount which depends only on the number of active firms.[6] The market has a decreasing demand curve so that there will always be that number of firms

[5] A more complex relationship between the ability to sustain failure and the previous history of the firm could be added to the model. For example, the excess number of success periods over fail periods could imply that one, two, or more fails could be accommodated by using up reserves. However, it could also be argued that previous failure increased the likelihood of future failure due to a worse commercial reputation. In this paper we ignore these issues by making the simplest assumption.

[6] In equilibrium, all other firms will be adopting G_e or B and thus have probabilities of success of s. There would therefore be little problem in assuming that a proportion s of other firms were successful and that only these firms supplied positive output to the market, leading to $S(N)$ as the expected surplus. Our approach is just the more straight-forward.

in the market to ensure zero expected surplus from entry, as new entrants in $t+1$ replace firms that go bankrupt in period t. We assume that $S(N)$ adjusts to ensure this. (We only specify $S(N)$ and keep H and L fixed for simplicity.)

The competitive lender must have R as expected repayment at the end of the period in order to provide the investment funds of 1 at the beginning of the period. We consider the two types of firm, entrants and continuing firms. Entrants have to use finance from outside and, extending the arguments of the single period model, they are restricted to technology B by contract. A new entrant has an expected value at the end of the current period t (the period of its entry) of

$$W_N = s(S - L - D + V) + (1 - s)0 - F = s(S - L + V) - R - F \quad (2)$$

where S is the surplus in period t from a successful outcome, and V is the value of future surpluses to the firm at the end of period t if it has been successful and can continue in business. (2) reflects the use of technology B in the initial period after entry since this is a condition of the loan set by the lender.

A continuing firm which has retained capital to use for its investment can choose technology G and then prefers G_e to G_i. It may not be necessary for the firm to have sufficient retained capital to finance all the investment, provided that the amount of loan to fund the balance is not so great as to make G_i more attractive. We will return to this issue later. Thus a firm which is continuing from the previous period has an expected value at the end of the current period of

$$W_C = s(S + V) - R - F \quad (3)$$

Clearly, $W_C > W_N$ and $W_C > h(S + H + V) - R - F$. All terms S, H, L, D, V, R, F are assumed to be measured in end of period money. Here V is the next period's W_C and thus

$$V = W_C/R \quad (4)$$

Since R is $1+$ deposit interest rate (recall the investment is normalised to 1), we assume that $sD = R$ for entrant firms adopting technology B (by the assumption of a competitive credit market). Also $W_N = 0$ by free entry of firms which effectively determines $S(N)$ from (2).

$$W_N = s(S - L + V) - R - F = 0 \quad (5)$$

To proceed, it is simplest to use the free entry condition (5) to substitute $S + V$ from (5) into (3) and use (4) to yield

$$VR = W_C = sL$$

and so

$$V = sL/R \quad (6)$$

And from (5) and (6) we obtain the size of the industry as the number of firms N such that

$$S(N) = (R + F)/s + L - sL/R \quad (7)$$

Thus the value of having earnings to retain for reinvestment is positive and depends on the superiority of the continuing firm's technology G_e over the entrants' technology B (that is the size of L). Clearly from (7), the surplus S is increasing, and thus the number of firms is decreasing, in the costs R, F and L, as well as in the probability of failure, $1 - s$. These effects are driven by the zero-profit entry condition (5). Note that $V = 0$ if $L = 0$ since then there is no advantage in having access to G rather than B, and free entry removes all positive profit. For the story to be consistent we need the limited liability effect for new firms to be binding in this continuing world. We write this as:

Moral hazard condition

$$h(S + H + V - R/s) - F > s(S + V - R/s) - F$$

or, using (6) and (7)

$$H > (s - h)[F/s + L]/h \tag{8}$$

The moral hazard condition (8) means that any entrant firm using technology G will select G_i rather than G_e, even if the repayment is low due to the lender (falsely) believing that G_e will be chosen.

