Moral Hazard in VC Finance: More Expensive than You Thought

Julius Tennert[1], Marie Lambert[2], and Hans-Peter Burghof[1]

[1]University of Hohenheim
[2]HEC Management School, University of Liege

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Abstract

Venture projects are fraught with exogenous market risk and endogenous agency risk. We apply a real options perspective to analyze the investment decision of the venture capitalist (VC) in this set-up. The solutions presented are conflictive: the VC reduces his exposure to exogenous risk by delaying investments to wait for informational updates (delay option), but he mitigates endogenous risk by advancing investments to discover entrepreneur's effort. So far, papers focus on the optimal timing of investments considering independence of exogenous and endogenous risk. We show that interdependence of exogenous risk and endogenous risk exists. We find that endogenous risk prompts the VC to accelerate the discovery process when exogenous risk is high, and to abandon the delay option when it is most valuable.

Keywords: Venture Capital; Real Option; Agency Cost; Moral Hazard

JEL classification: G11; G12; G24; D53

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1 Introduction

Venture firms operate in highly dynamic markets, where future market conditions are particularly uncertain and can change very fast. In this environment, the venture capitalist (VC) has to cope with two tasks: he has to manage his investment risk with respect to market uncertainty, and he has to manage the project with respect to agency conflicts. The market uncertainty describes exogenous risk that impacts the prospects of the venture project, such as technological progress within the industry, trending consumer behavior or competitor's response to new products and services. It is out of the control of the VC or the entrepreneur, making the venture project basically a bet on future market conditions. The agency conflicts between the VC and the entrepreneur describe endogenous risk that impacts the successful realization of the project, such as uncertainty about the effort of the entrepreneur.

In this set-up, we analyze the investment decision of the VC in a real options framework. Real options describe future decision rights, rights but not obligations to take some action in the future. This provides a decision maker flexibility to act upon informational updates (Dixit & Pindyck, 1994; McDonald & Siegel, 1982; Trigeorgis, 1996). The real options theory suggest that investments are exposed to two types of risk: exogenous risk that is irreducible through organizational activity, and endogenous risk that can be substantially influenced by organizational activity (Folta, 1998; McGrath *et al.*, 2004).

By applying staged capital infusion, the VC creates future investment opportunities. Once he committed an initial investment to a venture project, he receives the right to participate in future financing rounds of the project. Furthermore, the VC decides whether to immediately commit funds to advance the development of the project, or to defer investments to slow down the sped of development.

On the one hand, the VC can reduce his exposer to exogenous risk by deferring investments to wait for informational updates about the future market conditions: if market conditions turn out to be favorable, he commits additional funds to capitalize on the growth prospects of the project. Conversely, if market conditions turn out to be bad, he abandons the project to confine high downside losses (Li, 2008). On the other hand, the VC mitigates endogenous risk by learning about the behavior of the entrepreneur (Chi & McGuire, 1996): by investing the VC observes the performance of the project and aggregates beliefs about the effort of the entrepreneur.

The solutions presented to exogenous and endogenous risk are conflictive: with respect to exogenous risk, the VC defers investments to confine downside losses. With respect to endogenous risk, the VC advances investments to discover the effort of the entrepreneur. So far, papers focus on the optimal timing of investments considering independence of exogenous and endogenous risk (Li, 2008; Gompers, 1995; Neher, 1999; Bergemann & Hege, 1998). Interdependence of exogenous and endogenous risk is not yet considered. We assume that this interdependence exists. The reason is as follows: entrepreneurs will have motivation to expend their effort if future market conditions are seemingly favorable and prospects of the venture firm are high, but their motivation might decrease if expectations about future market conditions change and depress the firm's prospects. The interdependence of exogenous and endogenous risk refers to the idea of a relative value of private benefits. In periods of high market uncertainty, the entrepreneur's expected payoff from the project is downgraded. Private benefits from managing the firm become more attractive to the entrepreneur relative to the successful realization of the project. As a consequence, his incentive to behave opportunistically increases.

We introduce a formal model to show how agency conflicts tighten in a world of uncertainty and analyze the resulting decision making of the VC. To manage agency conflicts in times of high market risk, the VC has to accelerate investments to advance the learning process. As a consequence, he suffers opportunity loss because he abandons the delay option when it is most valuable. We find empirical support for our theory. We analyze a sample of individual European VC funding from 2003 - 2015. The joint effect of time-serial market risk and cross-sectional agency risk accelerates investments to venture projects.

The remainder proceeds as follows: section 2 gives an overview of the related literature, in section 3 we introduce a formal model to analyze the decision making of the VC, in section 4 we test the implications from the formal model empirically and conduct robustness checks, section 5 concludes.

2 Related Literature

In a set-up with exogenous and endogenous risk, the VC's funding decision can be analyzed in a real options framework (Hsu, 2010; Li, 2008). Real options are future decision rights, rights but not obligations to take some action in the future. Future decision rights offer a decision maker flexibility to act upon informational updates (Dixit & Pindyck, 1994; McDonald & Siegel, 1982; Trigeorgis, 1996). In the real world, decisions are not static. E.g., a decision maker can defer the initiation of a project to wait for additional information about future market condition, once started the project he can abandon it at any given stage of development if environmental conditions turn bad, and he has the option to expand the project if environmental conditions turn out to be more positive than expected (Trigeorgis, 1996). In venture finance, VCs use stage financing to create future investment opportunities. Once he committed an initial investment to a venture project, he usually receives the right to participate in future financing rounds (Li, 2008). Furthermore, this gives the VC the opportunity whether to concentrate funds in early stages of the project or defer investments shifting them to later stages. This decision is based on the information available and the information gathering process.

Exogenous risk in venture projects is related to unexpected market developments, e.g. technological progress within the industry, trending consumer behavior or competitor's response to new products and services that depress the project's expected value (Li, 2008). Exogenous risk is is out of the control of a decision maker and resolves primarily with the passage of time (McGrath, 1997; Pindyck, 1993; Dixit & Pindyck, 1994). In this case, the timing of investments can be seen as decision whether to hold the current option to invest and wait for informational updates about the market conditions or to invest immediately and capitalize on the information available (delay option) (Li, 2008). If market conditions turn out to be favorable, the VC commits additional funds to earn a high return. Conversely, if market conditions turn out to be bad, he abandons the project to confine high downside losses (Li, 2008). If uncertainty about future market conditions is high, the option to wait for informational updates is economically more valuable than immediate investment (Dixit & Pindyck, 1994; McDonald & Siegel, 1982; Trigeorgis, 1996). Recent research shows that VCs delay the initiating and continuation of venture projects when market uncertainty is particular severe (Li, 2008; Li & Mahoney, 2011).

