The Impact of Ambiguity on Managerial Investment and Cash Holdings

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ABSTRACT

Standard finance theory suggests that managers invest in projects that, in expectation, produce returns that justify the use of capital. An underlying assumption is that managers have the information necessary to understand the distributional properties of the payoffs underlying the decision. This paper examines firm investment behavior when managers are likely to find it more challenging to develop expectations of payoffs, namely during periods of increased macroeconomic ambiguity. In particular, we examine how macroeconomic ambiguity — proxied by the variance premium (Drechsler, 2010) and the dispersion in forecasts of corporate profits from the Survey of Professional Forecasters (Anderson et al., 2009) — impacts managerial capital investment and cash holdings. Consistent with ambiguity theory, we find that macroeconomic ambiguity is negatively associated with capital investment and positively associated with cash holdings. These results are robust to alternative explanations related to risk, investor sentiment, and economic conditions. Moreover, consistent with recent theoretical real options literature, we find that ambiguity reduces the value of investment opportunities, while risk increases the value of such opportunities. Overall, these findings provide initial empirical evidence on the economic distinction between ambiguity and risk with respect to managerial investment and cash holdings.
1. Introduction

Within a firm, the allocation of capital to its highest value use is one of the most important roles of a manager. The central determinant of successful capital allocation is the precision with which a manager is able to identify cash flow prospects and apply appropriate discount rates for the respective investment decisions. Typically, the investment literature assumes that managers know, or behave as if they know, the probability distributions of the cash flows and discount rates related to potential projects. In other words, although project payoffs are ex ante unknown, managers feel confident in their assessment of investment payoff probabilities.

Recent theoretical work by Nishimura and Ozaki (2007), however, argues that managers facing a decision regarding irreversible investment may not always have complete confidence in their perceived payoff probability measures. As Nishimura and Ozaki (2007) state, managers “might think other probability measures perturbed from the original one are also possible.” This uncertainty regarding investment payoff—characterized by a set of probability measures rather than a single probability measure—is defined as ambiguity, or Knightian uncertainty.\(^1\) The intuition developed in Nishimura and Ozaki (2007) draws from the large theoretical and experimental literature on ambiguity (e.g., Ellsberg, 1961; Bewley, 1986; Gilboa and Schmeidler, 1989), which builds on Knight (1921).\(^2\)

The purpose of this paper is to examine the impact of ambiguity on managerial investment and cash holding decisions. The ambiguity literature suggests that, in the presence of ambiguity,

\(^1\) The term ‘Knightian uncertainty’ is based on the seminal work of Knight (1921), which points out that ambiguity is a fundamentally different concept than risk. Specifically, risk relates to known, or objective, uncertainty, as in the roll of a die, where the outcome probabilities are known, or the probabilities can be estimated with confidence. In contrast, ambiguity relates to subjective uncertainty, where outcome probabilities are unknown, and the decision maker fears the estimated model is incorrect. Note that, although both risk and ambiguity ultimately relate to uncertainty regarding project payoffs, ambiguity relates to uncertainty as to the probability measure governing those outcomes as well. In this paper, we use the term ‘uncertainty’ to mean either risk or ambiguity or both. That is, uncertainty is comprised of both risk and ambiguity. We use the terms ambiguity and ‘Knightian uncertainty’ interchangeably.

\(^2\) See Epstein and Schneider (2010) for a review of the ambiguity literature.
ambiguity–averse individuals behave as if they assume ‘worst-case’ outcome scenarios — i.e., they incorporate the worst possible payoff probability measure in their consideration set into their decision. With respect to managerial investment, ambiguity-averse managers place a lower reservation price on potential projects than would be predicted using a rational expectations framework (Nishimura and Ozaki, 2007). As a result, their investment level declines, as anticipated project payoffs do not meet the lower reservation prices and they shift to holding riskless assets instead (Dow and Werlang, 1992; Epstein and Schneider, 2010). Following this intuition, we predict that when managers find it more difficult to develop expectations of future investment payoffs (i.e., when they are faced with ambiguity), they are likely to reduce their capital expenditures and increase their cash holdings.\(^3\)

To capture the impact of ambiguity, we develop our models of investment and cash holdings based on prior literature. In particular, we model a firm’s investment decision using Euler equations (e.g., Whited, 1992; Hubbard et al., 1995; Love, 2003), and we model a firm’s cash holdings following Opler et al. (1999).\(^4\) Our proxies for ambiguity are the variance premium (Drechsler, 2010) and dispersion in forecasts of corporate profits by the Survey of Professional Forecasters (Anderson et al., 2009).

We then estimate the firm-level investment and cash holding models, where we include as our main variable of interest the macroeconomic ambiguity measures. Consistent with expectations, we find that firms, on average, tend to invest less in capital expenditures and hold more cash as macroeconomic ambiguity increases. To rule out alternative explanations related to

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\(^3\) Note that a manager’s ability to develop expectations regarding future investment payoffs may also be affected by her overconfidence. However, in the context of investment, we believe that overconfidence is likely to work in the opposite direction as ambiguity. Specifically, we expect ambiguity to decrease the manager’s precision of the payoff distribution and thus lead to less investment. In contrast, as stated in Gervais, Heaton and Odean (2011, p.1738), “overconfidence captures the idea that individuals overestimate the precision of their information or their ability to interpret that information when they make economic decisions.” If overconfident managers overestimate the precision of their investment payoff distribution, we would expect overconfidence to lead to greater investment, biasing against our hypothesized results.

\(^4\) We also model cash holdings following Ozkan and Ozkan (2004) as an alternative analysis.
risk, investor sentiment, or economic output, we run our analyses controlling for idiosyncratic volatility (Dixit and Pindyck, 1994; Panousi and Papanikolaou, 2010) and market returns, the consumer sentiment index (Baker et al., 2003; Polk and Sapienza, 2004), and real Gross Domestic Product (GDP) growth (Durnev, 2010). In addition, we control for firm-specific factors, such as agency issues, compensation, earnings volatility, lagged cash holdings, and financing constraints. Our results are robust to the inclusion of these variables.

To further support our assertion that it is indeed ambiguity, as opposed to risk, that impacts managers’ investment, we examine how our ambiguity and risk measures each impact the value of investment opportunities. The standard intuition in the real options investment literature is that risk increases the value of irreversible investment opportunities because it increases the mean-preserving payoff spread (McDonald and Siegel, 1986; Dixit and Pindyck, 1994; Brealey and Myers, 2003). In contrast, the ambiguity literature suggests that ambiguity decreases the value of investment opportunities. Accordingly, we predict that increases in risk (ambiguity) increase (decrease) the value of irreversible investment opportunities. These differential predictions serve as a joint test of both the theory and our empirical measures.

Using contemporaneous Tobin’s Q to measure the value of investment opportunities available to a firm, we regress Q on our measures of risk and ambiguity, controlling for other determinants of Q. Consistent with predictions in the real options investment literature, we find that increased risk increases the value of investment opportunities. Further, consistent with the theoretical predictions from Nishimura and Ozaki (2007), we find that increased ambiguity reduces the value of such investment opportunities. Thus, our findings further support our assertion

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[5] See McDonald and Siegel (1986) and Dixit and Pindyck (1994) for detailed explanations of the relation between risk and irreversible investment under an option-theoretic framework. Empirical evidence supporting this contention can be found in Choi and Lee (2000), Bulan (2005) and Grullon et al. (2008), among others.
that macroeconomic ambiguity impacts management investment decisions in a different manner than does risk.

This study offers several contributions to current research in finance. First, we contribute to the ambiguity literature by providing empirical evidence regarding the impact of ambiguity on managerial investment behavior. In particular, we find that investment (cash holding) is negatively (positively) associated with ambiguity, even after controlling for risk, investor sentiment, economic conditions and several firm-specific factors. These findings add to the body of evidence from the nascent empirical ambiguity literature showing that market participants, on average, behave as if they are ambiguity-averse.

Second, we provide insight into how ambiguity affects corporate cash holdings. To date, empirical ambiguity research has focused solely on its effect on investment rather than on cash holdings. Our cash holdings analysis thus provides a more complete set of inferences about the effects of ambiguity by showing that firms not only reduce investment, but also increase cash holdings. This analysis also helps rule out alternative explanations related to risk.

Finally, we provide empirical evidence on the relation between ambiguity and the value of investment opportunities. Specifically, we find that ambiguity reduces the value of investment opportunities, consistent with the predictions in Nishimura and Ozaki (2007). Given that risk has the opposite prediction with respect to investment opportunities, this finding provides further support for our investment findings as well as justification for our ambiguity and risk measures.

The rest of the paper is organized as follows. Section 2 discusses the sample and variables, while Section 3 discusses the research design and results. Additional analyses and robustness tests are presented in Section 4. Section 5 concludes.

2. Sample and Variable Descriptions
This section presents an overview of our sample construction as well as operational definitions for the variables used in our models.

2.1. Sample construction

We obtain financial data from the Compustat Quarterly file. Our initial sample consists of all firm–quarter observations from 1987 to 2009 with sufficient data to estimate our investment and cash holdings models. We begin our analysis in 1987, as this is the first year for which Compustat provides cash flow statement data. After obtaining the intersection of CRSP and Compustat quarterly data, we remove regulated and financial firms (firms with SIC codes between 4000–4999 and 6000–6999, respectively) from our sample set, as they may have different incentive structures or regulatory restrictions on their investment behavior.

To control for ownership and governance characteristics, we collect ownership and CEO compensation data from ExecuComp and governance data from RiskMetrics. Since these databases provide annual data (rather than quarterly data), we use the beginning of the year data as the reference point for our quarterly observations. For each regression analysis, we require the observation to have all necessary data for the analysis. Since data are not available from RiskMetrics (ExecuComp) before 2005 (2002), we show our results with and without these control variables in our main analyses. By providing both sets of results, we are able to trade off sample size with enhanced specification. Table 1 details our sample selection process. To control for outliers, we winsorize all firm-specific variables at the 1st and 99th percentiles.