Note that G_i is dominated by B for borrowers since this is loss-making relative to B. We will term this:

Non-participation condition for G_i

$$h(S + H + V) < \max\{R + F, s(S - L + V)\} \tag{9}$$

Thus G_i will not be chosen by entrant firms, because either it makes a loss or it is dominated by technology B. (Remember the choice between G_i and B can be contracted.)

Hence only firms with their own retained earnings can obtain technology G, and will then choose G_e, if the moral hazard condition (8) holds. If the new firm is successful then it has an end-of-period cash surplus (denoted C) of $S - L - R/s$. From (2) set to zero and (6) this is $C = F/s - sL/R$, which can then be reinvested. If this is greater than one, then no loan is required. Otherwise a loan of $1 - C$ is required. Then it must be the case that G_i is inferior to G_e at a repayment of $(1 - C)R/s$. Thus we have a third condition:

Cash-flow (retained earnings) condition

$$h(S + H + V - (1 - C^*)R/s) < s(S + V - (1 - C^*)R/s) \tag{10}$$

where $C^* = \min\{F/s - sL/R, 1\}$ and V, S are given in (6) and (7). Note that (8) and (10) together imply

$$(s - h)(1 - C^*)R/s < s(S + V) - h(S + H + V) < (s - h)R/s$$

so that the efficiency advantage of G_e over G_i (the middle term in (10)) cannot be too high (else the moral hazard problem for new firms does not exist) and cannot be too low (else the moral hazard problem also exists for continuing firms who use retained earnings to borrow less). We can summarise these results in the following proposition.

Proposition 2. If the moral hazard condition (8), the non-participation condition for G_i (9) and the cash-flow condition (10) all hold then new (entering) firms will have loan finance and use technology B, while continuing firms will use retained earnings and use technology G_e.

Proof. Deviations from this claimed equilibrium would only occur if the lender offered a contract to finance technology G. By (8), whether the repayment was R/s or R/h, the firm would select G_i. Thus the competitive rate of repayment would be R/h. But by (9), the firm would do better either by accepting the loan contract for B or taking zero by not participating at all. Note that in our equilibrium the two terms in $\{,.,\}$ in (9) are the same due to the free entry condition of the B technology. (10) ensures that the successful new firm can reduce the size of its loan sufficiently so that the bank is willing to remove the restriction on use.

Consider the following numerical example. Choose the parameter values $s = 0.5$, $h = 0.1$, $R = 1.25$, $L = 0.5$, $F = 0.3$, then $S = 3.4$ from (7); $V = 0.2$ from (6), and $C = 0.4$.

Moral hazard condition (8):	$H > 4.4$
Non-participation condition for G_i (9):	$H < 11.9$
Sufficient retained earnings condition (10):	$H < 8.4$

Assume $4.4 < H < 8.4$ so that all conditions are satisfied. Then the technology G is available only to continuing firms. Entrants require full loan capital and have to commit to technology B. If they are successful they then require a loan of only $1-C = 0.6$ to finance the next period, and this removes the moral hazard from using G. An interesting question relates to the steady-state shares of the technologies. These are simply the shares of new and continuing firms. New firms have B and continuing firms have G_e. Then we can state the following result.

Proposition 3. A share s will use the G_e technology in steady state provided the moral hazard condition (8), the G_i non-participation condition (9) and the retained earnings condition (10) hold. A share $(1 - s)$ will use the B technology.

Proof. A proportion s of firms are successful if only G_e and B technologies are used. All these successful firms will use G_e in the next period, while new entrants will all use B. The proportion of new entrants is $1 - s$.

In our numerical example the steady state share of the G_e technology is $s = 0.5$. Thus the direct social cost of the asymmetric information is $(1-s)sLN = 0.125N$, although lost consumer surplus from the lower equilibrium number of firms is not modelled and not included.