Endogenous risk in venture projects is related to agency conflicts between the VC and the entrepreneur. The entrepreneur inhibits the role of a contracting agent and owns human capital, such as specific skills or knowledge, essential to realize the venture project (Hart & Moore, 1994). Furthermore, venture project's are characterized through a high fraction of intangible assets and growth opportunities giving great discretion to the action of the entrepreneur (Amit *et al.*, 1998; Bergemann & Hege, 1998; Cornelli & Yosha, 2003; Burchardt *et al.*, 2014; Gompers, 1995; Neher, 1999). He might be unwilling to expend effort to maximize shareholder's value (Gompers, 1995; Chan *et al.*, 1990; Hansen, 1992), or be willing to extract informational rents from information asymmetries (Aghion & Bolton, 1992; Hellmann, 1998; Kirilenko, 2001).
When risk can be substantially influenced by organizational activity, the VC can reduce his exposer by learning (Chi & McGuire, 1996): by investing the VC observes the performance of the project and aggregate beliefs about the effort of the entrepreneur. To avoid an inefficient continuation of the venture project, the VC implements various mechanisms like contingent control allocation (Chan *et al.*, 1990; Kirilenko, 2001), convertible securities (Casamatta, 2003; Cornelli & Yosha, 2003; Repullo & Suarez, 2004; Schmidt, 2003), and staging (Bergemann & Hege, 1998; Neher, 1999).
We argue that investing is always possible. Hence, in a world of uncertainty, the option to delay investments is economically more valuable than investing. Any characteristics of the project that force the VC to abandon the delay option must arise opportunity loss.

3 Formal Model

3.1 The Venture Project

We describe a venture project as a one-shot (static) problem. A financially constrained entrepreneur E owns a project with uncertain returns. The project is financed by a venture capitalist VC. E provides effort ε, with $\varepsilon = \{0, 1\}$. The effort of the entrepreneur is a critical resource for the success of the firm. Physical assets purchased have no value to the VC without the effort of the entrepreneur (Hart & Moore, 1994). The VC and the E are considered to be risk-neutral. The VC provides the total investment in equity financing only. The VC and E agree on a sharing contract in $t = 0$. The sharing contract defines the entrepreneur's share S_E of the project's payoff and the timing of the investments. The project requires a total investment I to be completed. The VC follows an investment path $i_0, ..., i_T$ to provide funds. The investment path gives the VC the opportunity to time his investments. The funding is completed at time T with $0 \leq T \leq 1$ and $I_T = I = \sum_0^T i_t$. Investments are sunk once committed to the project. Time is standardized to the interval $[0, 1]$. The discount rate is $d = 0$.
In $t = 1$, an exogenous stochastic shock π is realized with probability $(1 - p)$, with $p \in [0, 1]$. Probability $(1 - p)$ is related to the level of exogenous risk and is ex-ante known by the E and the VC. The project is valueless if the shock is realized, otherwise the project generates the payoff $V(\varepsilon)$. The project's value follows a Bernoulli distribution

$$V(\varepsilon) = \begin{cases} 0 & \text{w. Pr. } (1 - p) \\ V(\varepsilon) & \text{w. Pr. } p \end{cases} \tag{1}$$

with $V(1) > 0$ and $V(0) = 0$. In other words, the E has to expend effort to realize the project.
Probability $(1 - p)$ is out of the control of the E and the VC, and resolves with the passage of time. There is a confidence level $\theta_\pi(T)$ at time T that π is realized in $t = 1$. It describes the aggregation of beliefs about the future market conditions over time. $\theta_\pi(T)$ is based on the square-root-of-time rule. The rule allows higher frequency risk estimates to be scaled down to a lower frequency. It is commonly used when financial risk is time aggregated. The confidence level $\theta_\pi(T)$ is

$$\theta_\pi(T) = T^{0.5} \tag{2}$$

3.2 Maximization Function of the Venture Capitalist

Exogenous risk $(1-p)$ constrains the project's expected payoff. I_0 is a non-arbitrary staging path of the VC that immediately invests I in $t=0$. The VC's expected payoff $P(0)^{VC}$ is

$$P(0)^{VC} = -I_0 + (1-S_E)pV(\varepsilon) \tag{3}$$

Over time, the VC becomes more confident about the exogenous stochastic shock π being realized in $t=1$. I_1 is a non-arbitrary investment path, where the investment process is completed in $t=1$. To show the impact of delaying investments, we simplify the staging path I_1 to the situation where the VC invest I in $t=1$. Hence, the total investment is delayed until uncertainty about the realization of the shock is revealed. The VC only invests if π is not realized. The expected payoff $P(1)^{VC}$ is

$$P(1)^{VC} = (-I_1 + (1-S_E)V(\varepsilon))p \tag{4}$$

The staging path provides the VC the option to delay investments until he is more confident about the realization of the exogenous stochastic shock. The economic value of this delay option $D(T)$ is positively related to the probability $(1-p)$, and delay $T>0$.

$$D(T) = P(T)^{VC} - P(0)^{VC} \tag{5}$$

$$= \theta_\pi(T)[-I(p-1)] \tag{6}$$

The VC maximizes his total payoff $P(T)^{VC}$

$$P(T)^{VC} = \underset{T}{\operatorname{argmax}}\{(1-S_E)pV(\varepsilon) - I + \theta_\pi(T)[-I(p-1)]\} \tag{7}$$

3.3 Participation Constraint of the Entrepreneur

E chooses between the two effort levels $\varepsilon=1$, and $\varepsilon=0$. If E expend effort $(\varepsilon=1)$, he can realize $V(1)$ with probability p. Since E does not provide funds, the delay of investments has no economic value to him. His expected payoff $P(t,\varepsilon)^E$ is $P(1,\varepsilon)^E = P(0,\varepsilon)^E = P(\varepsilon)^E$, where $P(1,\varepsilon)^E$ specifies the case when the VC invests I in $t=1$ and $P(0,\varepsilon)^E$ specifies the case when the VC invests I in $t=0$.

Since tasks of the entrepreneur are highly interdependent and can not be monitored

accurately, his effort level ε can not be observed directly. The VC discovers the effort of the entrepreneur by aggregating beliefs conditional on the performance of the project. The discovery process is characterized by some imprecision α, with $\alpha \in [0, 1]$. Imprecision α is equal to zero if the effort of the entrepreneur and the performance of the firm are perfectly correlated. Conversely, if the effort of the entrepreneur and the performance of the firm are not perfectly correlated, it is $\alpha > 0$. This describes the level of project's endogenous risk. Endogenous risk differs across projects and is related to the discretion project's assets provide to the action of the E, e.g. when tasks of the entrepreneur are highly interdependent, observing the performance of the project will provide only little information about his true effort (Zenger, 1994).
In that, α defines a certain fraction of the investment I that E can divert for private use if he choose $\varepsilon = 0$. Choosing $\varepsilon = 0$, E degrades the project in T and earns imprecision cost C. It describes his dis-utility of effort.
Given imprecision, the VC has to discover the effort ε in an endogenous process to efficiently reduce agency risk: he updates his expectation about E's effort ε conditional on the performance of the project. A bad performance indicates $\varepsilon = 0$. The performance of the project is observed when it is continued; and funds are required to purchase assets to continue the project. In that, the discovery process is controlled by the VC conditional on the rate of investments. A high investment rate (small T) allows the VC to observe the performance of the project early and to discover entrepreneur's true effort ε sooner. By investing, the VC implements a set of binding provisions to reduce agency conflicts and confine imprecision cost. Hence, imprecision cost C is conditional on the rate of investments.

$$C = \alpha I T \tag{8}$$

Hellmann (1998) predicts that the more wealth constrained the entrepreneur is, the more likely is investor control. Furthermore, Kaplan & Stromberg (2003) show that VC's control rights are allocated such that the VCs obtain full control if the venture project performs poorly. If the VC discovers true effort $\varepsilon = 0$ in T, the VC gains full control over the project to punish E. In this case, E can not divert funds for private use. But, since the VC can not realize the project without E, payoff $P(T)^{VC}$ is zero as well. E maximizes

$$P(\varepsilon)^E = \underset{\varepsilon}{\operatorname{argmax}} \{s_E p V(\varepsilon) - C\} \tag{9}$$

