A Real Options Framework for CVC Investments under Technological Uncertainty

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Abstract

This paper studies the optimal timing of corporate venture capital investments and subsequent acquisition decisions under technological uncertainty. We consider a large firm interested in a technology being developed by a start-up. The firm has the option of investing in the startup at an early R&D stage through a CVC, or to wait until the technology is mature before acquiring it. While an early CVC allows the firm to start integrating the new technology, it induces the risk of losing the premium if the technology does not develop as expected. We formulate the problem as a real option problem where the firm aims at maximizing its profit at $t = 0$, considering possible CVC and acquisition decisions in the future. We solve the problem using a two-level dynamic programming algorithm and show the optimal firm decision.

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1 Introduction

It is often considered that small firms have large comparative advantages at early stages of innovation process, while large firms have advantages at later stages (Granstrand and Söjlander, 1990). In this context, the acquisition of small firms by larger established ones is a common practice that allows the latter to acquire interesting technological innovations. Ahuja and Katila (2001) found that large companies should focus their merger and acquisition activity on small targets if they would like to increase their innovative performance. This tendency has been recently confirmed in (Andersson and Xiao, 2016) using a data set from Sweden.

It is important to notice that, in these operations, the interest is usually reciprocal between both firms involved in the acquisition. From the perspective of the small firm, the acquisition is often considered as a more favorable outcome than an independent development. As a matter of fact, it has been observed that small businesses tend to over-invest in R&D before a potential acquisition to report their skills and attract interested buyers, leading to a positive correlation between R&D activity and the acquisition probability (Phillips & Zhdanov, 2011). On the other hand, from the buyer perspective, the acquisition of innovative firms is considered as a complement to the internal innovations generated by in-house R&D innovations (Granstrand and Sjölander, 1990; Desyllas and Hughes, 2008). we will focus on corporate venture activities and their link to acquisition activities Indeed, corporate venture can be a first step towards the acquisition of small firms by large ones that are interested by their technology. From a strategic point of view, corporate venture investment in technological firms may be regarded as a strategic hedging tool against the competition (in addition to the well known advantages of acquiring information and some other competencies).

Despite the ups and downs, the amount that firms have poured into corporate venture capital (CVC) deals has increased by about threefold from \$11.0 billion in 2007 to \$32.2 billion in 2016 (NVCA, 2017). In the same period, the number of deals concluded nearly doubled from 666 to 1204 (NVCA, 2017). The CVC arms of large firms such as Intel Capital and Microsoft Ventures continue to invest in the forefront of the latest technologies in autonomous machines, artificial intelligence and virtual reality.[1]. What induces such large corporations to set up CVC arms rather than relying solely on internal innovation? First, as opposed to independent venture capital (IVC) investments that focus mainly on financial returns, corporations that engage in CVC emphasize the strategic nature of their investments, often citing factors such as "gaining insight on innovative technologies", "increasing speed of innovation and reducing cost" and "identifying potential acquisitions" (Ernst & Young, 2008).[2]

Although the empirical and theoretical literature also emphasizes the strategic nature of CVC investments (Kim et al. 2016, Fulghieri & Sevilir 2009 and Tong & Li, 2011) not much research has gone into corporations' timing decisions to enter into a CVC investment. Similar to venture capital (VC) investments, CVC investments are often staged. This reduces the amount committed by the investing firm and gives the firm additional options to decide whether it is worth to pursue the investment possibly culminating in an acquisition.

In this paper, we analyze at what stage corporations enter into CVC investments. Our study is motivated by observations that not all CVC investments

[1]See the Forbes article and Microsoft Ventures website.

[2]MacMillan et al. (2008) and Dushnitsky and Lenox, (2006) also emphasize the strategic orientation of CVC and their potential to create value. Dushnitsky and Lenox (2005b) find evidence that CVC investments are subsequently associated with higher innovation output as referenced by future patent citation levels.

occur at the seed stage and some corporations prefer to take part in the project only at later stages. Take the example of 23andMe, a California-based genetics company helps individuals understand their own genetic information using DNA kits. Some corporations like Google have invested while 23andMe was still in the seed stage and followed up their investments through to the later stage. Others like Genentech have dropped out after the seed stage while others such as Johnson & Johnson have invested in the expansion stage.

