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Innovative Applications of O.R

Selection of entrepreneurs in the venture capital industry: An asymptotic analysis ☆

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ABSTRACT

We study a model of entrepreneurs who compete in an auction-like setting for venture capital (VC) funding in a setting where limited capital dictates that the VC can only finance the best entrepreneurs. With asymmetric information, VCs can only assess entrepreneurs by the progress of development, which, in equilibrium, reveals the quality of the new technology. Using an asymptotic analysis, we prove that in attractive industries having a large number of entrepreneurs competing for VC funding could lead to underinvestment in technology by entrepreneurs as the effort exerted by losing entrepreneurs is wasted. The study then proceeds to characterize the conditions under which a greater number of competing entrepreneurs is better. The model also demonstrates that VCs could possibly increase their payoff by concentrating on a single industry. In addition, the study also provides some insights on the effects of multiple investments by VCs and the effects of competition among VCs on the same investments.

1. Introduction

Venture capitalists (VCs) thrive by successfully gambling on a small number of companies that they fund from all the applications that they receive. This study focuses on whether increasing traffic in the VC firm would have a positive effect on the firm or, on the contrary, be counterproductive. Our model considers entrepreneurs who compete for VC funding in an auction-like setting where the VC acts as the auctioneer that sells financing to n entrepreneurs who bid for financing. The surprising finding is that having a large number of entrepreneurs who vie for funding can cause underinvestment in technology by entrepreneurs. Moreover, we find that this phenomenon is likely to occur when the industry is very attractive and populated with many high quality entrepreneurs. The reason for this result is that when the number of competitors is high, and there are many entrepreneurs who are likely to have high quality technology, the probability of getting funding from a VC decreases as competition becomes fierce. In turn, unfunded entrepreneurs would lose their development investments and, thus, as a preemptive move, they will reduce their technology investments prior to participation. Another interesting result is that VCs could possibly increase their payoff if they avoid overextending themselves and focus, instead, on a small number of industries. In addition, the study also provides some insights on the effects of multiple investments by VCs and the effects of competition among VCs on the same investments.

Venture capital financing for early-stage companies has dramatically increased in importance in the last two decades, and so has the academic research on this topic. The majority of the VC literature entails descriptive field and empirical studies (see, for example, Sahlman, 1990; Lerner, 1994; Gompers, 1995; Gompers and Lerner, 1999; Hellmann and Puri, 2000; Kaplan and Stromberg, 2002). The theoretical research in this area has largely focused on the mechanism of staged investments (see, for example, Neher, 1999; Wang and Zhou, 2004; Shepherd et al., 2005). Others have investigated whether financing should be provided in the form of debt, equity, or a hybrid instrument (Bergemann and Hege, 1998; Trester, 1998; Schmidt, 2003; Elitzur and Gavious, 2003). Several theoretical studies (see for example, Amit et al., 1998; Ueda, 2004) focus on the raison d'être of VCs and argue that VCs exist because of their ability to reduce informational asymmetries. Specifically, banks and other institutional lenders, in contrast to VCs, cannot distinguish between high and low quality entrepreneurs for such early stage companies. As such, VCs act essentially as financial intermediaries who thrive because of their superior ability to screen and monitor entrepreneurs. While several studies argue that screening prospective

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investments by VCs is crucial for the VC's success (see, for example, Zacharakis and Meyer, 2000; Shepherd et al., 2005), or that the VCs' superior ability to do so is the very reason for their existence (Amit et al., 1998; Ueda, 2004, for example), research on the screening pro cess is scarce. As such, this is the focus of this study: the screening process itself and its impact on technology development by entrepreneurs prior to their participation in the funding competition.

Our modeling method is related to the economic literature on private-value contests with incomplete information where many entrepreneurs seek venture capital financing. The venture capitalist has the power to choose the entrepreneur and boost the start-up firm. This type of modeling is different from the case of the double auction where both parties are engaged in simultaneous offers and neither of them has an advantage over the other (see Chatterjee and Samuelson's work (1983) on double auctions). The literature in this field (which includes, for example, Weber, 1985; Hillman and Riley, 1989; Krishna and Morgan, 1997) deals with an auctioneer who benefits from the bids (or efforts) made by the players while assuming a linear cost function. In this sense, our model is related to Moldovanu and Sela (2005) where a non-linear cost function is assumed. However, in contrast to the traditional literature in this field, our model assumes (in order to fit the venture capital industry) that the auctioneer (the venture capitalist in our model) benefits, in addition to the bid, also from the private value of the winner, which represents the firm's quality.

A recent line of literature that is related to our paper in the contests area includes Taylor (1995), Fullerton and McAfee (1999), Moldovanu and Sela (2005), and Fibich and Gavious (2009). However, the significant difference in the current work is that the VC benefits only from the winning bid and the highest technology (i.e., $\max(b_i + v_i)$) as opposed to the contest literature where the auctioneer receives also a payoff from the losing bids (i.e., $\sum_i b_i$).

The paper is organized as follows: Section 2 presents the model. Section 3 provides the analysis of the equilibrium bids. In Section 4 we endogenize the contracting between the VC and the entrepreneur and examine optimal contracting between the parties. Section 5 examines what would happen when VCs compete among themselves on entrepreneurs. Section 6 concludes.