The entrepreneur will choose $\varepsilon = 0$ if

$$C > s_E pV(\varepsilon) \tag{10}$$

$$\frac{C}{s_E pV(\varepsilon)} > 1 \tag{11}$$

The ratio describes the relative value of private benefits. This is the amount of funds diverted for private use (E chooses $\varepsilon = 0$), relative to the payoff from the project (E chooses $\varepsilon = 1$). E's incentive to behave opportunistically (to chooses $\varepsilon = 0$), is positively related to probability $(1 - p)$ that the exogenous shock π occurs, and the level of imprecision α. The entrepreneur is indifferent between $\varepsilon = 1$ and $\varepsilon = 0$ when his expected payoff from the project equals imprecision cost C. The participation constraint $P.C.^E$ that incentivizes E to chose $\varepsilon = 1$ is

$$s_E pV(1) \geq C \tag{12}$$

$$s_E pV(1) - \alpha It \geq 0 \tag{13}$$

3.4 Solution without Imprecision

In the first best case, there is no imprecision. By definition this is $\alpha = 0$ and there is no imprecision cost.

$$C = \alpha IT = 0 \tag{14}$$

Inserting $C = 0$ into the participation constraint of the entrepreneur $P.C.^E$, the minimum payoff $P(1)^E$ to incentivize E to choose$\varepsilon = 1$ is

$$P(1)^{E^{**}} = 0 \tag{15}$$

The E earns no surplus over his cost of capital. The VC maximizes $P(T)^{VC}$. T^{**} and S_E^{**} is

$$T^{**} = 1 \tag{16}$$

$$S_E^{**} = 0 \tag{17}$$

The payoff to the VC is

$$P(T^{**})^{VC} = [-I + V(1)]p \tag{18}$$

The VC earns all the payoff from the project and the total value of the delay option.

3.5 Solution with Imprecision

In the second best case, imprecision exists. By definition this is $\alpha > 0$. The effort of the E is not perfectly correlated with the observed performance of the project. For $T > 0$ imprecision cost C arise. The VC has to vest share S_E of project's payoff to E to incentivize him to choose $\varepsilon = 1$. With respect to the participation constraint of the entrepreneur $P.C.^E$, S_E is

$$P.C.^E : s_E pV(1) = \alpha IT \tag{19}$$

$$S_E = \frac{\alpha IT}{pV(1)} \tag{20}$$

For $I = 1$ and $V(1) = 1$, we maximize the payoff $P(T)^{VC}$ of the VC. T^* and S_E^* are

$$T^* = \frac{(p-1)^2}{4\alpha^2} \tag{21}$$

$$S_E^* = \frac{(p-1)^2}{4\alpha p} \tag{22}$$

Endogenous risk α and exogenous risk $(1-p)$ increase the share S_E vested to the entrepreneur and reduce the residuum share of the VC. The payoffs to the VC and the E are

$$P(T^*)^{VC} = (1 - S_E^*)pV(1) - I + \theta_\pi(T^*)[-I(p-1)] \tag{23}$$

$$P(1)^E = \alpha IT^* \tag{24}$$

The VC and E share the surplus from the project. The E earns the imprecision cost over his cost of capital. The VC receives the residuum payoff and the value of the delay option.

3.6 Opportunity Loss from Imprecision

In a world of uncertainty $(1-p) > 0$, the option to delay investments is economically more valuable than immediate investing. This is shown in (6): the value of delay option $D(T)$ is positively related to the probability $(1-p)$ that the exogenous shock is realized. Since delay T^* is negatively related to the level of imprecision α, agency risk forces the VC to advance investments. If $(1-p)$ is high, this must arise opportunity loss. Opportunity loss is present if $D(T) < D(1)$. In the first best solution, the VC invests I in $t = 1$ and realizes $D(1)$. There is no opportunity loss. In the second best solution, the VC maximizes his payoff $P(T)^{VC}$ with respect to the participation constraint of the entrepreneur $P.C.^E$. For $T > 0$ imprecision cost C arise. For $C > 0$, the VC has to vest share $S_E > 0$ to E, to incentivize him to choose $\varepsilon = 1$. The VC will benefit from deferring investments as long as the marginal profits from the delay option exceed the marginal compensation of E.

$$\frac{\partial P(0)^{VC}}{\partial t} + \frac{\partial D(T)}{\partial t} < \frac{\partial P(1)^E}{\partial t} \tag{25}$$

$$\frac{\partial([1 - \frac{\alpha T}{pV(1)}]pV(1) - I + T^{0.5}[-I(p-1)])}{\partial t} < \frac{\frac{\alpha T}{pV(1)}pV(1)}{\partial t} \tag{26}$$

For $I = 1$ and $V(1) = 1$,

$$-\alpha - \frac{(p-1)}{2T^{0.5}} < \alpha \tag{27}$$

The VC realizes the total value of the delay option if $T = 1$. For $T = 1$, (27) is

$$\alpha^* < \frac{(1-p)}{4} \tag{28}$$

The result shows the critical level of imprecision α^* at which the VC realizes the total value of the delay option $D(1)$. Formula (28) demonstrates that the critical level of imprecision α^* is multiplicative with respect to the probability $(1-p)$.

In table 1 and figure 1, we give a numerical example to illustrate the impact of exogenous and endogenous risk on VC's optimal timing of investments T^*. For $(1-p) > 0$ and $T^* < 1$ opportunity loss arise. We present the resulting opportunity loss $D(1) - D(T^*)$ in table 1 and figure 2. For any level of endogenous risk α, opportunity loss decreases in exogenous risk $(1-p)$. This means that the VC defers investments to capitalize on informational updates if exogenous risk is high. Conversely, for any level of exogenous risk $(1-p)$, opportunity loss increases in the level of endogenous risk α. This means that the VC accelerates investments and abandons a fraction of the delay option to initiate the discovery of entrepreneur's effort if endogenous risk is high. In that, endogenous risk restricts the value of the delay option.

The VC accelerates the discovery of entrepreneur's effort in exogenous risk $(1-p)$.

This is because the relative value of entrepreneur's private benefit $\frac{C}{s_E p V(\varepsilon)}$ increases in exogenous risk, increasing his incentive to behave opportunistically. As a consequence, the VC has to abandon a larger proportion of the delay option when it is most valuable. This accelerates his opportunity loss. We derive three testable hypotheses:

Hypothesis 1: VCs delay investments if exogenous market risk is high.

Hypothesis 2: VCs advance investments if endogenous agency risk is high.

Hypothesis 3: VCs accelerate investments if exogenous market risk and endogenous agency risk are high.