2.2. Construction of ambiguity and other aggregate measures

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6 While prior research shows that cash flows can be approximated using balance sheet data, it has been suggested that mixing the time series with the two different types of computation can create abnormalities in the time series (Hriobar and Collins, 2002).
2.2.1. Ambiguity measures

Although the empirical literature on ambiguity is still in its infancy, prior research identifies two macroeconomic measures of ambiguity: the dispersion in the Survey of Professional Forecasters (DISP) and the variance premium (VP). Following Anderson et al. (2009), we measure DISP as the amount of dispersion in the latest aggregate corporate profit forecasts before the quarter in the Survey of Professional Forecasters (also known as the ‘Anxious Index’). Specifically, DISP indicates the amount of disagreement among forecasters as to their expectations of future economic conditions. Given that forecasters are experts in macroeconomics with no incentive to withhold private information, their disagreement is likely due to differences in their expectations regarding the distributions governing the forecasted data, as opposed to differential abilities in forming expectations from commonly shared information. This is more consistent with ambiguity than risk (Camerer and Weber, 1992).

Our second proxy for ambiguity is the variance premium (VP). Drechsler (2010) models a direct link between the variance premium and Knightian uncertainty. The intuition behind the measure is that the premium arises out of investors hedging against ambiguity concerns. Prior literature (e.g., Drechsler and Yaron, 2009) defines the variance premium as the difference between the strike price and the expected payoff of a variance swap, where the swap's payoff is the realized variance of returns. Given that the realized variance represents known volatility, or risk, any price paid above the payoff reflects unknown volatility, or ambiguity.

Empirically, VP is calculated as the difference between the risk-neutral and physical expectations of the markets’ return variation. Specifically, we obtain an estimate of the risk-neutral variance expectations. Britten-Jones and Neuberger (2000) show that, for assets with continuous

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7 A variance swap is a contract that allows investors to hedge against volatility exposure or to speculate on the difference between the current stock price variance implicit in options prices and the actual stock price variance realized over a period of time.
prices, the risk-neutral expectation of the return variance is equal to the value of a portfolio of European call options. This is a ‘model-free’ approach, which does not depend on any particular option pricing model or its assumptions. In our study, we first use the CBOE model-free estimate of the expected variance for a 30-day contract on the S&P 500 beginning in 1990. We then calculate our conditional variance forecasts by summing the squared daily total market returns over each month. After obtaining these forecasts, we estimate a GARCH (1,1) model on the monthly time series to obtain a forecast of the physical expectations. We then calculate VP as the difference between the estimate of the risk-neutral variance expectations and the physical expectations.  

2.2.2. Macroeconomic control variables

To mitigate any potential bias associated with correlated omitted variables, we control for several aggregate factors known to be associated with investment decisions. Although we distinguish between risk and ambiguity on a theoretical level, we acknowledge that our empirical proxies of ambiguity — DISP and VP — may also capture some component of risk (Anderson et al., 2009). To separate out the risk component from our ambiguity proxies, we included the market return for the period as a direct proxy for macroeconomic risk. As the asset pricing literature indicates, the expected returns for the market represent the pricing of risk undertaken with respect to investment. To control for market risk, we follow prior research (e.g., Dittmar and Dittmar, 2010).

Prior research (Drechsler, 2010; Williams, 2010) provides empirical evidence consistent with the Chicago Board Options Exchange Volatility Index, VIX, being able to capture ambiguous environments as well. Drechsler (2010) finds that the VIX and the VP are highly correlated (over 90% in our sample), but argues that VP is theoretically the sounder measure of ambiguity. However, VIX allows for a longer time series of data, which can potentially increase the power of the test. Accordingly, in untabulated results, we proxy for ambiguity using VIX (calculated as the average daily level of the VIX over the last month of the prior quarter) and find qualitatively similar results to those reported for VP.
2008) and use the value-weighted market returns over the quarter, $ExpRET$.\footnote{We note that market returns in the short-run are a poor proxy for risk, especially when those returns are negative. Therefore, in untabulated tests, we examine the sensitivity of our results to using return measures computed over longer horizons. We find that our inferences are unchanged when we measure market returns over a six, twelve, eighteen, twenty-four, or thirty-six month horizon.} \footnote{In addition, we control for idiosyncratic or conditional volatility ($ExpIdioVol$) at the firm level, measured as the monthly forecasted volatility using a GARCH (1,1) for the firm at the beginning of the quarter.} \footnote{As indicated in section 4.3.1, our results are robust to using the Baker and Wurgler (2007) sentiment measure.}

In addition to controlling for risk, we control for investor sentiment, which can broadly be defined as “a belief about future cash flows and investment risks that is not justified by the facts at hand” (Baker and Wurgler, 2007). Prior studies show that investor sentiment can impact the market pricing of capital (e.g., Baker and Wurgler, 2007; Qiu and Welch, 2006) and therefore investment (e.g., Baker et al., 2003; Polk and Sapienza, 2004). As there is no clear measure that fully captures investor sentiment, Baker and Wurgler (2007) offer several potential proxies, including the Consumer Sentiment Index (CSI) published by the Michigan Consumer Research Center, which measures consumer optimism with respect to the state of the economy. Qiu and Welch (2006) find a positive relation between the CSI and the UBS/Gallup Survey. They also find that the CSI explains significant portions of ‘excess’ market pricing, thus reinforcing its ability to proxy for investor sentiment. Accordingly, we control for investor sentiment using the reported level of the quarterly Consumer Sentiment Index at the beginning of each fiscal quarter.\footnote{As indicated in section 4.3.1, our results are robust to using the Baker and Wurgler (2007) sentiment measure.}

Finally, we control for changes in aggregate economic activity by including growth in real GDP in our models. Economic indicators, such as GDP, are used to assess a country’s economic output, or overall economic health. Since the health of the economy is directly tied to the amount of investment undertaken for the period, we proxy for aggregate economic output using the percentage change in GDP, $\Delta GDP$. Specifically, we calculate $\Delta GDP$ as the percentage change in the seasonally-adjusted real GDP over that calendar quarter with the maximum overlap with a given fiscal quarter. This measure also captures any potential shifts in risk aversion due to changing
labor market conditions. For example, managers might be more (less) willing to take on risky projects if their employment opportunity set has increased (decreased) because of growth (decline) in the economy.

3. Research Design and Results

In this section, we explore whether managers adjust their investment in capital expenditures and cash holdings in response to ambiguity. The ambiguity literature suggests that ambiguity-averse individuals tend to shift resources from risky assets to riskless assets when faced with increased ambiguity, as they assume worst-case probability measures. We apply this intuition to the specific context of capital investments and predict that managers will decrease investment in capital expenditures and increase cash holdings as ambiguity increases. We also support these results by providing evidence on the impact of ambiguity and risk on the value of investment opportunities, highlighting the distinction between these two constructs.

3.1. Ambiguity and investment

Most prior research that models investment begins with a manager who maximizes firm value by solving an investment optimization problem (Hubbard, 1998). In these models, firms invest until the marginal adjustment cost is equal to the shadow price of capital (Tobin, 1969; Hayashi, 1982; McDonald and Siegel, 1986; Whited, 1992; Brealey and Myers, 2003; Nishimura and Ozaki, 2007). Typically, these models identify investment as a function of investment opportunities using either Tobin’s Q or sales growth; however, since we argue that ambiguity affects investment via investment opportunities, our model requires a proxy for investment opportunities that is exogenous to ambiguity.

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12 Related investment papers include early analytical work by Lee (1988), who models the timing decision on investment, and Trivoli and McDaniel (1987), who model the role of uncertainty in capital rationing decisions.
To address this issue, we model a firm’s investment decision using the investment Euler equation following Gilchrist and Himmelberg (1998) and Love (2003). The investment Euler equation relies on the intuition that the marginal cost of investing today equals the discounted marginal cost of investing tomorrow. Thus, it eliminates the need for developing an exogenous measure of investment opportunities. In developing our predictions, we argue that if a firm’s investment decisions are affected by macroeconomic ambiguity, the standard Euler equation would be misspecified, as our proxies for ambiguity would play a role in the decision.

3.1.1. The Euler equation model

In this section, we reproduce the investment Euler equations as in Gilchrist and Himmelberg (1998) and Love (2003). Although the model is simplified, this simplification does not affect the first-order conditions for investment, our main outcome of interest. In this model, managers maximize the present value of the firm, which is the expected present value of future cash flows subject to capital accumulation and external financing constraints, as follows:

$$V_t(K_t, \psi_t) = \max_{\{I_t, \psi_t\}_{t=0}} \left[ CF_t + E_t \left[ \sum_{s=1}^{\infty} \beta^{s-t} CF_{t+s} \right] \right]$$

subject to the constraints

$$CF_t = \Pi(K_t, \psi_t) - C(I_t, K_t) - I_t,$$  \hspace{1cm} (2)

$$K_{t+1} = (1-\delta)K_t + I_t,$$  \hspace{1cm} (3)

$$CF_t \geq 0$$  \hspace{1cm} (4)

In robustness tests, we use sales growth (in the prior period) as a proxy for investment opportunities that is exogenous to ambiguity.

Gilchrist and Himmelberg (1998) show that including debt in the optimization results requires a separate Euler equation for debt. However, they point out that the investment Euler equation is not directly related to the debt Euler equation and is thus not affected by adding debt to the model.
In the above model, $CF_t$ represents the net cash flows of the firm and is given by a profit function, $\Pi(K_t, \psi_t)$, which is already maximized; the adjustment cost of investment, $C(I_t, K_t)$; and investment expenditures $I_t$. Furthermore, $\psi_t$ is the productivity shock, $\beta_{t+1}$ is a discount factor from period $t+1$ to period $t$, $K_t$ is the capital stock at the beginning of the period, and $\delta$ is the depreciation rate. Following Love (2003), we introduce financing frictions as a non-negativity constraint on the firm’s net cash flow; the Lagrange multiplier on this constraint is denoted as $\lambda_t$, which represents the marginal cost of raising additional equity.\footnote{If a firm is constrained, it will be unable to have negative cash flows (i.e., issue equity).}

We next rearrange the first-order conditions to the above optimization problem to obtain the Euler equation (Love, 2003):

$$1 + \left( \frac{\partial C}{\partial I} \right)_t = \beta E_t \left[ \Theta_t \left( \frac{\partial \Pi}{\partial K} \right)_{t+1} + (1 + \delta) \left( 1 + \frac{\partial C}{\partial I} \right)_{t+1} \right],$$

(5)

where $\frac{\partial C}{\partial I}$ is the marginal adjustment cost of investment, $\frac{\partial \Pi}{\partial K}$ is the marginal product of capital (referred to as MPK), and $\Theta_t = (1 + \lambda_{t+1})/(1 + \lambda_t)$ is the relative shadow cost of external financing in periods $t$ and $t+1$. Note that the left hand side of equation 5 represents the marginal adjustment cost of investing today plus the price of investment goods (normalized to one), while the right hand side represents the discounted marginal cost of investing tomorrow. That is, the right hand side captures the opportunity cost of one additional unit of capital (i.e., MPK), the marginal adjustment cost of investing tomorrow, and the price of investing tomorrow (again normalized to one). Overall, the Euler equation suggests that the cost of investing today should equal the cost of investing tomorrow in present value terms.