2. The basic model

2.1. Brief description of the model

Consider n entrepreneurs competing for a single investment unit with size P offered by a VC at a cost of capital of d. Usually the decision made by the VC is a "go" or "no go" one. Namely, if the VC and other investors decide to support a new startup firm they will raise and invest as much money as needed. Hence, the investment amount, P, in our setting is independent of the entrepreneur's effort (and is based on the amount required by the entrepreneur to proceed) while the decision whether to invest in the entrepreneur ultimately depends on his effort. For sake of simplicity and without loss of generality we normalize P to 1. It is well accepted in practice that VCs invest a given amount of money per venture (or within a well defined range). Each entrepreneur i invests development effort e_i, $i = 1,2,\ldots,n$ where his idea has a value v_i which is private information and known only to the entrepreneur. The VC observes the efforts made by the entrepreneurs e_i, $i = 1,2,\ldots,n$ and decides on which entrepreneur he invests the investment unit in. The cost of effort for an i entrepreneur is $0.5e_i^2$. Using the investment unit, the entrepreneur starts a firm where it expected value is given by $(v + e)P$. The entrepreneur gets a fraction α of this value where the VC gets the rest. The VC chooses the entrepreneur with the highest effort as the winner. An entrepreneur i's payoff if he wins is $\alpha(v+e)P - 0.5e_i^2$ and his payoff in the case that he loses is the (negative) cost of effort $0.5e_i^2$. The VC's payoff is $(1-\alpha)(v+e)P - (1+d)P$.

2.2. Detailed assumptions

We model the selection of entrepreneurs by the VC as an all-pay auction. An-all pay auction is one where all bidders must pay regardless of whether they win the prize and thus, it is used to model tournaments. Araujo et al. (2008) state that, an important example of all-pay auctions is a tournament" (p. 416) since the tools used for analyzing all pay auctions are the same such as applied for tournaments. All-pay auction model makes sense here because when entrepreneurs compete for funding they have already made their investment in the technology (the payment), regardless of whether they get subsequent venture capital financing (the prize). Suppose there are n entrepreneurs competing over VC financing. We assume that the VC will finance $K \geqslant 1$ entrepreneurs, where in Sections 3 and 4 we study the case $K = 1$ and in Section 5 we let $K > 1$. Each entrepreneur i, $i = 1,\ldots,n$ knows the value of his technology v_i where $v_i \in [0,1]$ is private information of entrepreneur i. The value of each entrepreneur's technology, v_i, is drawn independently from a twice continuous distribution $F(v)$ defined over $[0,1]$. It is assumed that F has a strictly positive density $f(v)$,with bounded derivative f'. Observe that the term value of technology" is not in terms of money but in term of quality. As we will see later on, the firm's expected value in monetary units is a linear function of v.

We assume that the entrepreneur takes some actions to develop the product before approaching the VC and reaches a certain phase of development. These actions by the entrepreneurs (often referred to as effort in the game theory and principal-agent literatures, e.g., Amit et al., 1998; Moldovanu and Sela, 2005) are denoted as $e_i \geqslant 0$, $i = 1,\ldots,n$. The cost of these actions is $0.5e_i^2$, $i = 1,\ldots,n$. The specification $0.5e_i^2$ provides a simple cost function ensuring tractable analysis and incorporates costs that are increasing in development effort. Moreover, it is a strictly convex cost function with an increasing marginal cost, a standard assumption in microeconomics modeling.[1] Note that the cost function is the same across all entrepreneurs but they differentiate themselves in their technologies. We assume that e_i, is observed by the VC.

Let P be the VC's expected investment in the winning entrepreneur. We may assume that P is a random variable varying among entrepreneurs.[2] To avoid complexity we assume that all n entrepreneurs are in the same industry and in a similar stage. This assumption is reasonable as VCs normally specialize in an industry and in a stage of development (e.g., seed, first- or second-round, expansion, mezzanine and so forth). The realization of the investment is unknown to the VC and the entrepreneur and becomes known after the winning entrepreneur starts up the firm and the VC raises the money needed (probably, in several investment rounds). Note that, while the ex-post value of the investment is ex-ante unknown to the VC, its range is known. This assumption of having a range of investment amounts by the VC in each stage is consistent with the literature (as shown, for example, in Table V in Gompers (1995)) and actual practice (as evidenced, for example, in the website (n.d.) of Sequoia Capital). Since the VC and the entrepreneurs make their decisions based on their expected payoffs, we can avoid unnecessary complexity (which will not change the results) and define immediately the expected investment made by the VC. We assume that the winning firm's value increases in both the value of the technology, v, and the effort made by the entrepreneur, e. For mathematical simplicity we consider a linear relation between v, e and the firm's value. We assume that winning firm's ex-post value is

[1] Note, that, one can replace the constant 0.5 with any other constant. The advantage of using 0.5 as the coefficient (as opposed to, say, c) is that it provides a tangible and tractable function, without losing generality.

[2] We can define P_i, $i = 1,2,\ldots,n$, to be the VC's investment given that entrepreneur i wins. The investments P_i assumed to be independent and identically distributed (iid) random variables. The distribution of the investments P_i depends on the type of the industry and stage of the start up firm. However, P_i vanishes in the analysis since we consider expected payoffs and what is left is the expectation $E(P_i) = P$.