Our model is driven by three factors that either favor earlier CVC investment or lead the firm to postpone or even completely discard the CVC investment. First, the firm's ability to learn quickly from the startup and internalize its R&D means that the firm would invest earlier than it otherwise would. We call this channel the *absorptive capacity channel*. The second factor that affects the firm's timing is the *technological risk channel*. Joining the CVC at the initial or seed stage presents the firm with considerable technological uncertainty. Thus the firm faces the possibility that the R&D project will squander the firm's financial resources. The technological uncertainty channel thus favors a later investment. Finally, there is the *strategic effect* arising from the product market competition. When not only one firm is interested in the technology but potential rivals are also present, the firm may find itself in competition for a potentially groundbreaking innovation. Thus, it can become optimal to acquire a toehold in the startup early on. This results in two advantages for the firm: first, it can internalize the R&D output sooner. Second, depending on the size of the initial equity investment, the firm could act quickly to acquire the rest of the startup once the technology has been developed.

Our paper is organized as follows. In section II, we develop a real options framework for CVC and acquisition decisions and show how to solve it using a two-level dynamic programming algorithm. Section III illustrates the proposed framework using numerical applications and shows the sensitivity of the acquisition decision to the different model parameters. Section IV eventually concludes the paper.

2 The Model

In order to assess the role of competition on optimal timing of CVC investment and the possible acquisition decisions, we begin with a benchmark monopoly model. Consider, thus, an incumbent large (IT) firm that operates at a fixed technological (efficiency) level of $\bar{\theta}$. The technology level, $\bar{\theta}$, could reflect the firm's past accumulation of knowledge or investment in human capital. We assume that the firm generates a profit flow given by

$$\pi(\bar{\theta}) = \pi_0 + \gamma(\bar{\theta}) \tag{1}$$

where $\gamma(0) = 0$ and $\gamma'(.) \geq 0$.

The firm has the opportunity to enhance its profit flow through R&D activities. As argued by Dushnitsky and Lenox (2005), Fulghieri and Sevilir (2009), internal R&D may result in inertia and low productivity. Therefore, in industries characterized by high rates of innovation such as the IT industry, traditional in-house R&D can be considered less efficient than external R&D activities (Aghion *et al.* 2005). In this paper, we consider CVC as the external R&D channel.

We thus consider that another small [start-up] firm works on a technology that, if combined with that of the large firm, has the potential to enhance the large firm's profitability. Although we abstract from the details, we assume that the start-up may obtain financing from another VC firm which funds the project in the first development stage[3]. Denote by θ_t the level of technology that the small firm works on at time t. For simplicity, the small firm develops the technology in two stages, $i \in \{1, 2\}$. The first stage can be thought of as the seed/early stage where the technological risk is higher than the second stage which can be considered as the expansion/later stage. We assume that the technology that the startup develops evolves according to:

$$d\theta_{it} = \beta_i \theta_{it} dN_t \tag{2}$$

where $\beta_i > 0$ is a constant and N_t is a Poisson jump process with $dN = 1$ with probability $\lambda_i dt$ in stage i. In line with the argument above, we take $\lambda_1 < \lambda_2$, implying that the first stage is characterized by more technological uncertainty.

The firm can choose to make a corporate venture capital (CVC) investment by acquiring a certain fraction $\alpha < 50\%$ of the startup at a cost αI_i in the early stage (where I_1 is the value of the startup in stage 1). We assume that once the firm undertakes a CVC investment, it follows a passive strategy in the sense that it does not increase its stake in the startup.