3.1.2. Implementing the model
We implement the above model following Love (2003). Specifically, we parameterize $\Theta_i$ as a linear function of the firm’s stock of cash and cash equivalents (i.e., liquid assets):

$$\Theta_i = a_i + b \text{Cash}_{it-1},$$  \hspace{1cm} (6)

where $a_i$ is the firm-specific level of financing constraints, captured as a firm fixed effect.

The marginal product of capital (MPK) is derived from the firms’ profit maximization problem as a function of the sales-to-capital ratio, i.e., $\text{MPK} = \theta(s/k)$.\(^\text{16}\) We assume that the parameter $\theta$ is firm specific and empirically captured by the following approximation:

$$\text{MPK}_{it} = \theta_i \frac{S}{K_{it}} \approx \text{const.} + \theta_i + \overline{\theta} \frac{S}{K_{it}},$$  \hspace{1cm} (7)

where $\overline{\theta}$ is the average of all $\theta_i$. Note that this representation focuses on the within-firm variation in the sales-to-capital ratio. Following Love (2003), we assume a linear marginal adjustment cost of investment and obtain:

$$\frac{\partial C}{\partial I_i} = d \left( \frac{I}{K_{it}} - e \frac{I}{K_{it-1}} - v_i \right)$$  \hspace{1cm} (8)

As Love (2003) explains, this adjustment cost function includes a lagged investment-to-capital ratio. Thus, it better captures the strong persistence in investment-to-capital ratios observed in the data. The $v_i$ parameter can be interpreted as a firm-specific level of investment at which the adjustment costs are minimized.

\(^\text{16}\) Consider a firm with a Cobb-Douglas production function $y = Ak^{\alpha_k}l^{\alpha_l}$ where $A$ is the total factor productivity, $y$ is output, $k$ is capital stock and $l$ is any variable factor input. Assume that the firm faces an inverse demand curve $p(y)$, factor prices $w$, and fixed costs $F$, the profit function then is: $\pi(k, w, F) = \max p(y)y - w(l + F)$ subject to the constraint $y = Ak^{\alpha_k}l^{\alpha_l}$. The MPK can be obtained by solving this maximization problem and applying the envelope theorem. Specifically, $\text{MPK} = \partial \pi / \partial k = \theta(s/k)$, where $\theta = (1 + \zeta^{-1})\alpha^k$, $\zeta = (\partial y/\partial p)p/y$ is the price elasticity of demand, $\alpha^k$ is the capital share of output from the Cobb-Douglas specification, and $s = py$ is the firm’s sales. See Gilchrist and Himmelberg (1998) for details and arguments supporting the use of this measure.
3.1.3. Empirical investment model

To obtain our empirical model, we substitute equations 6 to 8 into equation 5. However, doing so creates a highly non-linear model with several firm-specific parameters: \( \iota_i, \Theta_i, \) and \( \nu_i. \)

To capture these parameters with one firm fixed effect, we linearize the model following Gilchrist and Himmelberg (1998) and Love (2003). Specifically, we linearize the product of \( \beta_i, \Theta_i, \) and the marginal benefit from investment, denoted \( \{.\}_i, \) using a first-order Taylor approximation around the means. Since \( \Theta_i \) could be above or below one, its mean value should be around one (Love, 2003). Denoting the unconditional mean of the expression as \( \gamma \) and the average discount factor as \( \beta \), the approximation is as follows:

\[
\beta_i \Theta_i \{.\}_i \approx \text{const.} + \beta \gamma \Theta_i + \beta \{.\}_i + \beta \gamma
\]  

(9)

We assume that the higher order terms in the approximation are captured by time and firm fixed effects. In untabulated robustness tests, we also include quadratic terms in our equations and find that our inferences are unaffected. After the required substitutions, linearization, and imposition of a rational expectations assumption (by replacing the expectations with realized values plus an error term), we obtain the following empirical model:

\[
\frac{I}{K_a} = \beta_1 \frac{I}{K_{a+1}} + \beta_2 \frac{I}{K_{a-1}} + \beta_3 \frac{S}{K_a} + \beta_4 \text{Cash}_{a-1} + \text{Industry}_j + e_a
\]  

(10)

where the coefficients are related to the model parameters as follows:

\[
\beta_1 = \frac{\bar{\rho}(1-\delta)}{g}, \quad \beta_2 = \frac{e}{g}, \quad \beta_3 = \frac{\bar{\beta} \Theta}{dg}, \quad \beta_4 = \frac{\bar{\beta} \gamma}{dg}, \quad \text{and} \quad g = 1 + \bar{\beta}(1-\delta)e.
\]

We then add our proxies for ambiguity, sentiment, and risk to equation 10. Specifically, we include macro-level controls, \( \text{ExpRET}, \text{CSI}, \) and \( \Delta \text{GDP}, \) to mitigate the concern that alternative explanations related to risk, investor sentiment, or general macroeconomic conditions drive our
findings. We also control for a number of firm-level variables that might affect investment. First, since Panousi and Papanikolaou (2010) indicate that idiosyncratic risk can impact investment decisions, we include a measure of the expected firm-specific idiosyncratic risk, $ExpIdioVol$. We measure $ExpIdioVol$ as the monthly forecasted idiosyncratic volatility using a GARCH (1,1) for the firm at the beginning of the quarter. To further capture the effect of volatility on managers’ investment decisions, we also include an earnings-based measure of volatility, $EarnVol$, defined as the standard deviation of EBIT scaled by total assets calculated over a period of 12 quarters.

Furthermore, prior investment research (e.g., Almeida and Campello, 2002; Almeida et al., 2004; Hirth and Uhrig-Homburg, 2010) finds that financing constraints can affect investment decisions. Consequently, we control for the possible effect of financing constraints ($Z$-Score) by including the inverse of the Altman Z-score ratio (Altman, 1968). Lastly, we include controls for managerial compensation ($%Options$) and governance characteristics ($CEO\ Ownership$, $DualRole$, $#Directors$ and $%IndepDir$) to capture agency costs that may affect a firm’s investment decisions (e.g., Masulis et al., 2009). $CEO\ Ownership$ is defined as the number of shares owned by the firm’s CEO, scaled by the total common shares outstanding. We define $%Options$ as the ratio of the Black-Scholes value of options granted to total compensation. $DualRole$ is an indicator variable that takes a value of one for firms where the CEO is also the president of the board, and zero otherwise. $#Directors$ and $%IndepDir$ are the log of the number of directors and the proportion of independent directors on the board, respectively (see the Appendix for a more detailed description of the variables). Table 2 provides the descriptive statistics for the ambiguity measures as well as the macro-level and firm-level control variables.

As stated previously, if firms’ investment decisions are affected by macroeconomic ambiguity, the standard Euler equation will be misspecified, and thus our proxies for ambiguity
may play a role in these investment decisions. We now estimate the model as follows (firm subscripts omitted):

\[
I/K_t = \beta_0 + \beta_1 I/K_{t-1} + \beta_2 I/K_{t+1} + \beta_3 S/K_t + \beta_4 Cash_{t-1} + \beta_5 Ambiguity_{t-1} + \beta_6 ExpRET_{t-1} + \beta_7 CSI_{t-1} + \beta_8 \Delta GDP_{t-1} + \beta_9 ExpIdioVol_{t-1} + \beta_{10} Z-Score_{t-1} + \beta_{11} EarnVol_{t-1} + \beta_{12} Options_{t-1} + \beta_{13} CEO Ownership_{t-1} + \beta_{14} DualRole_{t-1} + \beta_{15} #Directors_{t-1} + \beta_{16} %IndepDir_{t-1} + \epsilon \quad (11)
\]

Our main variable of interest in equation (11) is Ambiguity, defined as either VP or DISP. If our hypothesis holds, we would expect a negative and statistically significant coefficient on Ambiguity (\( \beta_5 < 0 \)). Note that the first four variables in equation (11) follow directly from the empirical implementation of the Euler model (Love, 2003). We define \( I/K_{t-1} \) and \( I/K_{t+1} \) as capital expenditures scaled by capital in periods t-1 and t+1, respectively, and \( S/K \) as sales scaled by total assets in period t.\(^{17} \) Cash_{t-1} is defined as cash plus cash equivalents scaled by total assets in period t-1.\(^{18} \)

We report the results from estimating our investment model (equation 11) in Table 3, using each of our ambiguity measures—VP and DISP. We also provide results controlling only for macroeconomic factors, volatility and financing constraints (first and third set of results). We then provide results controlling for these variables as well as our compensation and governance control variables (second and fourth set of results). Providing both sets of results allows us to balance sample size and control specification.

For the analysis in Table 3, we relax the assumption that error terms are independent across our outcomes of interest (i.e., investment and cash holdings). Specifically, we use seemingly unrelated regressions (SUR) to estimate both the investment regression and the cash holding

\(^{17} \)For more details on how our variables are calculated, see the appendix at the end of the paper.

\(^{18} \)Lagged cash is used as an instrument for contemporaneous cash, which is likely endogenous in the model. To test for endogeneity using our instrument, we conduct a Hausman test and find no evidence of endogeneity.
regression (described in Section 3.2) jointly, to allow errors to be correlated across equations.\(^{19}\)

For all of our empirical models, to account for the impact of CEO and time fixed effects, we estimate a first stage regression, where we first regress all dependent and independent variables on CEO and time fixed effects and then include the residuals (i.e., the demeaned variables) in our main models. We use CEO fixed effects in lieu of firm fixed effects to allow for the possibility that CEOs are differentially ambiguity averse. However, our results are robust to using a firm fixed effects model instead.\(^{20}\) We cluster standard errors by firm and quarter in the SUR estimation.