Table 1: Numerical Illustration

		T*					D(1)-D(T*)				
				α					α		
		0.4	*0.45*	*0.5*	*0.55*	*0.6*	*0.4*	*0.45*	*0.5*	*0.55*	*0.6*
	0.75	0.879	0.694	0.563	0.465	0.391	0.047	0.125	0.188	0.239	0.281
	0.7	0.766	0.605	0.490	0.405	0.340	0.088	0.156	0.210	0.255	0.292
$(1-p)$	*0.65*	0.660	0.522	0.423	0.349	0.293	0.122	0.181	0.228	0.266	0.298
	0.6	0.563	0.444	0.360	0.298	0.250	0.150	0.200	0.240	0.273	0.300
	0.55	0.473	0.373	0.303	0.250	0.210	0.172	0.214	0.248	0.275	0.298

We illustrate the optimal timing of the investment as a function of the delay of investments T^* in Fig. 1, and the resulting opportunity loss $D(1) - D(T^*)$ in Fig. 2; for $\alpha \in [0.4, 0.6]$; $(1-p) \in [0.55, 0.75]$.

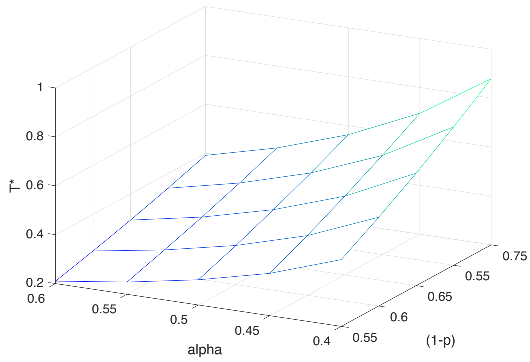

Figure 1: Delay T^*

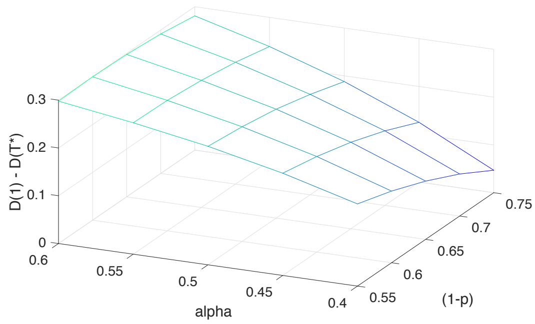

Figure 2: Opportunity Loss $D(1) - D(T^*)$

4 Empirical Approach

4.1 Data

Our sample covers individual financing rounds from venture projects based in 15 European countries[1] for the period from 2003/01/01 to 2015/12/31 from Dow Jones Venture Source. The sample period covers the post-dotcom bubble period and the financial crisis of 2007. Furthermore, the sample period covers the European sovereign debt-crisis in 2009 that came along with an expansive monetary policy of the European Central Bank.

We exclude venture firms from the energy and utilities sector. Energy-related infrastructure projects, and renewable energy production was strongly supported and highly regulated by the European Union within the sample period.

We use sector classifications provided by Dow Jones Venture Source. Sector classifications are matched to the GICS (Global Industry Classification Standard) classification scheme based on industry descriptions. We aggregate industries' end-of-the-year business ratios of listed firms from Compustat global.

4.2 Econometric Method

We analyze the the duration of a financing round. This is defined as the time between the completion of two subsequent financing rounds. An increasing duration characterizes a delay of investments. Conversely, a decreasing duration characterizes an advancement of investments (Gompers, 1995; Li, 2008).

We use a difference-in-difference approach to analyze the joint effect of exogenous and endogenous risk on the duration of the financing round. The method allows us to separately estimate a time-series effect of exogenous risk, a cross-sectional effect of endogenous risk, and a joint effect of exogenous and endogenous risk.

We use an accelerated-failure time model to fit information about the duration into a parametric regression model. We model duration by the survival time of the financing round. Failure is the completion of the round. The censoring date is the date of the initial public offering, acquisition or bankruptcy. Ongoing investments are censored after five years (1825 days). To follow each event for five years, we restrict our analysis

[1] Belgium, Austria, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, United Kingdom, Denmark, Finland, Sweden

to financing events that took place between 2003/01/01 and 2010/12/31. This leaves us with 7,336 observations.
The survival function $S(t)$ is the probability that a financing round is completed later than t

$$S(t) = P(T > t)$$

The failure time is modeled by a linear effect composed of the covariates and a random disturbance term ϵ. ϵ is a vector of errors assumed to come from a known distribution and σ is an unknown scale parameter. We fit the model to the natural logarithm of the duration and Weilbull distribution of the error term. The model fits the paper's focus on the timing of investments since the estimation parameters in the accelerated failure time model can be interpreted as the influence of the explanatory variables on the failure time. This model is commonly used in duration studies (Gompers, 1995; Li, 2008). The parameters are estimated by maximum likelihood method with a Newton-Raphson algorithm. The standard errors of the parameter estimates are estimated from the inverse of the observed information matrix. The model is

$$\begin{aligned} Log(Duration) = \alpha &+ \gamma_t(Exogenous_t) + \beta_i(Endogenous_i) \\ &+ \delta_{t,i}(Exogenous_t{}^{*}Endogenous_i) \\ &+ \zeta_i(Controls_i) + \sigma\epsilon_{t,i} \end{aligned}$$

where *Duration* is the duration of the financing round; $Exogenous_t$ is a time-series variable that captures exogenous market risk, γ_t estimates the time-series effect of exogenous market risk on the duration of the financing round. $Endogenous_i$ is a vector of cross-sectional variables that captures firm's exposure to endogenous agency risk. β_i estimates the cross-sectional effect of endogenous agency risk on the duration of the financing round. $\delta_{t,i}$ is the joint effect of exogenous and endogenous risk on the duration of the financing round. $Controls_i$ is a vector of individual control variables, ζ_i is the vector of its estimation parameters.

4.3 Measures

4.3.1 Exogenous Risk

Exogenous market risk is related to unexpected market developments that are out of the control of the entrepreneur and the VC (Li, 2008; McGrath, 1997; Pindyck, 1993;

Dixit & Pindyck, 1994). We relate exogenous risk to market price volatility. It captures the level of accumulated market uncertainty (Cochrane, 2005). VCs delay investments to ongoing projects and the initiation of new projects if the aggregate market volatility is high (Li, 2008, Li & Mahoney 2011). We use the level of the Euro Stoxx 50 Volatility Index (VStoxx 50) at the funding date to measure exogenous risk. The index is based on Euro Stoxx 50 options prices and reflects the one year ahead market expectation of volatility.

4.3.2 Endogenous Risk

We relate endogenous agency risk to tasks of a start-up entrepreneur in developing an innovative product, and scaling the venture firm. First, tasks in developing an innovative product are highly interdependent (Bishop, 1987), e.g technological process might accelerate or constrain the speed of developing an innovative product. The early performance of the project is conditional on technological process in that the entrepreneur reaches milestones faster if the technological environment is favorable. From the perspective of the VC, it is difficult to discover whether a good performance is solely up-on the effort of the entrepreneur or results from a favorable technological environment. This is especially the case for tasks where the entrepreneur has to expend primarily cognitive effort, because entrepreneur's true cognitive effort can not be discovered by observing his actions (Zenger, 1994). When the correlation of entrepreneur's true effort and the performance of the firm is highly imprecise, the VC has to advance the development of the firm to aggregate beliefs about entrepreneur's true effort. As a consequence, agency risk is high if the project requires substantial cognitive effort to develop a new innovative product. We relate the effort required to develop an innovative product to the R&D intensity of the industry. The development will require substantially more effort of the entrepreneur if the industry is R&D intense. VCs advance investments to ongoing projects if they operate in R&D intense industries (Gompers, 1995; Li, 2008). We measure R&D intensity by industry's median R&D-expenditures-to-sales ratio at previous year's end (Gompers, 1995; Li, 2008).

