The impact of asymmetric ambiguity on investment and financing decisions

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A B S T R A C T

The goal of this paper is to investigate the impact of asymmetric ambiguity on corporate investment and financing strategies. Asymmetric information comes from the fact that insiders know the probability of the growth prospects of the firm while outsiders do not. Also, we assume that there are two types of firms (good and bad types) that differ in the quality of their forecasting of future cash flows. Our numerical simulations reveal that firms with more accurate forecasting of cash flows have an interest in speeding up investment in order to make it more difficult for bad firms to mimic their actions. Moreover, we show that the presence of asymmetric ambiguity leads to costly cash holding. These findings may help firms when making their investment and financing decisions under asymmetric ambiguity.

1. Introduction

In standard real option models with perfect information, it is assumed that firms have enough resources to fund investment, or that the capital market has unlimited access to information about firms. To avoid this strong assumption, we follow the framework of Morellec and Schürho (2011), (MS (2011) hereafter), as we suppose that firms must raise funds from uninformed investors to finance capital expenditures. Morellec and Schürho (2011) assume that uninformed investors do not know which types of firms are good (with high cash flow) or bad (with low cash flow). In this situation, bad firms have the incentive to mimic good firms and sell overpriced securities. This distortion signals the quality of the firm to the market.

The objective of our paper is to analyse the introduction of Knightian uncertainty in the Morellec and Schürho (2011) approach. In a first model, we follow the Morellec and Schürho (2011) approach as we assume that there are two types of firms (good and bad types). Unlike Morellec and Schürho (2011), the two types of firms do not differ by their cash flow level (investment projects are identical in our setting) but by the quality of their forecasting of future cash flows.\textsuperscript{1} For the good type of firm, the quality of forecasting is "good", meaning that future cash flows can be modeled by a unique probability measure (as in Morellec and Schürho (2011)), but for the "bad" type of firm, future cash flows can only be modeled by a set of probability distributions (ambiguity case).\textsuperscript{2} The goal of good companies is to prevent bad companies from copying them. Therefore, they degrade their quality to become less attractive. In consequence, bad firms do not find it as interesting to mimic them, and a separating equilibrium is possible. In this equilibrium, the cost of external funds for good firms has increased (compared to the symmetric information case), the cost for bad firms stays the same. In a second model, we suppose that firms have a homogeneous quality of forecasting (there is only one type of firm) known by insiders but not fully recognised by outside investors.\textsuperscript{3} In the presence of information asymmetry, insiders make their decisions by distorting their first best investing/financing strategy (they change the investment trigger obtained under symmetric information). We show that this information asymmetry increases the cost of external funds for good firms. Accordingly, one of the distinctive features of our approach is the introduction of asymmetric ambiguity, showing that the objective of insiders is to decrease the cost of external financing by reducing dilution and, in doing so, to protect the intrinsic value of the firms.

Real option literature supposes that a firm is perfectly certain that future market conditions are governed by a particular probability measure; however, outside investors may not be sure about future uncertainty, and they may think other probability measures are also likely. Uncertainty that is characterised by a set of probability measures...
is often called Knightian uncertainty (Knight, 1921) or ambiguity. In the axiomatic framework of Epstein and Schneider (2003), in the presence of ambiguity, agents face not a single probability distribution but a set of probability distributions. In this case, an ambiguity-averse agent will act using the probability distribution leading to the worst outcome, named the worst scenario. The effect of symmetric ambiguity on the value of irreversible investment opportunity differs from the effect of risk: an increase in ambiguity reduces the value of an investment opportunity (Nishimura and Ozaki; 2007; Trojanowska and Kort, 2010), while the opposite is true for an increase in risk (Caballero, 1991; Leahy and Whited, 1996). For projects with infinite life, an increase in ambiguity lowers the reason to wait, which is the opposite of an increase in risk (McDonald and Siegel 1986; Dixit and Pindyck, 1994). This is because if a company perceives the future as ambiguous, then waiting will have less value because the expected value of new information is reduced. Accordingly, most information will have no effect on the worst scenario, and thus on the decisions of companies in this context.

The original contribution of this paper is that we investigate the effect of asymmetric ambiguity on the strategic financing/investing behavior of firms. The paper contributes significantly to the literature, as we demonstrate that insiders must distort their optimal investment behavior to cope with the presence of ambiguity in the market. This distortion reduces the value of their options. Specifically, our numerical simulations show that firms with more accurate forecasting of their cash flows have an interest in speeding up investment, leading to an erosion of the waiting option value. Moreover, the presence of asymmetric ambiguity leads to postponing investment compared to situations with symmetric or no ambiguity, and can justify costly cash holding.

Our results are helpful for firms and investors, because they have several implications for a firm’s investment and financing strategies. In fact, in the context of asymmetric ambiguity, it can be optimal for a firm to hold costly cash so as to benefit from good market conditions, and to reduce investment distortion and the associated loss in investment value. In other words, it may be optimal to disconnect the timing of financing and investing decisions. A firm can ask for financing when the cash flow shock is relatively high, reducing the dilution problem.