Consistent with our expectations, the coefficient estimates on both VP and DISP are negative and statistically significant across all four specifications. This indicates that increases in ambiguity result in decreases in managerial investment, after controlling for other factors known to affect investment. The results also indicate that idiosyncratic return volatility is negatively associated with investment, consistent with findings in Panousi and Papanikolaou (2012). However, we do not find a relation between market returns and investment. This may be because ambiguity is the main driver of managerial investment decisions at the macro level (Anderson et al., 2009).

Economically speaking, we find that a one standard deviation in VP (DISP) leads to a 1.55% (3.74%) decrease in a firm’s investment. Although the economic magnitude of ambiguity may seem relatively small, we note that it is comparable to that of our risk measures. For example, the economic significance of VP (-1.55%) is higher than that of \(\text{ExpRet} (-0.51\%)\), \(\text{EarnVol} (0.12\%)\), and \(\text{Z-Score} (-0.06\%)\), but lower than that for \(\text{ExpIdioVol} (-2.28\%)\). Moreover, the

\(^{19}\) When we test the residual correlation across the investment and cash holdings models, we find a correlation of 0.0234 (p-value <0.01), supporting our use of SUR. We also verify the robustness of our inferences to an alternate investment model (see section 4.1) and an alternate estimation method, Generalized Method of Moments (see section 4.4).

\(^{20}\) Although we use the demeaned variables for ease of interpretation, we also run the regression without demeaning the variables and including CEO indicators and results are robust.
economic significance of DISP (-3.74%) is higher than all four risk/volatility measures: ExpRet (0.18%), ExpIdioVol (-2.18%), Z-Score (-0.06%) and EarnVol (0.09%).21 Despite these relatively low economic effects, there is a large and well-developed literature that attempts to better understand how risk impacts investment and cash holdings. It is in this context that we hope to make a contribution by providing evidence on how firms adjust their investment and cash holdings under ambiguity as well as how the value of their investment opportunities differ under ambiguity than under risk.

We further find that CSI is positive and statistically significant, indicating that when investors are optimistic about the economy, investment increases. Finally, consistent with prior investment research, we find that a firm’s executive compensation and some board characteristics (e.g., the dual role of CEO and president of the board and the proportion of independent directors on the board) also impact its investment level, highlighting the importance of controlling for these characteristics when assessing the impact of ambiguity on investment.

3.2. Ambiguity and cash holdings

We next examine whether ambiguity impacts cash holdings by constructing a firm-quarter cash holdings model. In particular, we estimate the following regression using seemingly unrelated regressions (firm subscripts omitted):

\[
Cash_t = a_0 + a_1 Ambiguity_{t-1} + a_2 Q_t + a_3 Size_t + a_4 CFO_t + a_5 Working Capital_t + a_6 I/A_t + a_7 Leverage_t + a_8 R&D_t + a_9 Dividends_t + a_{10} \Delta Cash_{t-1} + a_{11} Cash_{t-1} + a_{12} CSI_{t-1} + a_{13} \Delta GDP_{t-1} + a_{14} ExpRet_{t-1} + a_{15} \Delta ExpIdioVol_{t-1} + a_{16} Z-Score_{t-1} + a_{17} \Delta EarnVol_{t-1} + a_{18} \% Options_{t-1} + a_{19} CEO Ownership_{t-1} + a_{20} DualRole_{t-1} + a_{21} \# Directors_{t-1} + a_{22} \% IndepDir_{t-1} + \varepsilon
\]  

(12)

Again, our main variable of interest is Ambiguity, defined as either VP or DISP. If our hypothesis holds, we would expect a positive and statistically significant coefficient on Ambiguity

\[\text{21 Economic magnitudes are similar in our cash holdings and investment opportunities analyses found in section 3.2 and 3.3.}\]
We include in this model several categories of control variables. First, following Opler et al. (1999), we control for investment opportunities (Q), firm size (Size), cash flows from operations (CFO), liquid asset substitutes (Working Capital), capital investment (I/A), leverage (Lev), the potential for financial distress costs (R&D), dividend payouts (Dividend) and the future change in cash, which allows for the existence of transitory cash holdings (ΔCASH_{t+1}). The descriptive statistics for these variables are included in Table 2.

These control variables are defined as follows: Q is the market value of assets, scaled by the book value of assets; Size is the natural logarithm of the market value of equity; CFO is the cash flows from operations reported in the statement of cash flow, scaled by total assets; Working Capital is the difference between non-cash current assets and current liabilities scaled by total assets; I/A is the amount of capital expenditures, scaled by total assets; Lev is the sum of short-term debt and long-term debt, scaled by total assets; R&D is the cost incurred to develop new products or services, scaled by total assets, and is coded as zero if missing; Dividend is an indicator variable set to 1 if the firm paid a dividend in the quarter and zero otherwise; and ΔCASH_{t+1} is the change (from period t-1 to period t) in cash and cash equivalents, scaled by total assets. We compute the total assets in the denominators of all variables as assets less Cash.

Second, we include controls for investor sentiment (CSI), general macroeconomic conditions (ΔGDP) and risk (ExpRET). We also control for a firm’s stock price volatility (ExpIdioVol) and earnings volatility (EarnVol), as prior research (e.g., Ozkan and Ozkan 2004; Kim et al., 1998) argues that volatility is an important determinant of cash holdings. To control for financial

---

22 As Opler et al. (1999, p.29) indicate, “[S]ome of the cash holdings are transitory, because a firm might have raised funds that it is waiting to spend, or the firm has raised funds simply because it is away from its target holdings. To allow for the existence of transitory cash holdings, we add next year’s change in cash holdings as an explanatory variable. If a firm has unusually high cash because the firm just raised funds that will be spent next year, this variable should capture the part of cash holdings that is transitory.”

23 See Opler et al. (1999) for detailed explanations for the inclusion of the variables.
constraints, we supplement the \textit{R&D} measure from Opler et al. (1999) with the inverse of the Altman Z-score ratio (Kim et al., 1998; Garcia-Teruel and Martinez-Solano, 2008).

As in our investment regression, we control for both executive compensation (\%\textit{Options}) and governance characteristics (\textit{CEO Ownership}, \textit{DualRole}, \#\textit{Directors} and \%\textit{IndepDir}) to capture any agency costs that may affect a firm’s cash holding decisions (Ozkan and Ozkan 2004). These variables are defined as before.

Table 4 provides the results from estimating our cash holdings model (equation 12). Specifically, when we measure ambiguity as the variance premium (\textit{VP}), we find that the coefficient of ambiguity is positively and statistically significant at the 5\% level, consistent with our expectations. However, when ambiguity is defined as the dispersion in quarterly corporate profit forecasts (\textit{DISP}), the coefficient of \textit{DISP} is not statistically significant at conventional statistical significance levels. Economically speaking, a one standard deviation in \textit{VP} leads to a 0.35\% increase in cash holdings, which is comparable in magnitude to the impact of our risk measures.

Further, we find that cash holdings are positively correlated with both \textit{Q} and cash flows, and negatively correlated with size, leverage, net working capital and dividends. In addition, consistent with our expectations, we find that the lagged values of cash holdings are a strong predictor of a firm’s current cash holdings. We also find that the coefficient on \textit{CSI} is negative and statistically significant, indicating that, when investors are optimistic about the economy, cash holdings decrease.

3.3. Ambiguity, risk and investment opportunities

To further support our findings that ambiguity impacts managerial investment behavior, we examine the effect of ambiguity on the value of a firm’s investment opportunities. To do so,
we draw on intuition developed in Nishimura and Ozaki (2007), who use a real options framework to analytically model irreversible investment under ambiguity. In their study, they find that both an increase in risk and an increase in ambiguity reduce irreversible investment. However, they also find that an increase in ambiguity decreases the value of irreversible investment opportunities, whereas an increase in risk increases the value.

The intuition for these predictions is best illustrated with an example (adapted from Nishimura and Ozaki (2007)). In particular, consider a risk–neutral firm contemplating whether to expand operations (e.g., build a new factory) in response to a demand shock. Suppose that there are two periods—period 0 and period 1. Further, suppose that there is no uncertainty in period 0, and that $\pi_0$ represents the profit from selling products in period 0. In period 1, the operating profit is $\pi_1$, which can be either $\pi_b$ or $\pi_s$ depending on whether there is a boom (where the demand shock persists) or a slump (where the demand subsides), respectively. In order to expand operations and exploit the opportunity, the firm must invest $I$, where $\pi_s < I < \pi_b$. The firm can choose to invest in period 0 or period 1. Let $p_b$ be the probability of boom in period 1 and $r$ be the discount rate. As Nishimura and Ozaki (2007) illustrate, if the firm expands operations (i.e., invests) in period 0, the present value of expected cash flows becomes:

\[
(p_0 - I) + \frac{1}{1 + r}(p_b \pi_b + (1 - p_b)\pi_s),
\]

(13)

whereas if it postpones investment until period 1, the present value of expected cash flows is:

\[
\frac{p_b}{1 + r}(\pi_b - I),
\]

(14)

---

24 Note that the risk-neutral assumption is not a necessary condition for this intuition to hold. Nishimura and Ozaki (2004) consider a model where the decision-maker is both risk-averse and uncertainty-averse, and find similar results.
since period 1’s cash flow is \((\pi_b - I)\) in a boom and zero in a slump.\(^{25}\) Absent ambiguity, the firm feels confident that the boom probability is \(p_b\). Therefore, the firm compares (13) and (14) to determine the optimal timing for its investment.

However, it is unlikely that a firm is certain about the probability of a boom, and thus more likely that the firm has a set of boom probabilities (\(P\)). Further, the firm may not even be certain about the relative likelihoods of these boom probabilities. In such a scenario, ambiguity theory proposes a set of axioms under which the firm evaluates an investment opportunity using that probability corresponding to its worst-case probability measure. Therefore, (13) is replaced by:

\[
(\pi_0 - I) + \frac{1}{1+r} \left( \min_{p_b \in P} (p_b \pi_b + (1-p_b)\pi_s) \right),
\]

\[
= (\pi_0 - I) + \frac{1}{1+r} \left( \pi_s + \left( \min_{p_b \in P} p_b (\pi_b - \pi_s) \right) \right),
\]

since \(\pi_b > \pi_s\), and (6) is now:

\[
\frac{1}{1+r} \left( \min_{p_b \in P} p_b (\pi_b - I) \right)
\]

(16)

Let us now examine the differential impact between an increase in risk and an increase in ambiguity on the value of investment opportunities. Assume that \(P=[p_b - \varepsilon, p_b + \varepsilon]\), where \(\varepsilon \in (0,0.5)\) captures an increase in ambiguity. That is, \(\varepsilon\) characterizes the degree of managerial confidence in the estimate of \(p_b\). By contrast, we characterize an increase in risk as the mean–preserving spread of the second–period operating profit, \(\pi_1\).