Second, scaling the venture firm is related to the realization of growth opportunities. But, from the perspective of the VC, it is difficult to discover whether a favorable performance, e.g. increasing sales volumes, results from high effort of the entrepreneur or are due to a favorable growth environment. This is especially the case, because growth opportunities provide the entrepreneur the chance to manipulate the growth signal revealed to the VC (Cornelli & Yosha, 2003). E.g. the entrepreneur might engage in short term sales activities to reveal a more positive signal to the VC without increasing his true (long-term) sales effort. When the performance revealed to the VC is manipulated in such a way, the correlation of entrepreneur's true effort and the observed performance of the firm is highly imprecise. The VC has to advance the development of the firm to aggregate beliefs about entrepreneur's true effort. Agency risk is high if the the venture project implies strong growth opportunities. Firm's growth opportunities are substantially larger if the industry is characterized by strong growth opportunities. VCs advance investments to ongoing projects if they operate in an industry characterized by high growth opportunities (Gompers, 1995; Li, 2008). Strong growth opportunities are signaled by a high market-to-book ratio (Chan & Chen, 1991). We measure growth opportunities by industry's median market-to-book ratio at previous year's end (Gompers, 1995; Li, 2008).

4.3.3 Contract Design

The financing instrument defines whether the VC is more actively involved in the operations of the project or inherits a passive role. By equity investments the VC receives power in the board of directors. This provides him the opportunity to monitor endogenous performance and approve significant decisions. It possesses strong governance abilities when compared to debt instruments in that it emphasizes behavior control of the entrepreneur (Fama & Jensen, 1983). This reduce exposure to endogenous risk and might encourage the VC to take rather advantage of the delay option than to advance the discovery process. We classify debt-like and an equity-like instruments. We assume pure debt and convertible debt to posses the characteristics of a debt instrument, whereas equity swaps and pure equity posses the characteristics of an equity instrument.

Small funding amounts limit opportunistic behavior of the entrepreneur in that they reduce the bargaining power of the entrepreneur (Neher, 1999). A small funding amount will prevent the investor's claim from a bid down. This reduce exposure to endogenous risk and might encourage the VC to take advantage of the delay option.

VCs syndicate to obtain a second opinion about the quality of the entrepreneurial project in the pre-investment phase and to provide improved value-adding in the investment phase (Lerner, 1994; Brander *et al.*, 2002). Moreover, those tasks are not independent from each other as an efficient selection of the project increase the effectiveness of the VC's involvement (Casamatta & Haritchabalet, 2007). VCs that syndicate their investment will perform more efficiently allowing them to implement monitoring and control mechanisms at lower cost. This allows the syndicate to implement closer monitoring and control activities. We classify deals with two or more investors involved as syndicated investments.

4.3.4 Firm-specific Information

Firm-specific information such as financial statements and interviews with employees reveal the entrepreneur's management ability, its motivation and effort. The availability of such type of information is linked to project's age (Amit *et al.*, 1998). It acts as a track-record of entrepreneur's past activities. When uncertainty about the entrepreneur's type is reduced, imprecise contracting diminishes. The VC can take advantage of the delay option instead of initiating a discovery process. We calculate project's age counting the days between the start date of the project and the date of the financing event.

Moreover, venture projects differ in quality. The VC gathers this information in the screening process (Casamatta & Haritchabalet, 2007; Sahlman, 1990). But, the screening process is exposed to adverse selection concerns. Higher quality projects have a more urgent need for capital to finance their future growth (Li, 2008). As a consequence, entrepreneurs initiating low quality projects have incentive to imitate higher quality projects to increase their funding. Hence, staging is more important for projects that pretend to be of high quality; since staged financing rejects low promising firms (Sahlman, 1990). By controlling for the quality of the project, we separate adverse selection risk and moral hazard risk, that is the concerns about a misrepresentation of project's quality and the concerns about the true effort of the entrepreneur. Moreover, effort of the entrepreneur is necessary but not sufficient for the success of the firm: even high quality projects will not succeed without entrepreneur's effort; however, even if the entrepreneur expend high effort to a low quality project, it will not succeed. We measure quality by an ex-post indicator of success, which is an exit of the firm (Gompers, 1995; Li, 2008; Brander *et al.*, 2002; Gompers & Lerner, 2000; Sorenson & Stuart, 2001). We use information about an exit of the firm based on the information available on Venture Source at the date of data generation. We classify projects that had an IPO or tradesale as high quality projects.

4.3.5 Environmental Conditions

VCs adjust their investments according to market signals such as the general boom and bust cycles of the public equity markets, and economic growth. We control for total VC funding in the previous year which is positively related to good funding conditions (Gompers *et al.*, 2008; Cherif & Gazdar, 2011; Félix *et al.*, 2013).
Favorable institutional environments such as a strong corporate governance and investor protection increase the power to mitigate agency conflicts (Cumming *et al.*, 2010; Jeng & Wells, 2000). We control for the home country of the venture firm to address the impact of different institutional environments.
At least, we control for venture firm's industry sector to account for unobserved sector-specific fixed effects.

4.4 Empirical Results

In our sample, the average duration of a financing round is 593 days, approximately 19.5 months. Table 2 presents descriptive statistics and correlations of the variables. None of the correlations are sources of concern for multi-collinearity.
To apply the difference-in-difference approach, we identify firms fraught with endogenous risk based on industries' R&D-to-sales ratio and market-to-book ratio; and financing rounds exposed to exogenous risk based on the aggregate level of market price volatility at the funding date. We use log rank test statistic to estimate break-point values of the variables. For any R&D-expenditures-to-sales ratio, market-to-book ratio, or level of the VStoxx 50 Index above the break-point value, we assign the project, resp. the financing round to be exposed to endogenous, resp. exogenous risk. We apply the method of Contal & O'Quigley (1999) to estimate the break-piont values. The method is an outcome-oriented approach to compute break-point values corresponding on its most significant relation with the outcome, and is designed for survival analysis with censored data. We compare our break-point values to median values in Table 3. The break-point value of the R&D-expenditures-to-sales ratio is higher than its median value. The higher break-point value indicates that only high levels of R&D intensity increase endogenous risk. The break-point value for market-to-book ratio equals its median value. The break-point value for the VStoxx 50 Index is lower than its median value. The lower break-point value indicates that even low levels of exogenous risk provide the VC an opportunity to take advantage of the delay option.

We show the results from the duration analysis in Table 4. Estimation (1) is the baseline model that includes the control variables. We find that VCs adjust the timing of investments according to the contract design, the availability of firm-specific information, and environmental conditions. Estimations (2) to (6) add information about exogenous and endogenous risk. The new information does not change the impact of the control variables.

The first hypothesis states that VCs delay subsequent investments to wait for informational updates about the market conditions when exogenous risk is high. We include the dummy variable *Market Uncertainty* in estimations (2), (4), (5) to analyze the impact of exogenous risk on the duration of the financing round. *Market Uncertainty* is equal to one if the VStoxx 50 Index is above the break-point value, and zero otherwise. We find that VCs defer investments with respect to exogenous risk. In estimation (2), we model the duration based on the control variables and *Market Uncertainty*. *Market Uncertainty* increases the duration by approximately two months. This corresponds to 9% of the average duration of a financing round. In estimation (4), we add information about project's endogenous risk. The impact of the variable *Market Uncertainty* remains unchanged. In estimation (5), we consider interdependence of exogenous and endogenous risk. The impact of the variable *Market Uncertainty* increases compared to estimations (2) and (4); in estimation (5) *Market Uncertainty* increases the duration by approximately three months. This corresponds to 14% of the average duration of a financing round. We explain this observation by a high value of the delay option. Considering interdependence of exogenous and endogenous risk, we find that the impact of *Market Uncertainty* increases. This indicates that endogenous risk restricts the delay of investments.