The equilibrium that we have described relies on the three conditions (8)–(10) holding. We complete this section by considering what outcomes would result if these conditions did not all hold. If the moral hazard condition did not hold then there would be no credit market problem. All firms would use G_e and obtain zero expected profit. Loans would be repaid at R/s, and there would be no difference between internal or loan funding. If the non-participation of G_i condition did not hold, then entrant firms would do better by paying back R/h and carrying out G_i rather than B. This would break even on average for the banks. If the cash-flow condition did not hold, then the use of B would not generate sufficient cash to enable G_e to be adopted by a successful firm in the next period. We have seen that all three conditions can be represented as bounds on H for given values of the other parameters. If H is too low then the moral hazard problem disappears ((8) not holding). If H is too high then either G_i replaces B ((9) not holding), or G_i remains a temptation for successful firms ((10) not holding).

3. Applications

Our model of the moral hazard G_i faced by firms can be applied to at least three different scenarios. These are simple manifestations: often situations could involve elements of all three.

a. Contemporary hazards
   Here the firm receives the capital from the lender and invests in a way of organising and enabling production which increases the profit if successful (by H), but also increases financial risk (from $1 - s$ to $1 - h$).
b. Ex post hazards
   Here if and only if the project is successful, the firm uses the surplus S as a bet in a further lottery, with probability of additional winnings H of h/s. If the bet loses then there is no surplus left. The combined success probability of the firm is $s(h/s) = h$.
c. Mixed hazards and adverse selection
   In this scenario, the assumption of identical potential firms is replaced by one where there are two types of potential firm: One type e has a project of type G_e, while the other type i has a project of type G_i (or equivalently has access to either G_e or G_i). Banks cannot distinguish a firm's type but the firm knows its own type. If G_i is more profitable for the firm than G_e when used within a credit contract with limited liability then banks' customers are composed of type i firms only (by competition to enter which drives down $S(N)$ and drives out type G_e firms), and if G_e is more profitable then only e-type firms are credit customers. With our moral hazard condition (8) only the former outcome arises for entrant firms, and so this is a case of "bad customers driving out good".[7]

In this section we will provide examples of all three of the above. However, we will concentrate in (i)–(iii) on the central case of (a). Example iv relates to (b); example v to (c).

[7] One response is a credit rationing response where banks limit the number of entrants to that number where both types of firm find it profitable to enter (but G_i firms find it more profitable) and then the adverse selection would be replaced by a random selection from the whole population of potential firms. An analysis of credit rationing and its function using the approach in this model is given in Ireland (2003).

i. Gambling on reliability

Suppose that technology G is the adoption of part-used machines. The firm can choose to spend money on reasonably reliable equipment and materials and this may be the most efficient technology yielding a chance s of a good profit S. However, the firm could choose a very cheap set-up, taking the high risk of breakdown $(1 - h)$, but with the prospect of very high profits $(S + H)$ if the equipment held up. Here H would be the cost savings from the cheap equipment. S is the benchmark surplus from the more reliable equipment. The lender cannot monitor the choice of purchase. For instance, the equipment may be being purchased in the part-used market. Instead of giving the firm discretion over equipment purchases, the firm can be required to purchase new equipment from reputable sources (for example with a quality standard kite-mark). This may be more expensive (by L) or, for the same money, the quality may be less that that obtained under G_e, and require further variable costs (L). Hence this is inefficient (technology B). However the firm can prove the nature of this investment since it is of established quality from established suppliers. Hence the lender will insist on B in order to prevent the firm choosing G_i.

ii. Bespoke technology

The firm can either adopt a bespoke technology which aims to do precisely the job required or an "off-the-peg" technology which is less well-matched. Consider these G and B respectively. However, the bespoke technology can be such that it is very expensive to repair or replace if things go wrong. Hence there is then a larger probability of bankruptcy, although higher profits are earned if the technology proves reliable. The extent of the specificity and the trade off between risk and potential cost savings are at the discretion of the firm and hence technology G divides into G_i and G_e. Some computer software would fall into this category. Do you develop software for your own specific needs or do you adapt your needs to existing commercial software? The lender may be able to insist on the latter, and this would be technology B.