\(^{25}\) Note that the value of an investment opportunity under the NPV rule is simply the outcome from (5). However, in a real–options framework, the value of investment opportunities includes the value of the option to postpone investment projects until more information becomes available. Hence, the value of the opportunity is the sum of the expected value of investing in period 0 (i.e., NPV today) and the value of the option to wait.
Suppose now that there is no ambiguity; however risk is increased such that the \((\pi_s, \pi_b)\) spread of \(\pi_1\) now becomes \((\pi_s - \gamma, \pi_b + \gamma)\). In this case, it is clear from (14) that the mean-preserving spread will always increase the value of the investment opportunity, as it increases the value of the option to postpone investment. Intuitively, this is because an increase in risk implies that when a firm waits, it can exploit the investment opportunity in the future, after uncertainty about the future state of the world is resolved. At the same time, an increase in risk does not impact the expected value of exploiting the investment opportunity today (see (13)). Therefore, the value of the investment opportunity will increase with an increase in risk.

Now suppose that ambiguity exists, but risk does not. In this case, the value of exploiting the investment opportunity in period 0 is characterized by (15), while the value of exploiting the opportunity in period 1 is characterized by (16). Expressions (15) and (16) show that an increase in \(\varepsilon\) decreases the lower bound of the set of possible boom state probabilities, \(P\), and hence, decreases the value of investing in either period 0 or period 1. Therefore, the value of the investment opportunity decreases with an increase in ambiguity. Since managers assume the worst-case probability measure when ambiguity increases, the value of the investment opportunity decreases.\(^{26}\)

Now that we have developed the intuition behind these predictions, we empirically test them using Tobin’s Q \((Q)\) as a proxy for investment opportunities. In particular, we regress \(Q\) on our macroeconomic ambiguity and risk measures as well as on our aggregate controls for economic

\(^{26}\) Note that managers need not assume the worst-case for our predictions to hold. Managers could simply assume more conservative estimates than they would under risk. Allowing \(\varepsilon\) to take on any value in the set captures this notion. Moreover, Nishimura and Ozaki (2007) show that the predictions from our two-period, two-state example generalize to a continuous time framework.
growth and investor sentiment and firm-level variables shown to be associated with Q (Yermack, 1996; Allayannis and Weston, 2001; Coles et al., 2008). This yields:

\[ Q_t = a_0 + a_1\text{Ambiguity}_t + a_2\text{Size}_t + a_3\text{CFO}_{t-1} + a_4\text{I}/\text{A}_{t-1} + a_5\text{Lev}_t + a_6\text{R} & \text{D}_t + a_7\text{CSI}_t + a_8\Delta\text{GDP}_t + a_9\text{ExpRET}_t + a_{10}\text{ExpIdioVol}_t + a_{11}\text{Z-Score}_t + a_{12}\text{EarnVol}_t + a_{13}\%\text{Options}_t + a_{14}\text{CEO Ownership}_t + a_{15}\text{DualRole}_t + a_{16}\#\text{Directors}_t + a_{17}\%\text{IndepDir}_t + \epsilon, \]  

(17)

where \textit{Ambiguity} represents one of our two ambiguity measures: \textit{VP} or \textit{DISP}, and all the other variables are defined as earlier. Note that, unlike the investment and cash holding analyses, where the outcomes of interest were firm decisions over the quarter, in the Q analysis, we examine expectations going into the quarter. Therefore, we measure all of our control variables contemporaneously to Q.

Table 5 reports the results from estimating the investment opportunity model using ordinary least squares regressions. As shown in Table 5, we find that the coefficient estimates of \textit{VP} and \textit{DISP} are negative and statistically significant at the 5\% and 1\% level or better, respectively, supporting our hypothesis that greater ambiguity reduces the value of investment opportunities. Conversely, we find that \textit{ExpRET} is positive and statistically significant at the 1\% level across all regressions, suggesting that macroeconomic risk increases the variance of potential investment payoffs, and thus the value of the investment opportunities.\textsuperscript{27} The coefficient estimates on \textit{ExpIdioVol} are also positive and statistically significant at the 1\% level, suggesting that firm-specific risk also has a significant impact on investment opportunities. Economically speaking, a one standard deviation in \textit{VP} (\textit{DISP}) leads to a 0.80\% (3.03\%) decrease in the value of a firm’s investment opportunities, which is comparable in magnitude to the impact of our risk measures.

\textsuperscript{27} Note that \textit{ExpRET} is measured at the market level whereas \textit{Q} is measured at the firm level, reducing concerns that the relation is mechanical. Furthermore, we measure \textit{Q} in period \textit{t} and \textit{ExpRET} over period \textit{t+1}, since we use realized returns as a proxy for expected returns.
Taken together, these findings support our hypothesis that ambiguity (risk) decreases (increases) the value of investment opportunities for a firm.

4. Robustness

4.1. Alternate investment model specification

In the neoclassical investment models, marginal $q$ is the only determinant of investment (Tobin, 1969; Hayashi, 1982). However, subsequent research identifies frictions arising from the separation of ownership and control, which may cause deviations from the neoclassical prediction.\(^{28}\) Further, since marginal $q$ is unobservable, and measurement error may prevent the proxies from completely controlling for investment opportunities (e.g., Erickson and Whited, 2000), we use an Euler equation approach to address these issues.

To test the robustness of our results, we empirically model investment using sales growth in the prior period ($SalesGrowth$) as the proxy for investment opportunities following prior literature (Wurgler, 2000; Lang et al., 1996; Billett et al., 2007; Kolasinski, 2009; Badertscher et al., 2013). We also include the age of the firm ($Age$) as a firm’s life cycle may be correlated with its investment opportunities (Rauh, 2006). We further include $CFO$, $Cash$ and $Lev$ to capture capital constraints, following Lang et al. (1996) and Denis and Sibilkov (2010). These additions yield the following pooled regression using ordinary least squares (firm subscripts are omitted):

$$
\frac{I}{A_t} = a_0 + a_1 Ambiguity_{t-1} + a_2 I/A_{t-1} + a_3 I/A_{t-4} + a_4 SalesGrowth_{t-1} + a_5 CFO_t + a_6 Cash_{t-1} + a_7 Lev_t + a_8 Size_{t-1} + a_9 Age_t + a_{10} CSI_{t-1} + a_{11} ΔGDP_{t-1} + a_{12} ExpRET_{t-1} + a_{13} ExpIdioVol_{t-1} + a_{14} Z-Score_{t-1} + a_{15} EarnVol_{t-1} + a_{16} %Options_{t-1} + a_{17} CEO Ownership_{t-1} + a_{18} DualRole_{t-1} + a_{19} #Directors_{t-1} + a_{20} %IndepDir_{t-1} + \varepsilon_{i,t}
$$

where $SalesGrowth$ is the change in sales for period $t-1$, and $Age$ is the natural logarithm of the difference between the first year the firm enters Compustat and the beginning of period $t$. All other

\(^{28}\) See Hubbard (1998) for a review of the literature.
variables are measured as before. We include the investment in both the previous quarter \((I/A_{t-1})\) and the same quarter the previous year \((I/A_{t-4})\), to control for any firm-specific component of investment not captured by the other variables.

In Table 6, we report the coefficient estimates and p-values from estimating our alternate investment model (equation 18). Consistent with our earlier findings in Table 3 and ambiguity theory, our ambiguity measures, \(VP\) and \(DISP\), are each negatively associated with investment. Results on our risk, sentiment and economic growth measures are similar to those found in Table 3 as well. In sum, this alternate investment specification supports our predictions.

4.2. Alternate cash holding model specification

To further assess the robustness of our cash holding findings, we follow Ozkan and Ozkan (2004) and estimate the following dynamic partial adjustment model of target cash holdings, where we include our ambiguity measures as well as our macro- and firm-level controls:

\[
Cash_t = a_0 + a_1 Ambiguity_{t-1} + a_2 Cash_{t-1} + a_3 CFO_t + a_4 Liquidity_t + a_5 Lev_t + a_6 Q_t + a_7 Size_t + a_8 Dividend_t + a_9 CSI_{t-1} + a_{10} \Delta GDP_{t-1} + a_{11} ExpRET_{t-1} + a_{12} ExpIdioVol_{t-1} + a_{13} Z-Score_{t-1} + a_{14} EarnVol_{t-1} + a_{15} %Options_{t-1} + a_{16} CEO Ownership_{t-1} + a_{17} DualRole_{t-1} + a_{18} #Directors_{t-1} + a_{19} %IndepDir_{t-1} + \epsilon,
\]

(19)

where \(Liquidity\) is current assets minus current liabilities and total cash, scaled by total assets, and all the other variables are defined as before. For instruments, we use \(Ambiguity_{t-2}, Cash_{t-2}, CFO_{t-2}, Liquidity_{t-2}, Lev_{t-2}, Q_{t-2}, Size_{t-2}, Dividend_{t-2}, CSI_{t-2}, \Delta GDP_{t-2}, ExpRET_{t-2}, ExpIdioVol_{t-2}, Z-Score_{t-2}, EarnVol_{t-2}, %Options_{t-2}, CEO Ownership_{t-2}, DualRole_{t-2}, Directors_{t-2}, %IndepDir_{t-2}, \) and \(COGS_{t-2}\), where \(COGS\) is defined as the cost of goods sold, scaled by assets. Table 7 presents our findings from the GMM estimation of model (19). We see from the test of over-identification (i.e., Hansen-J statistic) that none of the instruments are correlated with the error term. Moreover, we find a
positive and statistically significant (p-value <0.10) relation between VP and firm-level cash holdings consistent with our hypothesis.

4.3. Other robustness tests

To further test the robustness of our results, we run a battery of tests using alternative measures of our variables and alternative empirical specifications. We present the results below.

4.3.1. Alternate measures

- *Ambiguity*: Following prior research (Williams, 2010), we use the level of the VIX as a proxy for ambiguity, and find that our inferences are unchanged.

- *Sentiment*: We replace the Consumer Sentiment Index with the Baker and Wurgler (2007) index of sentiment (a constructed index based on trading volume), the dividend premium, the closed-end fund discount, the number of and first-day returns on IPOs, and the equity share in new issues). Once again, we find that our inferences are unchanged.