The second hypothesis states that VCs advance subsequent investments to advance the discovery process when endogenous risk is high. We include the dummy variables *R&D Intensity* and *Growth Opportunities* in estimations (3), (4), (5) to analyze the impact of endogenous risk on the duration of financing events. *R&D Intensity*, resp. *Growth Opportunities* is equal to one if industries' R&D-to-sales ratio, resp. market-to-book ratio is above the break-point value, and zero otherwise. We find that VCs advance investments with respect to endogenous risk. In estimation (3), we model the duration based on the control variables and *R&D Intensity* and *Growth Opportunities*. *R&D Intensity* decreases the duration by approximately two and a half months. This corresponds to 13% of the average duration of a financing round. *Growth Opportunities* does not impact the duration. In estimation (4), we add information about exogenous risk at the funding date. The impact of the variables remains unchanged. When interdependence of exogenous and endogenous risk is considered in estimation (5), the impact of the variable *R&D intensity* slightly increases compared to estimations (3) and (4); in estimation (5) *R&D Intensity* decreases the duration by approximately three months. This corresponds to 14% of the average duration of a financing round. *Growth Opportunities* increase the duration for low exogenous risk, but decrease duration for high exogenous risk. We explain the results by the initiation of a discovery process.

The third hypothesis states that VCs accelerate subsequent investments when exogenous and endogenous risk are high. In estimation (5), we consider interdependence of exogenous and endogenous risk by an interaction term of *Market Uncertainty*, and *R&D Intensity*, resp. *Growth Opportunities*. The interaction terms are equal to one if *Market Uncertainty*, and *R&D intensity*, resp. *Growth Opportunities* are equal to one, and zero otherwise. We find that interaction of exogenous and endogenous risk accelerates investments. *Market Uncertainty* does not affect the duration of financing rounds differently with respect to *R&D Intensity*. *Market Uncertainty* does not accelerate investments to projects that are fraught with endogenous risk, when measured by industries *R&D Intensity*. But, *Market Uncertainty* affects the duration of financing rounds differently with respect to *Growth Opportunities*. *Market Uncertainty* accelerates investments to projects that are fraught with endogenous risk, when measured by industries *Growth Opportunities* by approximately two and a half months. This corresponds to 13% of the average duration of a financing round. We explain the result by an acceleration of the discovery process.

Table 2: Descriptive Statistics and Correlation Matrix

		Mean	Std.	Min	Max	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Internal Risk														
(a)	R&D-expenditures-to-sales	0.200	0.291	0.000	1.004									
(b)	Market-to-book	6.188	3.561	1.070	28.927	-0.002								
External Risk														
(c)	VStoxx	0.235	0.101	0.116	0.875	-0.022 *	-0.185 ***							
Contract Design														
(d)	Debt	0.099	0.299	0.000	1.000	0.583	0.424	0.893						
(e)	Funding Size (mio. e)	3.185	8.705	0.002	502.740	0.095 ***	-0.019	-0.003	-0.025 **					
(f)	Syndication	0.576	0.494	0.000	1.000	0.054 ***	0.020 *	-0.008	-0.083 ***	0.125 ***				
						0.000	0.080	0.502	0.000	0.000				
Endogenous Information														
(g)	Firm's Age (Days)	1871	1987	0	38130	0.008	-0.020 *	-0.006	0.066 ***	0.068 ***	-0.019			
(h)	IPO	0.060	0.238	0.000	1.000	0.141 ***	0.022 *	-0.004	0.002	0.108 ***	0.036 ***	0.066 ***		
(i)	Tradesale	0.266	0.442	0.000	1.000	-0.021 *	0.102 ***	-0.053 ***	0.051 ***	0.047 ***	0.067 ***	0.013	-0.152 ***	
						0.069	0.000	0.000	0.000	0.000	0.000	0.274	0.000	
Environmental Conditions														
(j)	Total VC Funding (mio. e)	3707	927	2671	5529	-0.014	-0.057 ***	0.461 ***	0.064 ***	-0.031 ***	-0.001	-0.013	0.006	0.045 ***

Table 3: Variable Break-points

We identify firms fraught with endogenous risk based on industries' R&D-to-sales ratio and market-to-book ratio; and financing rounds fraught with exogenous risk based on the aggregate level of market price volatility at the funding date. We apply the method of Contal & O'Quigley (1999) to dichotomize the variables and use log rank test statistic to estimate break-point values of the variables. For any R&D-expenditures-to-sales ratio, market-to-book ratio, or level of the VStoxx 50 Index above the break-point value, we assign the project, resp. the financing round to be exposed to endogenous, resp. exogenous risk. The method of Contal & O'Quigley (1999) is an outcome-oriented approach to compute break-point values corresponding on its most significant relation with the outcome, and is designed for survival analysis with censored data.

	R&D-expenditures-to-sales	Market-to-book	VStoxx 50
Median	0.071	5.573	21.160
Break-point (Contal and O'Quigley, 1999)	0.113	5.538	19.900

Table 4: Duration Analysis

Accelerated failure time model. Weibull distribution of the error term. Dependent: Duration of a financing round, defined as the time between two subsequent financing events. The model is fit to the natural logarithm of the duration. Independent: R&D Intensity is a dummy variable equal to 1 if venture firm's industry R&D-expenditures-to-sales ratio is above the Contal and O'Quigley (1999) break-point value, and zero otherwise. Growth Opportunities is a dummy variable equal to 1 if venture firm's industry market-to-book ratio ratio is above the Contal and O'Quigley (1999) break-point value, and zero otherwise. Market Uncertainty is a dummy variable equal to 1 if the VStoxx 50 Index is above the Contal and O'Quigley (1999) break-point value at the funding date, and zero otherwise. The interaction variables are equal to 1 if Market Uncertainty and R&D Intensity, resp. Growth Opportunities are equal to 1, and zero otherwise.
*** indicates significance at the 1% significance level, **indicates significance at the 5% significance level, * indicates significance at the 10% significance level. [a] indicates that the classification variables are significant at the 1% significance level based on type-3-effect analysis.