Taking into account asymmetric ambiguity also makes a theoretical contribution to the literature on equity market timing that deals with the effect of current market conditions on the timing of equity emissions (Baker and Wurgler, 2002; Chang et al., 2006; Welch, 2004; Yagi and Takahama, 2012). Once firms have obtained funding, they no longer have to take into account the within the market into account to make their investment decisions. They can thus invest at the optimal investment threshold without ambiguity but whilst taking into account costly cash holding. Firms must balance the positive effect of reduced dilution and investment distortion and the direct and indirect cost of cash.

The rest of the paper is organised as follows. Section 2 describes the waiting option model in the presence of ambiguity. Sections 3 and 4 explore the effects of asymmetric ambiguity on a firm’s investment strategy in the presence of only one type of firm (Section 3) or two types of firms (Section 4). Section 5 investigates the link between ambiguity and cash holding. Section 6 presents our conclusions.

## 2. Waiting option model with ambiguity

We suppose that firms must issue stocks to invest in a risky project and that managers (insiders) know more about the process governing future cash flow than investors (outsiders). The investment model is an adaptation of Myers and Majluf (1984) and McDonald and Siegel (1986). Our hypotheses are similar to those of the above models, except that we suppose that firms can choose the timing of their investment and financing decisions. Accordingly, we suppose that financial markets are competitive, agents are risk neutral, and discount cash flows at a constant rate $r$, and that firms have an infinite life and monopoly rights to an investment project. The direct cost of irreversible investment is constant, denoted by $I$. At any time, $t$, after investment, the project produces a continuous stream of cash flows $X_t^r$, $f > 0$ represents constant operating expenses.

### 2.1. Ambiguity in continuous time

We suppose that the firm will invest in a new project (product, market, industry, etc.), so outside investors may think that other probability measures which arise from the original, $P$, are possible. Following Nishimura and Ozaki (2007), Trojanowska and Kort (2010), and Chen and Epstein (2002), we assume that outside investors consider a set of probability measures which have perfect agreement with $P$, and zero probability events. Under these two conditions, ambiguity can be measured by a unique parameter, $k$. Following Chen and Epstein (2002), we will call this simplified form of ambiguity $k$-ignorance. An investor’s set of probability measures describing ambiguity consists of probability measures equivalent to $P$, $dB = dB + dθt$, where $B_t$ a standard Brownian motion with respect to $P$ and $θ_0$, a stochastic process called a density generator, with $θ \in \Theta$ a set of density generators (Nishimura and Ozaki 2007; Trojanowska and Kort, 2010). Let $μ$ and $σ$ be real numbers; by Girsanov’s theorem, we have for any $θ \in Θ$,

$$dX_t = X_tμdt + σX_tdB_t − θ_0dt \Rightarrow dX_t = (μ − θ_0)X_tdt + σX_tdB_t$$ \hspace{1cm} (1)

Under $k$-ignorance, the set of density generators, $K$, is specified as $K = \{ k \}$ with $k > 0$, and the density generator degenerates to $θ = k$. If $k$ increases, it means that investors are less certain about the probability measure. This framework excludes the possibility of learning due to the difficulty of accommodating the responsiveness of ambiguity to information arriving continuously over time (Chen and Epstein, 2002; Epstein and Miao, 2003). In the case of $k$-ignorance, the firm assigns the lowest value of the growth rate to the project. Eq. (1) becomes

$$dX_t = (μ − kσ)X_tdt + σX_tdB_t$$ \hspace{1cm} (2)

As a consequence, the presence of $k$-ignorance on the market reduces the drift term of the stochastic process of cash flows.

### 2.2. Project value under $k$-ignorance

Before analysing the effects of asymmetric information, we start by reviewing the case in which all agents have the same level of $k$-ignorance. The firm wants to determine the optimal time to pay a sunk cost $I$ to obtain access to the profit stream described under Eq. (2). Suppose that the investment is undertaken at time $0$. The value of the project installed, $Π$, equals the expected present value of the perpetual stream of cash flows generated by the project when the level of ignorance is $k$ (Nishimura and Ozaki, 2007; Trojanowska and Kort, 2010):

$$Π_k(x) = \mathbb{E}\left[\int_0^\infty e^{-rT}X_tdt\mid X_0 = x\right] = \frac{x}{\lambda}$$ \hspace{1cm} (3)

With $λ \equiv r − (μ − kσ)$, so as to ensure convergence $r > μ$ (McDonald and Siegel, 1986; Dixit and Pindyck, 1994; Wong, 2007), then $λ$ turns out to be positive, since $k > 0$. The derivative of $λ$ relative to ambiguity is $dλ/dk > σ > 0$. Ambiguity thus reduces the value of the underlying project. We denote by $F$ the present value of operating expenses: $F = fr/r$. 

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5 Several papers have investigated the impact of ambiguity on financial markets. For more details see Ben Ameur and Prigent (2013), Kast et al. (2014), and Jeong et al. (2015).

6 Postponing investment was found by Grenadier and Wang (2005) in a moral hazard context.

7 Costly cash induces firms to invest earlier than in a situation without cash.
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