Startup Financing and Capital Structure: A Signaling Approach

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Abstract

We construct a single-stage startup financing model, in which the entrepreneur strategically chooses debt-equity ratio as a signaling device in order to inform his project value to the investors. In our model, there is a penniless entrepreneur who plans an innovative project and he seeks for seed investment to launch the project. Based on the entrepreneur's choice of capital structure, investors evaluate the project value. In particular, debt investors determine required return while equity investors ask their equity share for a given amount of investment. We allow for endogenous probability of bankruptcy which increases in the amount of debt as in Ross (1977).

KEYWORDS: principal-agent problem; executive compensation; information acquisition; price informativeness; price volatility

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1 Introduction

For technology startups, one of the most important issues is access to capital. Due to the absence of track records, it is essential for startups to inform the the value of their projects to potential investors. Thus startups need to reveal reliable information about their ability in order to attract investors in early financing stages. Intuitively, one may believe that the amount of patents filed credibly transmits information about the value of technology startups. Indeed, according to the empirical analysis of Graham et al. (2009), filing patent is useful for technology startups to securing financing and enhancing reputation. Recently, the role of the patent as a signaling device is extensively studied in the theoretical models of Conti et al. (2013a), Conti et al. (2013b), and Hahn et al. (2017) develop theoretic models.

On the other hand, there are few studies which examine how the choice of a startup's capital structure signals to potential investors in the early-stage financing. It is true that the conventional studies of Leland and Pyle (1977), Ross (1977), and Myers and Majuluf (1984) consider asymmetric information between insiders and outside investors and examine the the role of a firm's choice of capital structure as a signaling device to the investors. However, these studies are not closely related to startup financing. They do not take into account risky debt and initial issuance of equity share at the same time. As Denis (2004) point out, equity investment is essential part of early-stage financing since startups' project are not profitable yet in most cases. Practically, entrepreneurs make contracts about the distribution of initial equity share with outside investors such as venture capitals and business angels. Furthermore, most startups had some form of debt financing and as startups possess more fixed asset which can be collateral, they increase debt financing as shown in the empirical study of Cassar (2004). This implies that the debt is believed to be risky in startup financing. However, Ross (1977) and Myers and Majuluf (1984) assume equity investors who already invested to ongoing businesses and keep holding their shares and Leland and Pyle (1977) consider debt investment which yields risk-free return.

Our question is about the entrepreneur's choice of the capital structure. How does the entrepreneur choose the amount of debt or equity in order to send credible signal about the project value to potential investors? To find the answer to the question, we construct a single-stage startup financing model, in which the entrepreneur strategically chooses debt-equity ratio as a signaling device in order to inform his project value to the investors. In our model, there is a penniless entrepreneur who plans an innovative project and he seeks for seed investment to launch the project. Based on the entrepreneur's choice of capital structure, investors evaluate the project value. In particular, debt investors determine required return while equity investors ask their equity share for a given amount of investment. We allow for endogenous probability of bankruptcy which increases in the amount of debt as in Ross (1977).

The purpose of this study is to investigate effects of the entrepreneur's choice of debt-equity ratio on the startup financing. We derive separating perfect Bayesian equilibria in the signaling game. Since we endogenize the probability of the bankruptcy, the entrepreneur's signaling choice affects the expected project value and thus the signal is productive in the sense of Spence (1974).

This study is related to Conti et al. (2013a), Conti et al. (2013b), and Hahn et al. (2017), in which the entrepreneur signals the amount of patent to investors. We complement them in two aspects. First, we consider the entrepreneur's choice of capital structure as a signaling device. Although patent can play an important role in startup financing to secure finance as shown in Graham et al. (2009), some entrepreneurs may grasp business opportunities without filing patents. Indeed, their data also shows that, in software industry, there are one third of startups which do not hold patents. Our model can capture the behavior of startups in startup financing whether they acquire patents or not. Second, our model endogenizes the probability of bankruptcy, which increases in the amount of debt. In general, startups have relatively high possibility of bankruptcy and investors require compensation for taking the risk. Although Conti et al. (2013a) allow for debt investment from acquaintances, they assume that the debt yields risk-free return.