	(1)		(2)		(3)		(4)		(5)		(6)	
Intercept	11.354	***	13.100	***	11.286	***	12.894	***	12.678	***	8.699	***
	1.257		1.410		1.252		1.411		0.131		1.579	
Endogenous Risk												
R&D Intensity					-0.120	***	-0.113	***	-0.134	***	-0.096	**
					0.032		0.032		0.044		0.045	
Growth Opportunities					0.017		0.030		0.099	**	0.069	
					0.029		0.029		0.043		0.044	
Exogenous Risk												
Market Uncertainty			0.085	***			0.078	**	0.131	***	0.212	***
			0.030				0.030		0.043		0.045	
Joint Effect of Endogenous and Exogenous Risk												
Market Uncertainty*R&D Intensity									0.022		0.012	
									0.057		0.057	
Market Uncertainty*Growth Opportunities									-0.121	**	-0.119	**
									0.057		0.057	
Contract Design												
Debt	-0.489	***	-0.485	***	-0.481	***	-0.478	***	-0.478	***	-0.466	***
	0.042		0.042		0.042		0.042		0.042		0.042	
Log (Funding Size)	-0.018	*	-0.019	*	-0.017	*	-0.017	*	-0.017	*	-0.024	**
	0.010		0.010		0.010		0.010		0.010		0.010	
Syndication	-0.077	***	-0.076	***	-0.078	***	-0.077	***	-0.077	***	-0.072	**
	0.028		0.028		0.028		0.028		0.028		0.028	
Firm-specific Information												
Log (Firm's Age)	0.062	***	0.060	***	0.061	***	0.060	***	0.059	***	0.058	***
	0.009		0.009		0.009		0.009		0.009		0.009	
IPO	-1.019	***	-1.013	***	-1.014	***	-1.009	***	-0.827	***	-0.994	***
	0.052		0.052		0.052		0.052		0.030		0.051	
Tradesale	-0.845	***	-0.835	***	-0.834	***	-0.827	***	-0.478	***	-0.813	***
	0.030		0.030		0.030		0.030		0.042		0.030	
Environmental Conditions												
Log (Total VC Funding)	-0.183	***	-0.264	***	-0.179	***	-0.254	***	-0.245	***	-0.219	***
	0.057		0.064		0.056		0.064		0.065		0.064	
Firm's Country	included	a	included	a	included	a	included	a	included	a	included	a
Firm's Industry Sector	included	a	included	a	included	a	included	a	included	a	included	a
Market Timing of the VC												
Log (Stock Market)											0.431	***
											0.077	
N	7,336		7,336		7,336		7,336		7,336		7,336	
Weibull Shape	1.079		1.079		1.079		1.080		1.080		1.083	
Log Likelihood	-10,120		-10,116		-10,113		-10,110		-10,108		-10,092	

4.5 Robustness Checks

In estimation (6), we control for the aggregate level of equity valuation by the Euro Stoxx 50 Equity Price Index. This is done for two reasons: First, fund managers window dress their investments towards extant valuations to impress sponsors (Lakonishok *et al.*, 1991). Exogenous risk might be related to window dressing of the VC if market uncertainty and market valuation is correlated. If so, the impact of exogenous risk might account for window dressing activities instead of a strategic investment decision. Second, endogenous risk estimated by the market-to-book ratio might be biased towards the aggregate level of equity valuation. By its nature, the level of the market-to-book ratio is impacted by market valuation in the time series. We might assign more projects to be fraught with growth opportunities whose funding take place in periods of high a market valuation. In estimation (6), *Market Uncertainty* increases the delay of investments by approximately four and a half months. This corresponds to 24% of the average duration of a financing round. The impact of *Market Uncertainty* does not vanish when controlling for window dressing activities, indicating that *Market Uncertainty* comprises strategic investing. *Growth Opportunities* do not impact the duration for a low level of exogenous risk, indicating that the positive impact estimated in estimation (5) is driven by the selection bias. The interaction term *Market Uncertainty***Growth Opportunities* is still negative, its magnitude does not change when compared to estimation (5).

Krohmer *et al.* (2009) analyze the investment decision of the VC related to endogenous and exogenous risk by the development stage of the project: they argue that endogenous risk is more present in early stages of the project when uncertainty about entrepreneur's effort and ability is high; whereas exogenous risk is more present in later stages of the project when the VC decides about an exit, or writing off the project. We do sub-sample regressions based on project's investment status. We model failure time of projects' initial financing round to address timing of investments in the early stage of the project; and failure time of subsequent financing rounds of the same project to address timing of investments in later stages of the projects. Results are shown in table 5.

In estimation (7) and (8), we model the duration based on projects' initial financing round. The average duration of the financing rounds is 664 days, approximately 22 months. In estimation (7) we estimate the effects of exogenous and endogenous risk separately. In estimation (8) we consider interdependence of exogenous and endogenous risk. *Market Uncertainty* has no impact on the duration in estimation (7), but has a slightly significant impact in estimation (8). Exogenous risk only slightly impacts the duration of early stage projects, indicating that the delay of investments is not valuable in early stages. *R&D Intensity* strongly decreases the duration by almost seven months, corresponding to 30% of the average duration of a financing round. *Growth Opportunities* do not impact the duration.

In estimation (9) and (10), we model the duration based on the same projects' subsequent financing rounds. The average duration of the financing rounds is 564 days, approximately 18.5 months. In estimation (9) we estimate the effects of exogenous and endogenous risk separately, in estimation (10) we consider interdependence of exogenous and endogenous risk. *Market Uncertainty* increases the duration by approximately two and a half months in estimation (9), corresponding to 14% of the average duration of a financing round; and by almost four months in model (10), corresponding to 20% of the average duration of a financing round. *R&D Intensity* decreases the duration by approximately one month in model (9), corresponding to 7% of the average duration of a financing round; and by almost two month in estimation (10), corresponding to 10% of the average duration of a financing round. *Growth Opportunities* do not impact the duration in estimation (9); and increase duration by almost two month in model (10), corresponding to 10% of the average duration of a financing round. The interaction term *Market Uncertainty*Growth Opportunities* is negative. The magnitude is the same when compared to estimation (5) and (6). We find that the delay option is valuable in later stages of the project, when compared to early stages. Consequently, opportunity loss is more present in later stages of the project.

We test the fit of estimation (5) compared to alternative parametric estimations. We present likelihood-ratio statistics and correlations of predicted and observed failure times in table 6. Log-likelihoods are slightly higher for an exponential and log-normal distribution of the error term when compared to the Weibull model we use. Our results do not change if we apply an exponential or log-normal model. To calculate correlations of predicted and observed failure times, we proceed as follows: We predict individual failure time P by estimation (5) that includes all information about endogenous and exogenous risk. We transform the predicted failure times into censored data. We censor predicted failure times that exceed the pre-fixed time of five years. We correlate the simulated sample and the true sample to estimate the correlation coefficients. The correlation coefficients are approximately 0.38 for all models, and statistically significant at $p < 0.01$.

Table 5: Duration Analysis: Early Stage and Later Stages

Accelerated failure time model. Weibull distribution of the error term. Model (7) and (8) estimate the duration based on projects' initial financing round. Model (9) and (10) estimate the duration based on the same projects' subsequent financing rounds. Dependent: Duration of a financing round, defined as the time between two subsequent financing events. The model is fit to the natural logarithm of the duration. Independent: R&D Intensity is a dummy variable equal to 1 if venture firm's industry R&D-expenditures-to-sales ratio is above the Contal and O'Quigley (1999) break-point value, and zero otherwise. Growth Opportunities is a dummy variable equal to 1 if venture firm's industry market-to-book ratio ratio is above the Contal and O'Quigley (1999) break-point value, and zero otherwise. Market Uncertainty is a dummy variable equal to 1 if the VStoxx 50 Index is above the Contal and O'Quigley (1999) break-point value at the funding date, and zero otherwise. The interaction variables are equal to 1 if Market Uncertainty and R&D Intensity, resp. Growth Opportunities are equal to 1, and zero otherwise. Additionally we control for the financing instrument and quality more precisely; financing instruments are Debt, Convertible Debt, Equity Swap; and including a control for bankruptcy, indicating low quality.
*** indicates significance at the 1% significance level, **indicates significance at the 5% significance level, * indicates significance at the 10% significance level. [a] indicates that the classification variables are significant at the 1% significance level based on type-3-effect analysis. [c] indicates that the classification variables are significant at the 10% significance level based on type-3-effect analysis.