iii. In-house or contracting out

The firm's investment may involve the choice of trying to obtain a process or product innovation. Such a choice may be G, but there are risky "big" innovations and safe "small" innovations (i.e. G_i and G_e). The nature of the innovation being sought is unknown or unverifiable by the lender, and bankruptcy protection limits the impact of R&D disasters on the firm and leads to incorrect risk assessments. On the other hand, the contracting out of the investment to an external provider may be B, where the type of innovation or technical specification of the technology and its cost is fully specified in the sub-contract, and the risk is born by the sub-contractor. This case is easily extended to more general issues of contracting out. In particular, management services, such as consultants, lawyers, etc., can be hired from outside the firm rather than obtained from inside the firm. Advice from internal sources may be affected by internal political forces, by complementary interests or by trading favours. Saving money by neglecting outside advice may be taken too far ($G_e \to G_i$) and may lead to a lower chance of success (h less than s).

iv. Speculation

If the project is successful then the firm has the surplus S in its bank account prior to repaying the bank. The firm may now use this money to speculate in product or market development, or even in financial markets. If the risks are high (say h/s is the probability of success) then the creditor's chance of recovering its money is just $h = (h/s)s$. Clearly there are some activities here which border on the illegal. Nevertheless the financial risk to the creditor is very real. One defence a bank may use is to insist on stage repayments which keep the firm short of cash. This may involve additional costs for the firm (for example purchasing from suppliers who are more expensive but who offer better credit lines) and require delays and phasing of the production process. The result of adopting such a restrictive B-type credit contract with the bank would be to incur these additional costs and thus reduce the surplus by the amount L.

v. Risk and reputation

Potential firms may be either run by entrepreneurs (e-type) who have ambitions (and capability) to expand into further areas of activity, which would require further bank finance, and who would gain from a successful financial record, or be run by entrepreneurs (i-type) who have no such ambitions. Without information as to the firm's (entrepreneur's) type, the banks cannot distinguish those for whom G_i is effectively ruled out by the desire to enhance reputation. Suppose that there is no "B" technology and that the proportion of e-type entrepreneurs is θ. If new entrant firms are selected randomly, then the required repayment will be $R/(\theta s+(1-\theta)h)$, so that the banks will break even, and $N \leq N^*$ where N^* satisfies $s(S(N^*) + V + K - R/(\theta s + (1-\theta)h)) - F = 0$, so that the e-type firms also break even where K is the exogenous value to the firm of its enhanced reputation. (The i-type firms make a profit.) This is a credit rationing outcome where the rationing device is the number of firms receiving funding. However, if there is a technology B which yields a profit for an $(N+1)$ firm, because $s(S(N^*+1)-L+V) > R+F$, then the credit rationing cannot be implemented (some bank with no G-type contracts can make money out of a B-type contract), and only B contracts can exist for entrant firms. Using the parameter values in our example, letting $\theta = 0.5$ (equal shares of the two types of entrepreneurs), and assuming $S(N^*) \approx S(N^*+1)$, we find that unless K exceeds $7/6$ there are only B-type contracts for new entrant firms and in that case there is no mechanism for success to signal entrepreneur type. Thus if banks can use a B-type technology for new entrants they deprive the economy of information about entrepreneurs by eliminating a signalling mechanism. In this application, therefore, the existence of a credit restriction technology may mean that there are wider economic effects.