Since one of the main goals of a CVC is to learn about new technologies, we allow the firm to partially internalize the technology that the startup works on. Therefore, the firm's profit function becomes:

$$\pi_i(\bar{\theta}, \theta_{it}) = \pi_0 + \gamma_i(\bar{\theta}, \theta_{it}) \tag{3}$$

[3] Our model is sufficiently general for considering a general n-round financing, but we consider a one-stage model as it captures the main tradeoffs.

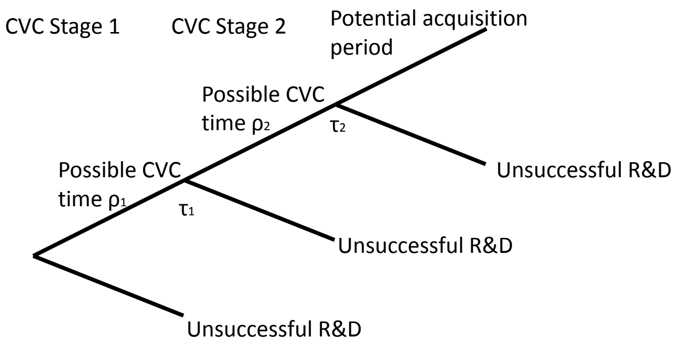

Figure 1: *Model timeline.*

We capture the relation between $\bar{\theta}$ and θ_{it} through a constant elasticity of substitution (CES) specification:

$$\gamma_i(\bar{\theta}, \theta_{it}) = A \left[a\bar{\theta}^b + (1-a)q_i\theta_{it}\right]^{c/b} \tag{4}$$

where $q_i \in [0, 1]$ indicates the portion of the technology that can be used in the learning process and thus contributes to the firm's profit. The CES specification nests several interesting cases including linear function with perfect factor substitution, Leontief function with perfect complementarity and the Cobb-Douglas function.

If the startup successfully completes the innovation process, the firm has the option to acquire the firm. If the firm has already acquired a portion α

of the startup, the acquisition takes place by acquiring the rest of the shares at the present value of expected profits that would be generated using the new technology, denoted by $C(Q)$. Note that the firm has the option to not make any CVC investments but acquire the startup only after the innovation has been made. Figure 1 shows our model's timeline.

Before specifying the firm's problem, we introduce some additional notation. We let ρ_c and ρ_a denote the optimal CVC time and the optimal acquisition time after the technology has been developed, respectively. The stopping time τ_1 denote the passage times when the startup completes the early R&D stage. As the CVC can take place in the early R&D phase, $\rho_c \in [0, \tau_1]$ if CVC occurs, while $\rho_a \in [\tau_1, \tau_2]$, the maturity time where the technology is not expected to be further developed. Given these definitions, our firm chooses the investment times (ρ_c, ρ_a) that maximize:

$$\begin{aligned} V(\rho_c, \rho_a) = \mathbb{E}_0 \Bigg\{ \int_0^{\rho_c \wedge \tau_1} \pi(\bar{\theta}) e^{-rt} dt + \mathbb{I}_{\rho_c \leq \tau_1} e^{-r\rho_c} \left[V_{CVC} - \alpha I_1 \right] + \\ + \mathbb{I}_{\rho_c > \tau_1} \left[\int_{\tau_2}^{\rho_a} \pi(\bar{\theta}) e^{-rt} dt + e^{-r\rho_a} \left[V_{acq} - C(\theta) \right] \right] \Bigg\} \end{aligned} \quad (5)$$

The first line in equation (5) states that until the firm makes a CVC investment in the seed/early stage, it generates a profit flow given by $\pi(\bar{\theta})dt$. The second term in the first line shows the value of the firm net of the investment cost if the firm decides to invest in the startup. The second line captures the case in which the firm does not perform CVC in the early phase but acquires the startup upon the completion of the technology development.

The main tradeoff in the model is the following: on the one hand, if the firm invests in the initial stage of the CVC, it faces a higher technological uncertainty captured by the high probability of failure $1 - \lambda_1 dt$. This could lead the firm to lose the cost of acquiring the initial stake, αI_1. On the other hand, an earlier investment in the CVC would imply that the firm could start learning from the startup's project at an earlier date. This is captured by equation (4).