	(7)		(8)		(9)		(10)	
Intercept	10.571	***	10.059	***	14.082	***	13.898	***
	2.605		2.632		1.694		1.713	
Endogenousl Risk								
R&D Intensity	-0.260	***	-0.256	***	-0.066	*	-0.093	*
	0.060		0.080		0.037		0.053	
Growth Opportunities	0.035		0.113		0.021		0.093	*
	0.052		0.076		0.034		0.052	
Exogenous Risk								
Market Uncertainty	0.041		0.128	*	0.132	***	0.185	***
	0.054		0.074		0.037		0.053	
Joint Effect of Endogenous and Exogenous Risk								
Market Uncertainty*R&D Intensity			-0.045				0.032	
			0.105				0.067	
Market Uncertainty*Growth Opportunities			-0.151				-0.125	*
			0.100				0.068	
Contract Design								
Debt	-1.642	***	-1.619	***	-0.280	***	-0.279	***
	0.399		0.399		0.060		0.072	
Convertible Debt	-1.351	***	-1.351	***	-0.463	***	-0.466	***
	0.185		0.185		0.037		0.053	
Equity Swap					0.097	***	0.092	***
					0.059		0.170	
Log (Funding Size)	0.034	*	0.034	*	-0.030	**	-0.030	**
	0.018		0.018		0.013		0.013	
Syndication	-0.047		-0.047		-0.049		-0.049	
	0.048		0.048		0.035		0.035	
Firm-specific Information								
Log (Firm's Age)	0.077	***	0.076	***	0.120	***	0.118	***
	0.012		0.012		0.020		0.021	
IPO	-0.809	***	-0.803	***	-0.970	***	-0.971	***
	0.108		0.107		0.060		0.060	
Tradesale	-0.645	***	-0.641	***	-0.787	***	-0.788	***
	0.058		0.058		0.037		0.037	
Bankrupt	0.509	***	0.514	***	0.319	***	0.324	***
	0.088		0.088		0.059		0.059	
Environmental Conditions								
Log (Total VC Funding)	-0.183		-0.161		-0.328	***	-0.320	***
	0.119		0.120		0.076		0.077	
Firm's Country	included	a	included	a	included	a	included	a
Firm's Industry Sector	included	c	included	c	included	a	included	a
N	2,421		2,421		4,915		4,915	
Weibull Shape	1.137		1.138		1.076		1.077	
Log Likelihood	-3,095		-3,094		-6,915		-6,913	

Table 6: Fit Statistics

The sample is the observed failure time, in days. $P_{Weibull}$ is the predicted failure time by the accelerated failure time model using Weibull distribution of the error term. $P_{Exponential}$, P_{Gamma}, $P_{Llogistic}$, $P_{Lnormal}$ are the predicted failure from exponential, general-Gamma, log-logistic modeling, and log-normal modeling. The log likelihood is reported for the respective models.

	Log Likelihood	Sample	$P_{Weibull}$	$P_{Exponential}$	P_{Gamma}	$P_{Llogistic}$
Sample						
$P_{Weibull}$	-10,108	0.380 ***				
$P_{Exponential}$	-10,128	0.379 ***	0.999 ***			
P_{Gamma}	-10,041	0.380 ***	0.995 ***	0.995 ***		
$P_{Llogistic}$	-10,024	0.377 ***	0.978 ***	0.978 ***	0.993 ***	
$P_{Lnormal}$	-10,136	0.376 ***	0.974 ***	0.974 ***	0.991 ***	0.997 ***

5 Conclusion

In this paper, we analyze the optimal timing of investments in a set-up with exogenous and endogenous risk. We consider interdependence of exogenous and endogenous risk in that the strength of endogenous agency risk is related to the level of exogenous market risk. This refers to the idea of a relative value of private benefits: in periods of high market uncertainty, the entrepreneur's expected payoff from the project is downgraded. Private benefits from managing the firm become more attractive to the entrepreneur relative to the successful realization of the project. As a consequence, his incentive to behave opportunistically increases.

We analyze the investment decision from a real options perspective. The VC can reduce his exposer to exogenous risk by delaying investment and mitigate endogenous risk by investing. If exogenous risk is particularly high, the VC has to increase the share vested to the entrepreneur to keep him expending effort in the hard times. Also, the tightened agency risk forces the VC to accelerate investments to aggregate information about the effort of the entrepreneur. As a result, the VC abandons a fraction of his delay option. In that, the discovery restricts the value of the delay option. This strongly decreases the value of his investment and thus arises high opportunity loss.

The interdependence of exogenous and endogenous risk on the timing of investments is economically significant in the real world. We find that VCs accelerate investments to projects fraught with endogenous risk in periods of high market uncertainty by approximately two and a half months when compared to periods of low market uncertainty. This corresponds to 13% of the average duration of a financing round. Furthermore, we find that the delay option is more valuable in later stages of a project when the VC decides about an exit, or writing off the project. Consequently, opportunity loss is more present in the later stages of a venture project.

Our paper has several implications for theory and practice. This study contributes to the extant research on agency risk in venture finance. So far, papers have considered agency conflicts in venture projects to be time invariant (Bergemann & Hege, 1998; Neher, 1999; Cornelli & Yosha, 2003). We show that this assumption is not realistic. Moreover, the strength of agency conflicts is influenced by exogenous factors and varies over time. We present one of those, namely market uncertainty.

On the one hand, our results might help to explain observed return patterns of VC portfolios by an agency perspective. Since agency conflicts are the main reason for the existence of a VC industry (Amit *et al.*, 1998), it is reasonable that they have a considerable impact on the realized returns. Cochrane (2005) shows that return patterns of VC portfolios characterize through a high alpha and a high market beta. First, the alpha accounts for "abnormal" return that can not be explained by common risk factors. The real options perspective might explain the phenomenon: VC investors successfully apply stage financing to reduce downside losses. This results in an option like payoff structure, where the option premium accounts for the alpha. Second, the high market beta accounts for a high sensitivity of the return to market risk. Out idea of a relative value of private benefits might explain the phenomenon: agency risk tightens in a period of high market uncertainty and forces the VC to accelerate investments. As a result, the timing of VC investments is biased towards periods of high market risk.

The results suggest the implementation of contractual claims that focus eypecially on the mitigation of agency conflicts in an environment of high exogenous risk. From the perspective of the entrepreneur, exogenous market risk can be viewed as a high-risk employment situation. The entrepreneur will lose his employment and future income if the VC decides to abandon the project. Amernic (1984) and Eisenhardt (1989) show that the principal has to compensate the cost of risky employment to retain managers in high-risk situations. A fix compensation payment in periods of high exogenous risk acts like a put-option: the entrepreneur can sell his shares to the VC at a pre-fixed price if the project's value is below a critical level. The compensation payment reduces the relative value of private benefits in periods of high market risk, relaxing entrepreneur's incentive to behave opportunistically. This will allow the VC to capitalize on a larger proportion of the delay option when it is most valuable.

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