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DEBT FINANCING AND R&D INVESTMENTS

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Abstract

Our model shows that firm´s debt-equity ratio decreases with R&D investment returns, firms´ R&D specialization degree, and internal funds availability. Our basic hypothesis is that firms specialized in R&D assimilate faster than others their R&D investment.

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1. INTRODUCTION

There is a set of stylized empirical facts that links *R&D* investment and firm financial structure. Goodacre *et al.* (1995) survey the main empirical findings on this topic. First, there is a negative relationship between leverage and *R&D* activity (e.g. Long *et al.* 1985). Second, debt-equity ratio is lower for small undiversified firms specialized on *R&D* investment than for diversified firms in less intensive *R&D* sectors (e.g. Hall 1992 and Goodacre *et al.* 1995). Third, small firms in high-tech industries use mainly internal funds to finance their *R&D* investment (e.g. Hao *et al.* 1990 and Himmelberg *et al.* 1994). Moreover, the last authors also show that among outside financing instruments, these firms prefer equity to debt (low debt-equity ratio).

We build up a two-period theoretical model based on three assumptions; the existence of limited liability, the non-verifiability of *R&D* returns as well as firm cash flow, and most importantly, the superior rhythm at which R&D-specialized firms convert their *R&D* investment returns in knowledge production. Rapoport (1971) finds that in *R&D* intensive sectors like electronics, the *R&D* gestation lag to incorporate *R&D* expenditures in knowledge production is 2.5 times lower than that of less *R&D* intensive sectors like machinery.

The previous three assumptions allow us to reproduce the empirical findings referred above. Limited liability defines an upper limit to firm debt payments. As firm's profits increase on *R&D* returns, we obtain in this way a decreasing relationship between the firm relative leverage (debt-equity ratio) and the *R&D* returns. Second, as firms become more focused on *R&D* investment, the losses for the entrepreneur are low if he triggers a short-term financier liquidation by not attending the debt obligations. This is the case when the firm has already assimilated a substantial amount of the *R&D* returns in the initial period. To prevent this behavior, the financier reduces the firm debt payments. The final result is an overall reduction in the firm's debt-equity ratio. Finally, concerning the availability of internal funds, the higher they are, the lower the need of external funds is, and the lower the firm debt payment obligations.

The novelty of our model is to provide a theoretical background to the previous empirical findings, not assuming a low collateral that *R&D*-specialized firms can offer to obtain debt financing, but looking at the differential rhythm at which these firms assimilate their *R&D* investment returns. We think this is relevant because in a dynamic context each assumption has different effects in the evolution of the debt-equity ratio for *R&D*-specialized firms. As these firms improve their efficiency, and consequently their reputation as time goes on, they can offer an increasing real collateral guarantee to potential lenders. This leads to a rise of firms' debt-equity ratio. On the other hand, firms' efficiency improvements are translated into reductions of their *R&D* gestation lag. This diminishes firms' debt-equity ratio according to our model.

We use a model formally similar to Bolton and Scharfstein (1996), although we address a completely different question. Their focus is on the optimal number of creditors to prevent the entrepreneur opportunistic behavior linked to the non-verifiability of firm cash flows.

Within the formal setting designed, some other results are obtained. In particular, we prove that debt length has to be lower for *R&D*-specialized firms.

The rest of the paper is structured as follows. In Section 2 we define and solve the model, while in Section 3 we discuss the results and present some conclusions

2. THE MODEL

We consider a two-period model, where a risk-neutral firm borrows external funds I_E from a competitive credit market to finance a project which requires a layout of $I = I_E + d$ units, where d is the value of the firm's internal funds. A firm with a high d (low I_E) is said to have followed a *deep pocket* policy.

The project lasts for two periods and involves some *R&D* investment. The returns of this project are of two types: a deterministic non-liquid return E [1], and a cash flow Y, received at the end of the first period with probability p. Both are assumed to be non-verifiable. E measures benefits generated by the *R&D* investment such as human and physical capital accumulation. A part βE of this return is generated at the end of the first period, and the rest accrues at the end of the second period. Thus β measures the speed of *R&D* assimilation, and a high β will be meant to characterize *R&D*-intensive firms.