- *Economic growth*: We use the level of economic growth as opposed to the change in economic growth and find that our inferences are unchanged.

4.3.2. Alternate specifications

- *GMM Estimation of Investment Model*: Following prior literature (e.g., Love, 2003), we estimate our investment model using the generalized method of moments (GMM) and find that our results are robust to this alternative estimation method.29

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29 As instruments, we use the second lag of all independent variables plus cost of goods sold lagged two periods and industry fixed effects following Love (2003). We also test for over-identification and find the p-value for the Hansen J-Statistic is equal to 0.2940 (DISP model) and 0.2586 (VP model), indicating that our instruments are jointly valid.
• **Market Physical Expectation:** We include a control for market risk associated with conditional volatility, calculated as total volatility less the idiosyncratic volatility, \( \text{ExpIdioVol} \). One might argue that such physical expectations are readily available to the market and therefore capture risk. To calculate the conditional variance of the market returns \( (\text{VOL}) \), we follow the same procedure as outlined in calculating \( VP \). \( \text{VOL} \) is the resulting forecasted value for the upcoming period’s physical expected variance. We obtain results consistent with our predictions and find that our inferences are qualitatively similar to those obtained from our main tests.

• **Non-Linearity:** Our reported specification assumes a linear relationship between ambiguity and our outcomes of interest (investment, cash holdings and investment opportunities). However, it is possible that non-linearities in our ambiguity proxies may impact our results. To allow for this possibility, we include a squared ambiguity term in our regressions and find that our results are robust to this inclusion.

• **Quantile Regressions:** To ensure that our results are not a function of outliers, we estimate quantile regressions at the 25\(^{th}\), 50\(^{th}\), and 75\(^{th}\) percentiles. Our inferences are robust across the percentiles.

• **Outliers:** Lastly, we examine the robustness of our results to winsorizing the data at three different levels; 0.05, 0.02 and 0.005. Our inferences remain unchanged.

5. **Conclusion**

In this study, we empirically examine the effects of ambiguity on managerial investment and cash holding decisions. Although traditional investment theory focuses on the risk-return trade-off in investment decisions, recent theoretical research suggests that macroeconomic ambiguity may play a separate role in influencing managerial investment. Following ambiguity
theory, we predict that greater ambiguity will lead managers to reduce capital expenditures and increase cash holdings. To rule out alternative explanations for our findings related to risk, investor sentiment, or economic growth, we control for market returns, the CSI, and changes in GDP, respectively. We also control for various firm-specific factors, such as agency issues, compensation, earnings volatility, lagged cash holdings, and financing constraints. Consistent with ambiguity theory, we document that, as ambiguity increases, firms both decrease investment and increase cash holdings.

To provide further support for our findings, we examine the effect of ambiguity on the value of investment opportunities. Drawing on the intuition developed in Nishimura and Ozaki (2007), we predict that an increase in ambiguity will decrease the value of investment opportunities, whereas an increase in risk will increase the value of investment opportunities. We provide empirical evidence consistent with this prediction.

This study offers several contributions. First, we contribute to the ambiguity and investment literatures by providing empirical evidence regarding the impact of ambiguity on managerial investment decision-making, and showing that this impact holds after controlling for various market and firm-specific factors. Second, we provide evidence as to the manner in which ambiguity affects corporate cash holdings. Finally, our empirical evidence on the relation between ambiguity and investment opportunities provides support for the use of our ambiguity and risk measures.
References


## Appendix - Variable Definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I/K$</td>
<td>= capital expenditures (CAPXY) scaled by beginning period capital (PPENTQ - CAPEXY + DAQ)</td>
</tr>
<tr>
<td>Cash</td>
<td>= cash plus cash equivalents (CHEQ) scaled by total assets (ATQ)</td>
</tr>
<tr>
<td>$Q$</td>
<td>= market value of assets scaled by the book value of assets (ATQ)</td>
</tr>
<tr>
<td>$VP$</td>
<td>= variance premium calculated over the last month of the prior quarter</td>
</tr>
<tr>
<td>DISP</td>
<td>= dispersion in quarterly corporate profit forecasts from the Survey of Professional Forecasters</td>
</tr>
<tr>
<td>$S/K$</td>
<td>= sales (REVTQ) scaled by beginning period Capital (PPENTQ - CAPEXY + DAQ)</td>
</tr>
<tr>
<td>Size</td>
<td>= natural logarithm of the market value of equity (PRCCQ x CSHOQ)</td>
</tr>
<tr>
<td>CFO</td>
<td>= cash flows from operations reported in the statement of cash flow (OANCFQ) scaled by total assets (ATQ)</td>
</tr>
<tr>
<td>Working Capital</td>
<td>= difference between non-cash current assets (ACTQ less CHEQ) and current liabilities (LCTQ) scaled by total assets (ATQ)</td>
</tr>
<tr>
<td>$I/A$</td>
<td>= capital expenditures (CAPXY) scaled by total assets (ATQ)</td>
</tr>
<tr>
<td>Lev</td>
<td>= sum of short-term debt and long-term debt (LTQ), scaled by total assets (ATQ)</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>= cost incurred to develop new products or services (XRDY) scaled by total assets (ATQ), and is coded as zero if missing</td>
</tr>
<tr>
<td>Dividend</td>
<td>= an indicator variable set to 1 if the firm paid a dividend in the quarter (DVY), zero otherwise</td>
</tr>
<tr>
<td>$∆Cash$</td>
<td>= change in cash and cash equivalents (CHEQ) scaled by total assets (ATQ)</td>
</tr>
<tr>
<td>CSI</td>
<td>= reported level of the quarterly Consumer Sentiment Index constructed by the Michigan Consumer Research Center at the beginning of each fiscal quarter</td>
</tr>
<tr>
<td>$∆GDP$</td>
<td>= percentage change in seasonally-adjusted real GDP over the calendar quarter with the maximum overlap with each fiscal quarter</td>
</tr>
<tr>
<td>$ExpRET$</td>
<td>= value-weighted market return over the quarter</td>
</tr>
<tr>
<td>$ExpIdioVol$</td>
<td>= monthly forecasted idiosyncratic volatility using a GARCH (1,1) for the firm at the beginning of the quarter. To calculate the idiosyncratic volatility used in the forecasts over the month, we sum the squared daily residuals from a firm specific regression of daily returns on the Fama-French three factors</td>
</tr>
</tbody>
</table>
| Z-Score$_t$ | = inverse of the Altman Z-score ratio (Altman, 1968) calculated as:  
\[ Z = \frac{3.3 \times EBIT(PIQ+XINTQ)}{TotalAssets(\text{ATQ})} + \frac{Sales(REVTQ)}{TotalAssets(\text{ATQ})} + 1.4 \frac{\text{retained earnings}(\text{REQ})}{\text{TotalAssets}(\text{ATQ})} + 0.6 \frac{\text{MarketValueEquity}(\text{CSHO*PRCCQ})}{\text{BookValueTotalDebt}(\text{LTQ})} \] |
| $EarnVol$ | = standard deviation of EBIT (PIQ+XINTQ) scaled by total assets (ATQ) calculated over a period of 12 quarters |
| %Options | = ratio of the Black-Scholes value of options granted (OPTION_AWARDS_BLK_VALUE) scaled by total compensation (TDC1) |
| CEO Ownership | = the number of shares owned by the CEO scaled by total common shares outstanding |
| DualRole | = indicator variable that takes a value of one for firms where the CEO is also the president of the board and zero otherwise |
| #Directors | = natural logarithm of the number of directors |
| %IndepDir | = number of independent directors scaled by the total number of directors on the board |
Table 1 – Sample Selection

This table reports the sample selection process for the samples used in our main analyses (Tables 3, 4 and 5). In parentheses, we indicate the database from which we collect the data for each of the variables.

<table>
<thead>
<tr>
<th></th>
<th>VP Sample</th>
<th>DISP Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observations</td>
<td>Data Range</td>
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<tr>
<td>All dependent variables,</td>
<td>295,847</td>
<td>'89-'09</td>
</tr>
<tr>
<td>ambiguity variable, primary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>independent control variables,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and macro control variables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Compustat, CRSP, Federal Reserve, Michigan Sentiment Index)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatility &amp; financing constraint variables (Compustat &amp; CRSP)</td>
<td>199,808</td>
<td>'89-'09</td>
</tr>
<tr>
<td>CEO identifier (ExecuComp)</td>
<td>59,223</td>
<td>'92-'09</td>
</tr>
<tr>
<td><strong>Large Sample</strong></td>
<td>59,223</td>
<td>'92-'09</td>
</tr>
<tr>
<td>Compensation variable (ExecuComp)</td>
<td>58,553</td>
<td>'92-'09</td>
</tr>
<tr>
<td>Governance variables (Risk</td>
<td>35,063</td>
<td>'95-'09</td>
</tr>
<tr>
<td>Metrics)</td>
<td></td>
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</tr>
<tr>
<td><strong>Small Sample</strong></td>
<td>35,063</td>
<td>'95-'09</td>
</tr>
</tbody>
</table>
Table 2 – Descriptive Statistics