This study is also closely related to signaling model of Leland and Pyle (1977) and Ross (1977). In our model, the entrepreneur raises fund from both debt investors and equity investors as in Leland an Pyle (1977). However, their model assumes that the debt yields a fixed risk-free rate and its value is independent of the project value. To capture the feature of startup financing, in our model, the debt is risky and its value and return are endogenously determined based on the market evaluation of the entrepreneur's project. We take into account endogenous bankruptcy probability, which increase in the amount of the debt as in Ross (1977). However, Ross (1977) does not allow for new equity contract and thus his model cannot explain the participation of venture capitals and business angels in startup financing. Furthermore, in Ross (1977), the manager's compensation is the weighted average of the firm's current and future values. In this model, the entrepreneur uses all investment to launch the project and get paid after the project value is realized.

2 Model

An entrepreneur has an innovative project which requires initial investment K. He plans to raise funds from two types of investors: banks and venture capitals (VCs). In this model, we assume that the entrepreneur makes debt contract with the banks and makes equity contract with the VCs and both investment markets are under Bertrand competition. Thus banks and VCs are represented by a single investor, respectively. There is asymmetric information between the entrepreneur and the investors. Only the entrepreneur knows his exact type while the bank and the VC do not. The entrepreneur's type space is given by $T \equiv \{H, L\}$. We call the entrepreneur whose types is H the high type and whose type is L the low type. The investors have prior belief μ about the entrepreneur's type such that $\mu(H) = q$.

The game between the entrepreneur and the investors is played over three period ($\tau = 0, 1, 2$). In period $\tau = 0$, nature determines the entrepreneur's type $t \in T$. Let $\hat{t} \in T$ be the entrepreneur's type perceived by the investors. We assume that the entrepreneur's project value X_t at $\tau = 2$ is uniformly distributed between zero and x_t (i.e., $X_t \sim U[0, x_t]$) where $x_H > x_L$. In period $\tau = 1$, the entrepreneur chooses the face value D_t of the debt in order to signal his type to the bank and the VC. One may believe that as higher debt value means a lower quality of a firm. However, at the beginning of the project, firms have incentive to increase debt-ratio to maximize leverage effect. Note that the face value D_t should be less than x_t. After observing the signal, the bank and the VC make investment decisions. The entrepreneur and the bank make a debt contract, in which the bank invests V_0^D for face value D_t paid at $\tau = 2$. On the other hand, the entrepreneur and the VC make a equity contract, in which the VC invests $K - V_0^D$ for equity share $\theta_{\hat{t}}$. In period $\tau = 2$, project value X_t is realized and the entrepreneur, the bank, and the VC get paid. The sequence of the event is illustrated in Figure 1 below.

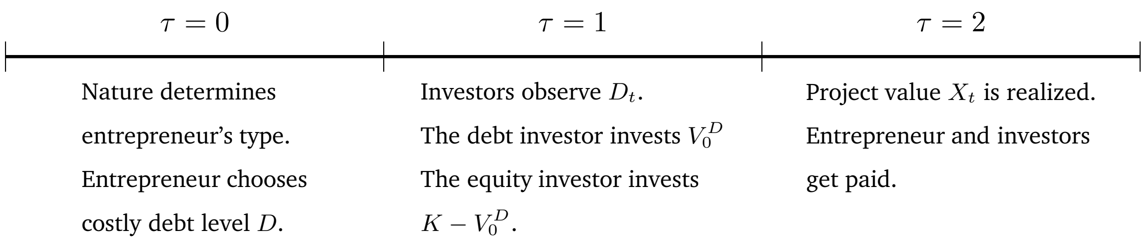

Figure 1: Sequence of events

An increase in debt obligation D_t at $\tau = 2$ leads to the rise the default probability of the entrepreneur. Specifically, each type's default probability is given by D_t/x_t. Therefore, if the both types have the same debt level, the high type has a lower default probability than the low type. Our model takes into account the bankruptcy cost. After bankruptcy, the bank (debt holder) can take only the fraction of the remaining value, which is given by $(1-\alpha)X_t$ where $\alpha \in (0,1)$.

Let F_t be the distribution function of X_t. Then the expected project value is given by

$$\begin{aligned}\mathbb{E}[X_t] &= \frac{1}{1+r_f}\left[(1-\alpha)\int_0^{D_t} x dF_t(x) + \int_{D_t}^{x_t} x dF_t(x)\right] \\ &= \frac{1}{1+r_f}\left[\frac{x_t}{2} - \frac{\alpha D_t^2}{2x_t}\right]\end{aligned}$$

where r_f is the risk-free rate. The first term $x_t/2$ in the bracket is the expected project value without bankruptcy cost and the second term $\alpha D_t^2/(2x_t)$ is the loss of the expected project value due to the bankruptcy cost. For simplicity, henceforth, we set $r_f = 0$. The expected project value $\mathbb{E}[X_t]$ increases in maximum project value x_t while it decreases in the bankruptcy cost represented by α. Note that the entrepreneur's debt level D_t is a productive signal since it affects the expected project value. To ensure the participation of the investors, the minimum expected project value should be greater than required investment K to launch the project and thus we assume that[1]

$$\frac{(1-\alpha)x_L}{2} > K. \tag{2.1}$$

[1]To find the minimum expected project value between all types, we should consider changes of t and D_t at the same