4. Institutional responses to the survival of inefficient technologies

It is obvious that the firm may have collateral, which removes the risk for the lender, and it is the essence of the current analysis that entrant firms do not have such collateral and do not have access to general equity finance and thus have to borrow the start-up finance. There remain two obvious responses to the inefficient equilibrium we have been considering. The first involves the lender in actively monitoring the firm's behaviour so that the choice of G_i over G_e is essentially verifiable and the choice of G_e can be enforced. This involves monitoring costs, such as membership of a board of directors, or independent auditing, which have to be paid for either by the firm or by the lender. The joint gain from such monitoring is at least sL per entrant firm. If monitoring costs, denoted M, are less than this gain, then entrants can contract for and adopt technology G_e. However, if the monitoring cost is paid by the bank, then the successful firm's repayment to the bank must be $(R+M)/s$, since a bankrupt firm will repay neither the loan nor the monitoring cost. Then N will increase to reduce $S(N)$ so that the entrant's W_n is zero. The lower $S(N)$ reduces the profit of successful firms, since their monopoly power is reduced due to the keener competition from entrants. This scenario may be appropriate to large firms where the fixed cost of monitoring is small relative to the efficiency gains. Also, there is a matching tendency where investors avoid, for example, high-technology firms outside their experience (Reid, 1998, pp. 172–173). This line of response does not require further analysis.

However start-up firms are rarely large and then an alternative institutional response may be valid. We consider here the normal venture-capitalist process where the borrowing firm benefits from a mixture of loan and equity (share) finance.[8] A reasonably acceptable view of a lender would then be an agent who would lend the money required for a share (denoted λ) of the worth of the company at the end of the period. We could consider this as being the surplus, plus the future value, minus some part of the firm's own incurred cost F, denoted ϕF. Here $\phi = 1$ would be when all of this cost is deducted to calculate worth, and $\phi = 0$ when none can be deducted. The latter may be the case if F related to non-monetary costs or opportunity costs. Thus the expected repayment to the venture capitalist in a G-type contract would be 0, $\lambda(S + V - \phi F)$ or $\lambda(S + H + V - \phi F)$ depending on the outcomes of failure, or success with G_e or success with G_i. It is an essential part of the venture capitalist's involvement with the firm that any extra surplus H would be observable to the venture capitalist and hence would have to be shared. We denote the auditing costs of the venture capitalist necessary for such observation as A. For entrants to be permitted to choose G the moral hazard constraint cannot be binding, that is G_e must be preferred to G_i :

$$\begin{aligned} &s((1-\lambda)(S+V-\phi F)) - F(1-\phi s) \\ &> h((1-\lambda)(S+H+V-\phi F)) - F(1-\phi h) \end{aligned} \tag{11}$$

Since $s > h$ and $sS > h(S + H)$ this condition always holds for $\lambda < 1$. That is

[8] The venture capitalist would be interested mostly in the equity finance, while limited loan finance might be provided by other institutions.

Proposition 4. An equity finance contract will enable technology G to be implemented for all F and all ϕ

Proof. Directly from (11), which can be rewritten

$$(sS - h(S + H)) + (s - h)(V + \phi F(\lambda/(1 - \lambda))) > 0$$

The lender's commitment to pay a proportion of F back to the firm out of profits in effect operates the opposite way to a commitment for the firm to repay debt to the lender. Thus the higher is ϕF, the greater the positive value of (11). Given Proposition 4, G would be stipulated in competition, the firm would choose G_e rather than G_i and free entry would mean that $S(N)$ would adjust so that the typical firm's expected share of worth is equal to its expected cost: $s((1 - \lambda)(S + V - \phi F)) = (1 - s\phi)F$. It is important to notice that the contract would share both current surplus and V, but that competition among lenders and prospective firms would ensure that the venture capitalist covers its costs, $s\lambda(S + V - \phi F) = R + A$, so that $s(S + V) = F + R + A$ for all entrant firms, and $VR = W_C = A$ while $W_N = 0$. The inefficient technology disappears and the positive profits for continuing firms are limited to their saving in monitoring costs.