The value functions V_{CVC} and V_{acq} all have similar forms to the value function in equation (5). When the firm invests in the seed/early stage, its value is given by:

$$V_{CVC} = \mathbb{E}_{\rho_c} \left\{ \int_{\rho_c}^{\rho_a} \pi(\bar{\theta}, \theta_{1t}) e^{-rt} dt + e^{-r\rho_a} \left[V_{acq} - (1-\alpha) C(\theta) \right] \right\} \tag{6}$$

The value function when the firm acquires the startup in the mature R&D phase is given by:

$$V_{acq} = \mathbb{E}_{\rho_a} \left\{ \int_{\rho_a}^{\infty} \pi(\bar{\theta}, \theta_{\tau_1}) e^{-rt} dt \right\} \tag{7}$$

2.1 Problem resolution

The maximization problem formulated above can be solved by dividing it into sub-problems as follows. First, the acquisition option can be evaluated for two cases, depending on whether a CVC has occurred in phase 1 or not. At any moment in $[\tau_1, \tau_2]$, if the firm acquires the startup without any prior CVC, its net profit will be equal to the difference between the profit with the new technology, integrated on a long time horizon, and the profit with the initial technology, minus the acquisition cost. However, if a CVC has occurred before, the current technology is already enhanced but the acquisition cost is lower.

The values of these acquisition options at τ_1 are used for computing the CVC option value at the end of the CVC period τ_1. Indeed, when the firm takes the CVC decision, it has to integrate into its decision the impact of this CVC on the acquisition option. If the firm abandons the CVC, its profit at τ_1 is equal to the acquisition option value at τ_1 with no prior CVC. Otherwise, it pays the premium αI_1 and gets the value of the acquisition option with prior CVC.

We develop a dynamic programming algorithm that follows this reasoning in a discrete time system. The algorithm starts at τ_2 for the acquisition options, both with and without CVC, and evaluates the final decision (acquire or definitely abandon). It then moves backwards one step a time and evaluates the values of the immediate investment and the waiting decisions, based on the expected net profit, until reaching τ_1. Then starts the CVC option evaluation, taking as input the acquisition option value at τ_1.

3 Numerical application

This section aims at illustrating the main tradeoffs

We start by a simple case where the large firm takes a CVC decision at $t = 0$, does not undertake any action during the R&D phase, and then takes the acquisition decision starting from τ_2. We illustrate in Figure 2 the impact of the CVC decision at time $t = 0$ on the subsequent acquisition decision. The acquisition probability is drawn function of the technological potential of the target startup. This potential is related to the probabilities of increase of the technology efficiency of the underlying jump processes $p_1 \in [0, \tau_1]$ and $p_2 \in (\tau_1, \tau_2]$. We consider for illustration $p_2 = 5p_1$ and use p_1 as the technology potential indicator at the x-axis. The CVC corresponds here to a proportion

$\alpha = 0.3$ of the startup. Figure 2 illustrates two cases: a CVC performed at $t = 0$ for sure, and a no CVC strategy. We can see that a prior CVC makes the acquisition more profitable and thus increases its probability.