Since the investment markets are competitive, the expected utilities of the bank and the VC should be zero, respectively. Thus the investment V_0^D of the bank at $\tau = 1$ is given by

$$V_0^D(\hat{t}) = (1-\alpha)\int_0^{D_t} x dF_{\hat{t}}(x) + \int_{D_t}^{x_{\hat{t}}} D_t dF_{\hat{t}}(x).$$

Let the project's equity value be denoted by V_0^E. Then we have

$$V_0^E(\hat{t}) = \int_{D_t}^{x_{\hat{t}}} (x - D_t) dF_{\hat{t}}(x).$$

Therefore, the VC's investment at $\tau = 1$ is given by

$$K - V_0^D(\hat{t}) = \theta_{\hat{t}} \int_{D_t}^{x_{\hat{t}}} (x - D_t) dF_{\hat{t}}(x) = \theta_{\hat{t}} V_0^E(\hat{t}).$$

The entrepreneur's expected revenue is given by

$$w_{\hat{t}}(D_t) \equiv (1-\theta_{\hat{t}}) V_0^E(\hat{t}) = (1-\theta_{\hat{t}}) \int_{D_t}^{x_t} (x - D_t) dF_t(x).$$

If the entrepreneur fails to repay the dept at $\tau = 2$, he may lose his reputation or would gain a bad credit rating. Thus we consider the individual loss γ of the entrepreneur when his project ends with bankruptcy. Then the entrepreneur's expected individual loss when bankruptcy occurs is given by $\gamma D_t / x_t$. Let $\gamma_H \equiv \gamma / x_H$ and $\gamma_L \equiv \gamma / x_L$. Since $\gamma_H < \gamma_L$, the low type's each dollar of debt incurs a higher cost than the high type's. The entrepreneur's expected utility is given by

$$U_E(D_t; t) = w_{\hat{t}}(D_t) - \gamma_t D_t.$$

3 Separating Equilibria

In separating equilibria, the investors correctly perceive the entrepreneur's true type, i.e., $\hat{t} = t \in T$. For each type $t \in T$, the debt value at $\tau = 1$ is given by

$$\begin{aligned} V_0^D(t) &= (1-\alpha)\int_0^{D_t} x dF_t(x) + \int_{D_t}^{x_t} D_t dF_t(x) \\ &= \frac{(1-\alpha)D_t^2}{2x_t} + \frac{D_t}{x_t}(x_t - D_t) = \frac{D_t}{x_t}\left[x_t - \frac{(1+\alpha)D_t}{2}\right]. \end{aligned}$$

It is clear that debt value V_0^D increases in maximum project value x_t and decreases in default cost measured by α. However, the effect of face value D_t on V_0^D is unclear. It is because an increase

time. For the high type and the low type, the minimum expected project values are given by

$$\mathbb{E}[X_H] = \frac{(1-\alpha)x_H}{2} \quad \text{and} \quad \mathbb{E}[X_L] = \frac{(1-\alpha)x_L}{2},$$

respectively, and we have $\mathbb{E}[X_H] - \mathbb{E}[X_L] = (1-\alpha)(x_H - x_L)/2 > 0$.

in D_t raises both the bank's payoff and the default probability of the entrepreneur. Debt value V_0^D increases in face value D_t if and only if the maximum project value x_t relative to D_t is sufficiently high such that $x_t/D_t > 1+\alpha$ holds.