We consider a contract $\{R, \alpha\}$, where R is the payment made by the firm to the financier at the end of the first period, and α is the probability that the financier decides to liquidate the project conditional on the fact that the entrepreneur does not pay R [2]. The financier obtains a rent L from liquidation. *R&D* benefits are assumed to be relatively high so that a first-best solution would involve no liquidation ($L < (1-\beta)E$). The contract cannot specify second-period payments, as E is not verifiable and the entrepreneur has no resources once the project has been undertaken. Thus, an *ex-post* renegotiation between the financier and the

[1] A non-deterministic E would have not changed our main findings

[2] This kind of contract (*à la* Bolton Scharfstein) can be *ex-post* implementable if, there is a referee (a venture capitalist, for example) who determines, consistently with α, the decision of liquidation. Venture capitalists are intermediaries between lenders and R&D-specialized firms (star-up firms) whose activity is based on their reputation of not behaving opportunistically

entrepreneur is not possible. The optimal contract trades off the cost of an increase in α, due to inefficient liquidation, against the benefit of preventing the entrepreneur to cheat over cash flow Y. We solve the first-best problem:

$$Max\ \pi_{\{0\leq\alpha\leq 1,R\}} = p(Y-R+E)+(1-p)[1-\alpha(1-\beta)]E-d \quad (1)$$

$$\text{S.t. } pR+(1-p)\alpha L - I_E = 0 \quad (2)$$

$$\text{S.t. } 0 \leq R \leq Y \quad (3)$$

$$\text{S.t. } Y - R + E \geq Y + \alpha\beta E + (1-\alpha)E \quad (4)$$

Expression (1) of entrepreneur expected profits (π) coincides with the social utility due to the financier's zero-profit condition of equation (2), (3) is the limited liability constraint, and (4) is a truth-telling constraint.

We assume project feasibility, that is, $\pi \geq 0$ and financier's profits to be zero for $0 \leq \alpha \leq 1$. In the Lemma, we precise feasibility conditions.

From (4), we get $\alpha \geq \frac{R}{(1-\beta)E}$, and we can distinguish two situations:

a/ If $Y \geq \overline{Y}$ (with $\overline{Y}$ being a lower bound as defined below) the limited liability constraint $R \leq Y$ is not binding for the optimal R. Thus, given that the entrepreneur profits, π, are decreasing in α, we will have $\alpha = \frac{R}{(1-\beta)E}$. Substituting this value of α into the financier's zero-profit condition (2), we find:

$$R[p(1-\beta)E + (1-p)L] - I_E(1-\beta)E = 0 \Rightarrow R = \frac{I_E(1-\beta)E}{p(1-\beta)E+(1-p)L} \quad (5)$$

Making use of (4), we can define $\overline{Y} \equiv \frac{I_E(1-\beta)E}{p(1-\beta)E+(1-p)L}$

b/ If $Y < \overline{Y}$ the firm is liquidity-constrained, that is, its project cash flow is entirely exhausted attending debt payments. In that case the limited liability condition is binding ($R = Y$) for $\alpha = \frac{R}{(1-\beta)E}$. Thus, $\alpha > \frac{R}{(1-\beta)E}$ for sure. We compute this value using the financier's zero-profit condition:

$$pY + (1-p)\alpha L - I_E = 0 \Rightarrow \alpha = \frac{I_E - pY}{(1-p)L} \quad (6)$$ [3]

<u>Lemma</u>

The project is feasible if $Y > \underline{Y} = \frac{1}{p}\{I_E - \frac{L}{(1-\beta)E}(E-d)\}$ *and* $I_E \leq pR + (1-p)L$, *with* R *given below. In that case, the optimal contract* $\{R,\alpha\}$ *becomes:*

- If $\underline{Y} \leq Y < \overline{Y} \equiv \frac{I_E(1-\beta)E}{p(1-\beta)E+(1-p)L}$, $R = Y$ *and* $\alpha = \frac{I_E-pY}{(1-p)L}$

- If $Y \geq \overline{Y}$ *, then* $R = \overline{Y}$ *and* $\alpha = \frac{R}{(1-\beta)E}$

At this stage, we can compute the firm's debt-equity *ratio* $DE = R/\pi$, where π are the firm's profits ($\pi = p(Y-R+E)+(1-p)[1-\alpha(1-\beta)]E$) [4]. Using the

[3] Condition $Y \leq \overline{Y}$, ensures $\alpha \geq 0$

[4] This is a flow measure, not a stock measure. Moreover, within our setting, π depends on some intangible assets like E (knowledge production). The point is that firms' books generally do not estimate the value of the non-verifiable *R&D* returns E. In this sense any empirical implementation of our model should be aware of these shortcomings.