This table reports summary statistics for our measures of investment, cash holdings, investment opportunities, ambiguity, macroeconomic controls, and firm-level controls. \( I/K \) is capital expenditures scaled by beginning period Capital. \( Cash \) is cash plus cash equivalents scaled by total assets. \( Q \) is the market value of assets scaled by the book value of assets. \( VP \) is the variance premium calculated over the last month of the prior quarter. \( DISP \) is the dispersion in quarterly corporate profit forecasts from the Survey of Professional Forecasters. \( S/K \) is the ratio of sales to beginning period capital. \( Size \) is the natural logarithm of the market value of equity. \( CFO \) is the cash flows from operations reported in the statement of cash flow scaled by total assets. \( Working\ Capital \) is the difference between non-cash current assets and current liabilities scaled by total assets. \( I/A \) is capital expenditures scaled by total assets. \( Lev \) is the sum of short-term debt and long-term debt scaled by total assets. \( R&D \) is the cost incurred to develop new products or services scaled by total assets and are coded as zero if missing. \( Dividend \) is an indicator variable set to 1 if the firm paid a dividend in the quarter, zero otherwise. \( ΔCash \) is the change in cash and cash equivalents scaled by total assets. \( CSI \) is the last reported level of the quarterly consumer sentiment index constructed by the Michigan Consumer Research Center at the beginning of each fiscal quarter. \( GDP\%) \) is the percentage change in seasonally adjusted real GDP over the calendar quarter with the maximum overlap with each fiscal quarter. \( ExpRET \) in the value weighted market return over the following fiscal quarter. \( ExpIdioVol \) is firm specific conditional volatility. \( Z\)-Score is the inverse of the Altman Z-score ratio (Altman, 1968). \( EarnVol \) the standard deviation of EBIT scaled by total assets calculated over the prior 12 quarters. \( %Options \) is the ratio of the Black-Scholes value of options granted/to total compensation. \( CEO\ Ownership \) is the number of shares owned by the CEO scaled by total common shares outstanding. \( Disp \) is an indicator variable that takes a value of one for firms where the CEO is also the president of the board, and zero otherwise. \#Directors \) is the natural logarithm of the number of directors. \%IndepDir \) is the number of independent directors scaled by the total number directors on the board. \( Liquidity \) is current asset minus current liabilities and total cash scaled by total assets. \( Age \) is the age of the firm in years.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>StdDev</th>
<th>1st Percentile</th>
<th>99th Percentile</th>
</tr>
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<tbody>
<tr>
<td>Dependent Variables:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I/K )</td>
<td>0.0643</td>
<td>0.0484</td>
<td>0.0610</td>
<td>0.0031</td>
<td>0.3009</td>
</tr>
<tr>
<td>( Cash )</td>
<td>0.1319</td>
<td>0.0562</td>
<td>0.1683</td>
<td>0.0001</td>
<td>0.7237</td>
</tr>
<tr>
<td>( Q )</td>
<td>1.8015</td>
<td>1.3123</td>
<td>1.7369</td>
<td>0.4241</td>
<td>8.5252</td>
</tr>
<tr>
<td>Ambiguity Variables:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( VP )</td>
<td>0.0031</td>
<td>0.0027</td>
<td>0.0026</td>
<td>0.0003</td>
<td>0.1226</td>
</tr>
<tr>
<td>( DISP )</td>
<td>0.3099</td>
<td>0.2695</td>
<td>0.1895</td>
<td>0.1066</td>
<td>0.8288</td>
</tr>
<tr>
<td>Investment, Cash Holdings &amp; Investment Opportunities Variables:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( S/K )</td>
<td>1.8988</td>
<td>1.0820</td>
<td>3.4015</td>
<td>0.0784</td>
<td>19.6424</td>
</tr>
<tr>
<td>( Size )</td>
<td>8.5499</td>
<td>7.4301</td>
<td>8.9896</td>
<td>4.2934</td>
<td>10.3352</td>
</tr>
<tr>
<td>( CFO )</td>
<td>0.0276</td>
<td>0.0265</td>
<td>0.0380</td>
<td>-0.0831</td>
<td>0.1436</td>
</tr>
<tr>
<td>( Working\ Capital )</td>
<td>0.0824</td>
<td>0.0759</td>
<td>0.2007</td>
<td>-0.4441</td>
<td>0.4894</td>
</tr>
<tr>
<td>( I/A )</td>
<td>0.0159</td>
<td>0.0113</td>
<td>0.0160</td>
<td>0.0007</td>
<td>0.0840</td>
</tr>
<tr>
<td>( Lev )</td>
<td>0.2454</td>
<td>0.2407</td>
<td>0.1746</td>
<td>0.0000</td>
<td>0.7186</td>
</tr>
<tr>
<td>( R&amp;D )</td>
<td>0.0533</td>
<td>0.0000</td>
<td>0.2773</td>
<td>0.0000</td>
<td>0.6363</td>
</tr>
<tr>
<td>( Dividend )</td>
<td>0.5818</td>
<td>1.0000</td>
<td>0.4932</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>( ΔCash )</td>
<td>-0.0021</td>
<td>0.0002</td>
<td>0.1401</td>
<td>-0.4134</td>
<td>0.3116</td>
</tr>
<tr>
<td>Macro Variables:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( CSI )</td>
<td>92.8900</td>
<td>92.1000</td>
<td>12.5800</td>
<td>55.3000</td>
<td>111.3000</td>
</tr>
<tr>
<td>( ΔGDP%)</td>
<td>0.6538</td>
<td>0.7345</td>
<td>0.6826</td>
<td>-1.6475</td>
<td>1.9506</td>
</tr>
<tr>
<td>( ExpRET )</td>
<td>0.0165</td>
<td>0.0277</td>
<td>0.0844</td>
<td>-0.2382</td>
<td>0.2129</td>
</tr>
<tr>
<td>Volatility &amp; Financing Constraints:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( ExpIdioVol )</td>
<td>0.0153</td>
<td>0.0099</td>
<td>0.0193</td>
<td>0.0016</td>
<td>0.0889</td>
</tr>
<tr>
<td>( Z)-Score</td>
<td>0.4136</td>
<td>0.4641</td>
<td>27.4234</td>
<td>-1.2910</td>
<td>4.3349</td>
</tr>
<tr>
<td>( EarnVol )</td>
<td>0.0142</td>
<td>0.0097</td>
<td>0.0138</td>
<td>0.0019</td>
<td>0.0671</td>
</tr>
<tr>
<td>Compensation:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( %Options )</td>
<td>0.7054</td>
<td>0.7710</td>
<td>0.2245</td>
<td>0.0039</td>
<td>0.9856</td>
</tr>
<tr>
<td>Governance:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( CEO\ Ownership )</td>
<td>0.0218</td>
<td>0.0029</td>
<td>0.0601</td>
<td>0.0000</td>
<td>0.3080</td>
</tr>
<tr>
<td>( DualRole )</td>
<td>0.5458</td>
<td>1.0000</td>
<td>0.4979</td>
<td>0.0000</td>
<td>1.0000</td>
</tr>
<tr>
<td>#Directors</td>
<td>9.3223</td>
<td>9.0000</td>
<td>2.3946</td>
<td>5.0000</td>
<td>16.0000</td>
</tr>
<tr>
<td>%IndepDir</td>
<td>0.6796</td>
<td>0.7142</td>
<td>0.1710</td>
<td>0.2000</td>
<td>0.9166</td>
</tr>
<tr>
<td>Additional Controls:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Liquidity )</td>
<td>0.0779</td>
<td>0.0652</td>
<td>0.1474</td>
<td>-0.2678</td>
<td>0.4576</td>
</tr>
<tr>
<td>( Age )</td>
<td>3.0928</td>
<td>3.2188</td>
<td>0.7293</td>
<td>1.3862</td>
<td>4.0430</td>
</tr>
</tbody>
</table>
Table 3 – Investment on Ambiguity Regression Results

This table reports the results obtained from estimating the investment regression (jointly with the cash holdings regression) using SUR, where \( \Delta K_t \) (capital expenditures scaled by beginning period capital) is the dependent variable. \( VP \) is the variance premium calculated over the last month of the prior quarter. \( DISP \) is the dispersion in quarterly corporate profit forecasts from the Survey of Professional Forecaster. \( S/K_t \) is the ratio of sales to beginning period capital. \( Cash \) is cash plus cash equivalents scaled by total assets. \( CSI \) is the last reported level of the quarterly Consumer Sentiment Index constructed by the Michigan Consumer Research Center at the beginning of each fiscal quarter. \( \Delta GDP \) is the percentage change in seasonally-adjusted real GDP over the calendar quarter with the maximum overlap with each fiscal quarter. \( ExpRET \) is the value weighted market return over the following fiscal quarter. \( ExpIdioVOL \) is firm-specific conditional volatility for the following quarter. \( Z-Score \) is the inverse of the Altman Z-score ratio (Altman, 1968). \( EarnVol \) is the standard deviation of EBIT, scaled by total assets calculated over the prior 12 quarters. %Options is the ratio of the Black-Scholes value of options granted/total compensation. CEO Ownership is the number of shares owned by the CEO scaled by total common shares outstanding. DualRole is an indicator variable that takes a value of one for firms where the CEO is also the president of the board, and zero otherwise. #Directors is the natural logarithm of the number of directors. %IndepDir is the number of independent directors, scaled by the total number directors on the board. All variables are regressed on CEO and time fixed effects in a first stage regression, then these demeaned variables are used in the main analysis. The standard errors are clustered by firm and quarter (Petersen, 2009).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( VP_{t+1} )</td>
<td>-</td>
<td>-0.5689*** [0.00]</td>
<td>-0.3841*** [0.00]</td>
<td>-0.0191*** [0.00]</td>
<td>-0.0127*** [0.00]</td>
</tr>
<tr>
<td>( DISP_{t+1} )</td>
<td>-</td>
<td>0.2559*** [0.00]</td>
<td>0.2569*** [0.00]</td>
<td>0.2555*** [0.00]</td>
<td>0.2573*** [0.00]</td>
</tr>
<tr>
<td>( I/K_{t-1} )</td>
<td>-</td>
<td>0.0051*** [0.00]</td>
<td>0.0055*** [0.00]</td>
<td>0.0052 [0.20]</td>
<td>0.0627*** [0.00]</td>
</tr>
<tr>
<td>( S/K_{t-1} )</td>
<td>-</td>
<td>0.0068*** [0.00]</td>
<td>0.0057*** [0.00]</td>
<td>0.0068*** [0.00]</td>
<td>0.0058*** [0.00]</td>
</tr>
<tr>
<td>( Cash_{t-1} )</td>
<td>-</td>
<td>0.0405*** [0.00]</td>
<td>0.0273*** [0.00]</td>
<td>0.0408*** [0.00]</td>
<td>0.0267*** [0.00]</td>
</tr>
<tr>
<td>Macro Controls:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( CSI_{t-1} )</td>
<td>-</td>
<td>0.0002*** [0.00]</td>
<td>0.0002*** [0.00]</td>
<td>0.0001*** [0.00]</td>
<td>0.0001*** [0.00]</td>
</tr>
<tr>
<td>( \Delta GDP_{t-1} )</td>
<td>-0.0041 [0.15]</td>
<td>-0.0002 [0.61]</td>
<td>-0.0006 [0.13]</td>
<td>-0.0005 [0.27]</td>
<td>-0.0014 [0.61]</td>
</tr>
<tr>
<td>Volatility &amp; Financing Constraints:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( ExpIdioVOL_{t-1} )</td>
<td>-0.0517*** [0.00]</td>
<td>-0.0758*** [0.00]</td>
<td>-0.0485*** [0.00]</td>
<td>-0.0725*** [0.00]</td>
<td></td>
</tr>
<tr>
<td>( Z-Score_{t-1} )</td>
<td>-0.0000 [0.92]</td>
<td>-0.0000 [0.92]</td>
<td>-0.0000 [0.90]</td>
<td>-0.0000 [0.91]</td>
<td></td>
</tr>
<tr>
<td>( EarnVol_{t-1} )</td>
<td>-0.0011 [0.70]</td>
<td>0.0055 [0.48]</td>
<td>-0.0016 [0.58]</td>
<td>0.0044 [0.57]</td>
<td></td>
</tr>
<tr>
<td>Compensation:</td>
<td>-</td>
<td>0.0044*** [0.00]</td>
<td>0.0050*** [0.00]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( %Options_{t-1} )</td>
<td>-0.0000 [0.49]</td>
<td>-0.0000 [0.52]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Governance:</td>
<td>-</td>
<td>0.0015** [0.03]</td>
<td>0.0012* [0.06]</td>
<td>0.0002 [0.31]</td>
<td></td>
</tr>
<tr>
<td>( %IndepDir_{t-1} )</td>
<td>-0.0086*** [0.00]</td>
<td>-0.0056** [0.03]</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Observations</td>
<td>59,223</td>
<td>35,063</td>
<td>60,119</td>
<td>35,717</td>
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<tr>
<td>R-squared</td>
<td>0.1131</td>
<td>0.1286</td>
<td>0.1146</td>
<td>0.1306</td>
<td></td>
</tr>
</tbody>
</table>