The entrepreneur raises remaining fund $K - V_0^D = \theta_t V_0^E$ by making the equity contract with the VC. For each type $t \in T$, the value of the equity share θ_t at $\tau = 1$ is given by

$$\begin{aligned} \theta_t V_0^E(t) &= \theta_t \int_{D_t}^{x_t} (x - D_t) dF_t(x) \\ &= \frac{\theta_t}{2x_t}(x_t - D_t)^2. \end{aligned}$$

Note that V_0^E increases in x_t and decreases in D_t. The entrepreneur's revenue is value of his equity share $1-\theta_t$, given by

$$w_t(D_t) = \frac{(1-\theta_t)}{2x_t}(x_t - D_t)^2.$$

Proposition 3.1. *For each type $t \in T$, the VC asks equity share*

$$\theta_t = \frac{2x_t}{(x_t - D_t)^2}\left[K - \frac{D_t}{x_t}\left(x_t - \frac{(1+\alpha)D_t}{2}\right)\right].$$

PROOF : Since $E^0(t) = K - D^0(t)$ for each t, we have

$$K - \frac{D_t}{x_t}\left[x_t - \frac{(1+\alpha)D_t}{2}\right] = \frac{\theta_t}{2x_t}(x_t - D_t)^2$$

for each type $t \in T$. Then it follows Lemma 1. ■

Note that $\theta_t \in (0,1)$ always holds by (2.1). It is clear that the equity share θ_t for the VC increases in the required investment K. We also find that an increase in the expected project value $x_t/2$ decreases the VC's equity share since

$$\frac{\partial \theta_t}{\partial x_t} = -\frac{2[(K - D_t)x_t + (K + \alpha D_t)D_t]}{(x_t - D_t)^3} < 0,$$

for each $t \in T$. Thus as the entrepreneur's project is expected to yield a higher value, he can take more equity share.

The entrepreneur's expected revenue is given by

$$w_t(D_t) = \frac{(1-\theta_t)}{2x_t}(x_t - D_t)^2 = \frac{1}{2}\left[x_t - \frac{\alpha D_t^2}{x_t} - 2K\right]$$

for each $t \in T$. Therefore his expected utility is given by

$$U_t(D_t; t) = \frac{1}{2}\left[x_t - \frac{\alpha D_t^2}{x_t} - 2K\right] - \gamma_t D_t.$$

for each $t \in T$. For each type, the entrepreneur's expected utility increases in the expected project value while it decreases in the bankruptcy cost, debt level and the amount of initial investment.

Suppose that the investors choose cutoff debt level $D^* > 0$. The investors consider the entrepreneur who chooses debt level higher than D^* as the high type and who chooses debt level less than or equal to D^* as the low type. If the high type mimics the low type, the investors consider him as the low type and thus his revenue becomes

$$w_H(D_L) = (1-\theta_L)\int_{D_L}^{x_H}(x - D_L)dF_H(x) = \frac{(1-\theta_L)}{2x_H}(x_H - D_L)^2.$$

If the entrepreneur knows that the cutoff debt level is given by D^*, the low type chooses zero debt level ($D_L = 0$). Thus we have

$$w_H(0) = \frac{(1-\theta_L)x_H}{2} = \frac{(x_L - 2K)x_H}{2x_L} \equiv u_H.$$

On the other hand, if the low type mimics the high type, the investors believe that the entrepreneur is the high type and thus his revenue becomes

$$w_L(D_H) = (1-\theta_H)\int_{D_H}^{x_L}(x - D_L)dF_L(x) = \frac{(1-\theta_L)}{2x_L}(x_L - D_H)^2.$$

Then we have incentive compatibility constraints to separate the entrepreneur's type:

$$\begin{aligned} w - \gamma_H D &\geq \frac{(1-\theta_L)H}{2} = \frac{(x_L - 2K)x_H}{2x_L} \equiv u_H, \\ w - \gamma_L D &\leq \frac{(1-\theta_L)L}{2} = \frac{x_L - 2K}{2} \equiv u_L. \end{aligned}$$

Proposition 3.2. *In separating equilibria, the high type and low type's debt level are given by*

$$\begin{aligned} D_L^* &= 0, \\ D_H^* &\in [\underline{D}_H, \bar{D}_H] \end{aligned}$$

where

$$\begin{aligned} \underline{D}_H &= \frac{-\gamma_L x_H + \sqrt{x_H(\gamma_L^2 x_H + \alpha x_H - \alpha x_L)}}{\alpha}, \\ \bar{D}_H &= \frac{-\gamma_H x_H x_L + \sqrt{x_H x_L(\gamma_H^2 x_H x_L + 2\alpha x_H k - 2\alpha k x_L)}}{\alpha D_L}. \end{aligned}$$

4 Concluding Remarks

We construct a single-stage startup financing model, in which the entrepreneur strategically chooses debt-equity ratio as a signaling device in order to inform his project value to the investors. We derive separating perfect Bayesian equilibria. The high type signals his ability by choosing a certain level of debt while the low type raises fund only from equity investors.

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