Lemma, we obtain the following expression for the feasible projects ($Y > \underline{Y}$):

$$DE = \begin{cases} \frac{YL}{E[L-(1-\beta)(I_E - pY)]} & if\ Y < \overline{Y} \\ \frac{Y}{pY+E-\overline{Y}} & if\ Y \geq \overline{Y} \end{cases} \quad (7)$$

Making use of (7) and the lemma, the following comparative statics are obtained:

Proposition

If the project is feasible, then:

- The debt-equity ratio DE is decreasing in d and β. Moreover,

If $Y < \overline{Y}$ then $\frac{\partial DE}{\partial E} < 0$

If $Y > \overline{Y}$ then $\frac{\partial DE}{\partial E} > (<)\ 0$ if $E < (>)\ \overline{E} = \sqrt{\frac{(1-p)LY}{1-\beta}}$

- Debt length (which is inversely related with α), is increasing in E, d, and L and decreasing in β for $Y > \underline{Y}$. For liquidity-constrained firms ($Y < \underline{Y}$) debt length is constant with respect to E and β, and is increasing in L and d.

Proof

By differentiation making use of $L < (1-\beta)E$ and that $pY \leq I_E$ for $Y \leq \overline{Y}$

3. DISCUSSION AND CONCLUSIONS

Our model shows that leverage is negatively related to *R&D* returns (E). This is strictly true for all financially-constrained firms ($Y < \overline{Y}$) and for those unconstrained firms which have high returns to *R&D*. The assumption of firms' cash flow (Y) and E to be non verifiable, prevents lenders from forcing an ex-post renegotiation with the entrepreneur and extracting rents from potential increases in E by charging higher debt payments (R). The result is that firms' profits rise with E more than R. This is especially true for high values of E, and for liquidity-constrained firms, where the limited liability condition is binding, and R is independent of E. Thus, we find a low debt-equity ratio for high values of E. This is in accordance with the first type of empirical findings referred to in the introduction. Second, for those firms specialized on *R&D* activities, that is, those which generate a high proportion of *R&D* returns in the short-term (high β), we obtain a low debt-equity ratio. The higher β is, the lower the maximum rents lying over Y the entrepreneur can lose ($(1-\beta)E$). To prevent this fact, the financier, reduces entrepreneur's costs of telling the true Y by reducing debt payments (R). Together with the positive relationship between firms' profits and *R&D* specialization (β), this produces a negative relationship between specialization in *R&D* and the debt-equity ratio. This is consistent with the second type of empirical evidence referred to in the introduction, where young non-diversified firms focused on *R&D* activities, present a lower debt-equity ratio than old firms in more mature sectors. Third, there is a trivial negative relationship between firms' debt-equity ratio and the amount of internal funds available. This result is consistent with the second and the third type of empirical evidence mentioned in the introduction: small firms in high-tech industries that use basically internal funds to finance their activities, present low debt-equity ratios. Finally, we have found that debt length diminishes in two cases: when the project has a small liquidation value (specific assets); and when the entrepreneur's incentives to behave dishonestly are high (*i.e.* β is high, external funding I_E is large, or interestingly *R&D* returns E are low). Thus under the optimal contract, E acts as a disciplinary mechanism which prevents the entrepreneur from behaving opportunistically: the benefits the entrepreneur may lose if he lies, $(1-\beta)E$, increase with E. This would explain why in the presence of high returns to *R&D* the lender would like to offer long-term debt.

Finally in a dynamic context, as *R&D*-specialized firms become more efficient by reducing their *R&D* gestation lag, we predict a decreasing evolution of the debt-equity ratio for these firms. Future empirical work would have to test these predictions.

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APPENDIX

For the Lemma, the only point which is worth to mention is that condition $I_E \leq pR + (1-p)L$ ensures financier's profits $pR + (1-p)\alpha L - I_E = 0$ for $\alpha \leq 1$, otherwise, this condition could only be achieved for $\alpha > 1$, which does not make sense. Note that for $Y < \overline{Y} \Rightarrow \alpha = \frac{I_E - pY}{(1-p)L} \leq 1$ if $I_E \leq pR + (1-p)L$ (as $R = Y$). On the other hand, for $Y > \overline{Y} \Rightarrow \alpha = \frac{I_E}{p(1-\beta)E+(1-p)L} \leq 1$ if $I_E \leq pR + (1-p)L$ (as $R = \alpha(1-\beta)E$).