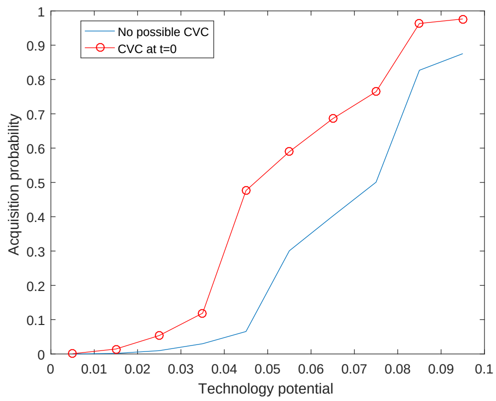

Figure 2: *Impact of an initial CVC decision on the acquisition.*

We now consider a more dynamic case, where the firm can undertake the CVC decision at any time between 0 and τ_1. Figure 3 illustrates the impact of the technological potential of the target startup on the probability of CVC and the probability of acquisition. Figure 3 shows that both CVC and acquisition probabilities increase when the startup has a larger technology potential, and that CVC is always more likely to occur than acquisition. Figure 4 considers the case where the startup may abandon the development of the technology if, at the end of the early R&D stage, the technology does not reach a certain maturity threshold. The results show that this abandoning option has a negative impact on the acquisition decision.

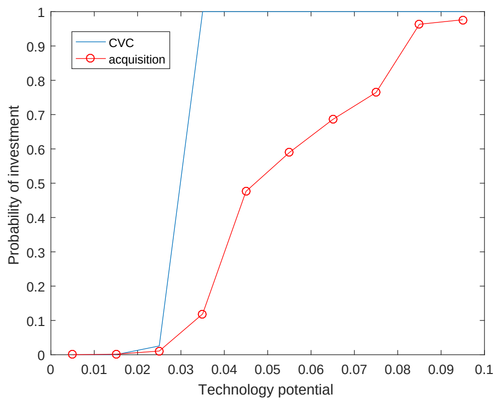

Figure 3: *Impact of the technology potential of the startup on the investment.*

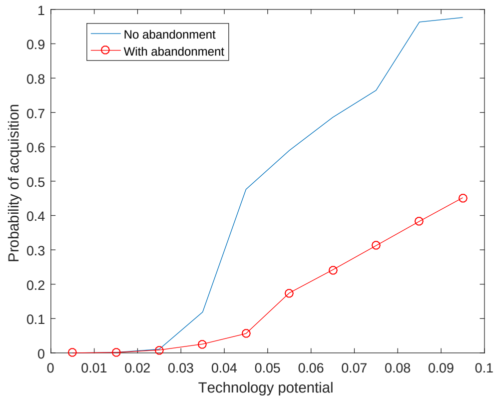

Figure 4: *Impact of the early R&D failure event.*

We now turn to the impact of the proportion α of the stratup acquired in case of CVC. Figure 5 shows the probability of acquisition function of α. It can be observed that the probability of acquisition is an increasing function of α. The Figure also illustrates the impact of early integration of technology, as it considers two cases: a case where the technology integration starts directly after the CVC, and the case where the firm integrates the technology only upon the final startup acquisition. An early technology integration clearly increases the option value.

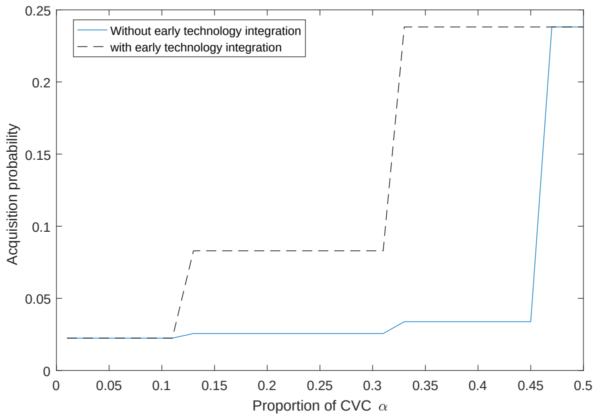

Figure 5: *Impact of α on the probability of acquisition.*

4 Conclusion

In this paper, we developed a real options framework for the analysis of CVC as a first step for the acquisition of small innovative firms by larger ones interested in their technology. We model the problem as a two-stage option where CVC occurs during the early technology development phase if the large firm detects an interesting technology development trend. This early investment allows a partial acquisition of the startup, thus lowering its cost upon an eventual acquisition, but also permits an early integration of the target technology. Our numerical results shows that a CVC increases the value of the acquisition option and increases the probability of acquisition. In our future work, we aim at incorporating the impact of competition on the firm's decision.

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