However, the solution here relies on the firm's outcome being dictated by surplus maximisation, while the lower marginal reward for additional cost savings (sharing with the outside equity provider) may imply other kinds of moral hazard losses. This raises the issue of monitoring from the different perspective of motivating firm effort.[9] An appropriate question to ask concerns the minimum share in a mixed debt/equity share financing model that solves the moral hazard problem of choosing G_i rather than G_e. This would presumably minimise the agency problem of providing incentives for effort and thus the need for monitoring, while still making the choice of G_e incentive compatible. The simplest approach is to consider that the probability of success is decreasing in λ. Then write h as h_λ, s as s_λ and h_0, s_0 as the associated success probabilities of a firm with no external equity ($\lambda = 0$). Let D be the debt repayment to the lender if the firm is successful. Consider then that the expected amount the lender is repaid is the sum of fixed and share elements: $\lambda s_\lambda(S + V - \phi F) + s_\lambda D$ using G_e and $\lambda h_\lambda(S + H + V - \phi F) + h_\lambda D$ if the firm is using G_i. For G_e to be incentive compatible for the firm we need

$$\begin{aligned}&(1 - \lambda)s_\lambda(S + V - \phi F) - s_\lambda D - (1 - \phi s_\lambda)F\\ &\geq (1 - \lambda)h_\lambda(S + H + V - \phi F) - h_\lambda D - (1 - \phi h_\lambda)F, \text{ or}\\ &D \leq (1 - \lambda)\{S + V - h_\lambda H/(s_\lambda - h_\lambda)\} + \lambda\phi F\end{aligned}$$

Since the maximum value of D implies the minimum λ, we can write

$$D = (1 - \lambda)\{S + V - h_\lambda H/(s_\lambda - h_\lambda)\} + \lambda\phi F \tag{12}$$

[9] The extent of the agency problem when the firm admits external equity is arguable, however there is certainly a tradition of venture capital firms taking seats on boards of directors or other executive posts in SME start-ups. This may play a role in adding expertise to the firm and indicate a "joint venture" feature, but otherwise indicates the need to monitor the investment from within the firm, and hence address possible agency issues. On the other hand, Reid (1998), p184, reports "investees were sufficiently exposed to risk post-contract to sustain effort." Also the investee share of equity could be increased to reward effort and performance (a kind of non-listed equivalent of share options).

Note that (12) in fact limits the debt repayment D net of the firm's cost recovery from the lender $\lambda\phi F$. Both events occur only if the firm is successful. To ensure an expected repayment to permit the lender to at least break even, we require $\lambda s_\lambda(S + V - \phi F) + s_\lambda D \geq R + M + A$, where M and A are the monitoring and auditing costs of the lender. Substituting out D using (12), the lenders' equity share must be sufficient to satisfy

$$\lambda s_\lambda(S + V - \phi F) + s_\lambda(1 - \lambda)\{S + V + -h_\lambda H/(s_\lambda - h_\lambda)\} \qquad (13)$$
$$+\lambda s_\lambda \phi F \geq R + M + A$$

The terms in ϕF cancel and then we can solve for the lender's minimum equity share, which must satisfy

$$\lambda \geq [R + M + A - s_\lambda\{S + V - h_\lambda H/(s_\lambda - h_\lambda)\}]/[h_\lambda s_\lambda H/(s_\lambda - h_\lambda)] \quad (14)$$

Zero expected profit for entrants implies $s_\lambda(S + V) = R + M + A + F$, and then the bound is just

$$\lambda \geq 1 - (s_\lambda - h_\lambda)F/(h_\lambda s_\lambda H) \qquad (15)$$

For λ to exist, it must lie between 0 and 1. Any λ, including zero, will satisfy (15) if $(s_\lambda - h_\lambda)F > h_\lambda s_\lambda H$. Otherwise a lower bound for λ is given by (15), provided $s_1 > h_1$ and $F > 0$. The parameter ϕ and monitoring and auditing costs play no role in (15), but they do determine the pay-out to the venture capitalist and the equilibrium number of firms. Actual equity shares taken by venture capitalists vary enormously. They range from trivial proportions to almost 100% (see Reid (1998), Table 14.5).