For the Proposition, we provide the derivation of those non-trivial derivatives:

-With regard to the derivatives of DE for $Y < \overline{Y}$, all are trivial once we note that $I_E - pY > 0$ for $Y < \overline{Y} = \frac{I_E(1-\beta)E}{p(1-\beta)E+(1-p)L} = \frac{I_E}{p}\{\frac{1}{1+(\frac{1}{p}-1)\frac{L}{(1-\beta)E}}\} < \frac{I_E}{p}$

- For the derivatives of DE for $Y \geq \overline{Y}$, we compute the following ones:

$\frac{\partial DE}{\partial \beta}$

$\frac{\partial}{\partial \beta}\{\frac{\overline{Y}}{pY+E-\overline{Y}}\} = \frac{\partial}{\partial \beta}\{\frac{1}{\frac{pY+E}{\overline{Y}}-1}\} = \frac{\frac{pY+E}{\overline{Y}^2}\frac{d\overline{Y}}{d\beta}}{[\frac{pY+E}{\overline{Y}}-1]^2} < 0$ where we have used the fact that:

$\frac{d\overline{Y}}{d\beta} = \frac{d}{d\beta}\{\frac{I_E(1-\beta)E}{p(1-\beta)E+(1-p)L}\} = \frac{d}{d\beta}s\{\frac{I_E}{p+\frac{(1-p)L}{(1-\beta)E}}\} = -\frac{I_E(\frac{(1-p)L}{(1-\beta)^2E^2})E}{(p+\frac{(1-p)L}{(1-\beta)E})^2} < 0$

$\frac{\partial DE}{\partial E}$

We first compute the following derivative:

$\frac{d\overline{Y}}{dE} = \frac{d}{dE}\{\frac{I_E(1-\beta)E}{p(1-\beta)E+(1-p)L}\} = \frac{d}{dE}\{\frac{I_E}{p+\frac{(1-p)L}{(1-\beta)E}}\} = \frac{I_E(\frac{(1-p)L}{(1-\beta)^2E^2})(1-\beta)}{(p+\frac{(1-p)L}{(1-\beta)E})^2} = \overline{Y}(\frac{1}{E}\frac{(\frac{(1-p)L}{(1-\beta)E})}{p+\frac{(1-p)L}{(1-\beta)E}}) \equiv$
$\equiv \frac{1}{E}\overline{Y}(\frac{1}{1+\frac{p}{F}})$ $With\ F \equiv (\frac{(1-p)L}{(1-\beta)E})$

With this expression, we can ensure:

$\frac{\partial}{\partial E}\{\frac{\overline{Y}}{pY+E-\overline{Y}}\} = \frac{\partial}{\partial E}\{\frac{1}{\frac{pY+E}{\overline{Y}}-1}\} = -\frac{\frac{\overline{Y}-(pY+E)(\frac{d\overline{Y}}{dE})}{\overline{Y}^2}}{(\frac{pY+E}{\overline{Y}}-1)^2} = -\frac{\overline{Y}-(pY+E)(\frac{d\overline{Y}}{dE})}{\overline{Y}^2(\frac{pY+E}{\overline{Y}}-1)^2} =$
$\frac{1}{\overline{Y}^2(\frac{pY+E}{\overline{Y}}-1)^2}\{(pY+E)\frac{1}{E}\overline{Y}(\frac{1}{1+\frac{p}{F}})-\overline{Y}\} = \frac{\overline{Y}}{\overline{Y}^2(\frac{pY+E}{\overline{Y}}-1)^2}\{(pY+E)\frac{1}{E}(\frac{1}{1+\frac{p}{F}})-1\} =$
$\frac{1}{\overline{Y}(\frac{pY+E}{\overline{Y}}-1)^2}\{\frac{(1+\frac{pY}{E})}{1+\frac{p}{F}}-1\}$

Consequently $\frac{Y}{E} \gtrless \frac{1}{F} \equiv \frac{(1-\beta)E}{(1-p)L} \Rightarrow \frac{\partial}{\partial E}\{\frac{\overline{Y}}{pY+E-\overline{Y}}\} \gtrless 0$

As $\frac{Y}{E} \gtrless \frac{1}{F} \equiv \frac{(1-\beta)E}{(1-p)L} \Leftrightarrow E \lessgtr \sqrt{\frac{(1-p)LY}{1-\beta}} \equiv \overline{E}$, therefore we obtain:

$$\frac{\partial DE}{\partial E} \gtrless 0 \ if \ E \lessgtr \overline{E} = \sqrt{\frac{(1-p)LY}{1-\beta}}$$