To extend our numerical example, keep the same values of all parameters, let $H = 5$ and let $s_\lambda = (1 - \lambda)/2$, and $h_\lambda = (1 - \lambda)/10$. Write $x = (1 - \lambda)$, and rearrange (15) as $x^2 - 0.48 \leq 0$ or $\lambda \geq 0.31$.

More generally, equity sharing contracts may be impeded by other factors. Pre-existing senior debt to other parties, sovereign rights, and imperfect markets for shares in unquoted companies all may be relevant problems. Also, equity shares in excess of 0.5 may threaten to remove control of the firm from the current entrepreneur. This would lead to the possibility of a reverse moral hazard problem, where the lender takes control of the firm and operates it in the lender's own interest counter to those of the original entrepreneur.

We have been portraying an equilibrium where competition among prospective firms and venture capitalists drive rents to zero. If there is a limit on the capacity of venture capitalists, in terms of the number of firms with whom they can contract, then the marginal firm / bank contract may be a B technology contract. There will be fewer firms, a higher S, and rents will be earned by the venture capitalists. These rents are the difference between L and monitoring costs $M + A$. As the venture capitalist sector expands, there is no difference in the equilibrium number of firms until all the B contracts have been replaced by venture capitalist contracts. Similar points hold if the venture capitalists vary in efficiency. However if both firms and venture capitalists vary in terms of their efficiency, then the analysis has to incorporate a model of the matching process, between firms and venture capitalists, to determine the equilibrium outcome.

5. Conclusions

Our analysis has reflected the argument that asymmetric information in the credit market may give rise to restrictions on the use of credit rather than the credit rationing behaviour often linked to limited liability rights. In our analysis, restrictions to eliminate opportunistic and inefficient behaviour themselves produce inefficiency due to the removal of discretion from management. In this scenario, those firms, which have to rely on credit to finance investment, have a technological disadvantage over those that do not. Hence if self-reliance is only gained by past success, new firms have the disadvantage while continuing firms can use retained profits for investment. Then firms that are continuing have a positive expected value, even though entry to the industry takes place up to the point where entrant firms have zero profit expectations. Because the sub-optimal technology is identified with new firms, and continuing firms do not always survive, two technologies exist in steady-state.

We have investigated how equity shares replacing loan finance do much to eliminate this problematic outcome, and how this reflects the behaviour of venture capitalists. Venture capitalists can use monitoring of the firm to directly remove the moral hazard. This is in effect a variation of the B technology: if it is superior to an already-present B technology, it is used instead. We have also shown how the minimum equity share in a mixed debt and equity loan contract negates the limited liability effect while minimising orthogonal problems of moral hazard arising from equity dilution. The venture capitalist is distinct from other lenders. The willingness to seek better ways of monitoring the firm's activity and to spend resources on such monitoring sets the institution apart from other banks. If the venture capitalist provides equity finance by requiring repayment by means of a share of the firm's surplus, then its ability as the major fund provider to audit the firm's performance and outcome is clear. We have shown how a venture capitalist is able to perform a role of reinstating an efficient technology for the start-up firm that has no access to equity markets.

The paper has many simplifications. It ignores tax issues, although debt may have tax advantages over equity finance, and venture capitalists often have equivalent or superior tax treatment over their equity stakes. There are no intermediate points in time, where lenders can respond to events or information by taking control of the firm or renegotiating the debt contract, as analysed for example in Hart and Moore (1998). We assumed instead that the lenders' rights are limited and contracted at the start. Also each firm had at most a single creditor, and so conflicts of interest among creditors do not occur.[10] Each lender considers each investment in isolation and so portfolio effects are absent (see Leshchinskii, 2003). Hopefully, our simple model has allowed us to focus on a general equilibrium where, in the absence of venture capitalists, an inefficient technology is observed in use alongside an efficient technology. The inefficiency permits the opportunity for venture capitalists to participate.

[10] See Bigus (2002) for a recent assessment of the operation of bankruptcy protection when there are different classes of creditors.

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