***, **, * indicates significance at the 0.01, 0.05 and 0.10 level, respectively.
Table 4 – Cash Holdings on Ambiguity Regression Results

This table reports the results obtained from estimating the cash holdings regression (jointly with the investment regression) using SUR, where CASH (cash and cash equivalents scaled by total assets) is the dependent variable. VP is the variance premium calculated over the last month of the prior quarter. DISP is the dispersion in quarterly corporate profit forecasts from the Survey of Professional Forecasts. Q is the market value of assets scaled by the book value of assets. Size is the natural logarithm of the market value of equity. CFO is the cash flows from operations reported in the statement of cash flow scaled by total assets. Working Capital is the difference between non-cash current assets and current liabilities scaled by total assets. I/A is capital expenditures scaled by total assets. Lev is the sum of short-term debt and long-term debt scaled by total assets. Dividend is an indicator variable set to one if the firm paid a dividend in the quarter, zero otherwise. CSI is the last reported level of the quarterly Consumer Sentiment Index constructed by the Michigan Consumer Research Center at the beginning of each fiscal quarter. ΔGDP is the percentage change in seasonally-adjusted real GDP over the calendar quarter with the maximum overlap with each fiscal quarter. ExpRET is the value-weighted market return over the following fiscal quarter. ExplDivol is firm-specific conditional volatility for the following quarter. Z-Score is the inverse of the Altman Z-score ratio (Altman, 1968). EarnVol is the standard deviation of EBIT scaled by total assets calculated over the prior 12 quarters. %Options is the ratio of the Black-Scholes value of options granted/total compensation. CEO Ownership is the number of shares owned by the CEO scaled by total common shares outstanding. DualRole is an indicator variable that takes a value of one for firms where the CEO is also the president of the board, and zero otherwise. %Directors is the natural logarithm of the number of directors. %IndepDir is the number of independent directors scaled by the total number directors on the board. All variables are regressed on CEO and time fixed effects in a first stage regression, then these demeaned variables are used in the main analysis. The standard errors are clustered by firm and quarter (Petersen, 2009).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VP_{t-1}</td>
<td>+</td>
<td>0.1564** [0.04]</td>
<td>0.1754** [0.05]</td>
<td>-0.0038 [0.16]</td>
<td>-0.0018 [0.38]</td>
</tr>
<tr>
<td>DISP_{t-1}</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Q_{t}     |               | 0.0021*** [0.00] | 0.0021*** [0.00] | 0.0020*** [0.00] | 0.0019*** [0.00] |
| Size_{t}  | -0.0000*** [0.00] | -0.0000*** [0.00] | -0.0000*** [0.00] | -0.0000*** [0.00] | -0.0000*** [0.00] |
| CFO_{t}   | 0.3618*** [0.00] | 0.3746*** [0.00] | 0.3628*** [0.00] | 0.3754*** [0.00] |                |
| Working Capital_{t} | -0.0246*** [0.00] | -0.0260*** [0.00] | -0.0253*** [0.00] | -0.0263*** [0.00] |                |
| I/A_{t}   | -0.5406*** [0.00] | -0.5124*** [0.00] | -0.5398*** [0.00] | -0.5357*** [0.00] |                |
| Lev_{t}   | -0.0143*** [0.00] | -0.0130*** [0.00] | -0.0137*** [0.00] | -0.0127*** [0.00] |                |
| R&D_{t}   | 0.0047*** [0.00] | 0.0024*** [0.03] | 0.0046*** [0.00] | 0.0029*** [0.01] |                |
| Dividend_{t} | -0.0017** [0.02] | -0.0016 [0.10] | -0.0018** [0.02] | -0.0017* [0.07] |                |
| ΔCASH_{t-1} | -0.0427*** [0.00] | -0.0444*** [0.00] | -0.0423*** [0.00] | -0.0430*** [0.00] |                |
| Cash_{t-1} | 0.7508*** [0.00] | 0.7610*** [0.00] | 0.7510*** [0.00] | 0.7607*** [0.00] |                |

Macro Controls:

| CSl_{t}   | -0.0001*** [0.00] | -0.0001*** [0.00] | -0.0001*** [0.00] | -0.0001*** [0.00] |                |
| ΔGDP_{t-1} | 0.0012*** [0.00] | 0.0009*** [0.02] | 0.0010*** [0.00] | 0.0008*** [0.04] |                |
| ExpRET_{t} | 0.0066** [0.01] | 0.0074*** [0.01] | 0.0038* [0.08] | 0.0049* [0.06] |                |

Volatility & Financing Constraints:

| ExpDivol_{t} | 0.0197 [0.15] | 0.0099 [0.61] | 0.0249* [0.07] | 0.0165 [0.39] |                |
| Z-Score_{t}  | -0.0000 [0.65] | 0.0000 [0.88] | -0.0000 [0.67] | 0.0000 [0.88] |                |
| EarnVol_{t}  | 0.0099 [0.71] | 0.0126* [0.08] | 0.0008 [0.73] | 0.0125* [0.08] |                |

Compensation:

| %Options_{t} | -0.0026*** [0.01] |                |                | -0.0027*** [0.01] |                |

Governance:

| CEO Ownership_{t} | 0.0000 [0.61] |                | 0.0000 [0.62] |                |
| DualRole_{t}      | 0.0004 [0.53] |                | 0.0004 [0.48] |                |
| %Directors_{t}    | -0.0008*** [0.00] |                | -0.0008*** [0.00] |                |
| %IndepDir_{t}     | 0.0024 [0.31] |                | 0.0023 [0.34] |                |

Observations 59,223 35,063 60,119 35,717
R-squared 0.6545 0.6659 0.6553 0.6658

***, **. * indicates significance at the 0.01, 0.05 and 0.10 level, respectively.
Table 5 – Investment Opportunities on Ambiguity Regression Results

This table reports the results obtained from our estimation of quarterly data by OLS, where investment opportunities (Q) is the dependent variable. \( VP \) is the variance premium calculated over the last month of the prior quarter. \( DISP \) is the dispersion in quarterly corporate profit forecasts from the Survey of Professional Forecasters. \( Size \) is the natural logarithm of the market value of equity. \( CFO \) is the cash flows from operations reported in the statement of cash flow scaled by total assets. \( I/A \) is capital expenditures scaled by total assets. \( Le v \) is the sum of short-term debt and long-term debt scaled by total assets. \( R&D \) is the cost incurred to develop new products or services, scaled by total assets. \( CSI \) is the last reported level of the quarterly Consumer Sentiment Index constructed by the Michigan Consumer Research Center at the beginning of each fiscal quarter. \( \Delta GDP \) is the percentage change in seasonally adjusted real GDP over the calendar quarter with the maximum overlap with each fiscal quarter. \( Exp RET \) is the value-weighted market return over the following fiscal quarter. \( Explidio VOL \) is firm-specific conditional volatility for the following quarter. \( Z-Score \) is the inverse of the Altman Z-score ratio (Altman, 1968). \( Earn Vol \) is the standard deviation of EBIT scaled by total assets calculated over the prior 12 quarters. \( \% Options \) is the ratio of the Black-Scholes value of options granted/total compensation. \( CEO Ownership \) is the number of shares owned by the CEO scaled by total common shares outstanding. \( DualRole \) is an indicator variable that takes a value of one for firms where the CEO is also the president of the board, and zero otherwise. \#Directors \ is the natural logarithm of the number of directors. \% Indep Dir \ is the number of independent directors scaled by the total number directors on the board. All variables are regressed on CEO and time fixed effects in a first-stage regression, then these demeaned variables are used in the main analysis. The standard errors are clustered by firm and quarter (Petersen, 2009).

<table>
<thead>
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<th></th>
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<tbody>
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<td>( VP_{t-1} )</td>
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<td>-11.9727*** [0.00]</td>
<td>-5.5220*** [0.02]</td>
<td>-0.6102*** [0.00]</td>
<td>-0.2880*** [0.00]</td>
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<tr>
<td>( DISP_{t-1} )</td>
<td>-</td>
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<td></td>
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<tr>
<td>( Size_{t-1} )</td>
<td>0.0001*** [0.00]</td>
<td>0.0001*** [0.00]</td>
<td>0.0001*** [0.00]</td>
<td>0.0001*** [0.00]</td>
<td></td>
</tr>
<tr>
<td>( CFO_{t-1} )</td>
<td>0.1365*** [0.00]</td>
<td>0.1533*** [0.00]</td>
<td>0.1354*** [0.00]</td>
<td>0.1532*** [0.00]</td>
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<tr>
<td>( I/A_{t-1} )</td>
<td>3.5611*** [0.00]</td>
<td>3.3762*** [0.00]</td>
<td>3.5335*** [0.00]</td>
<td>3.3712*** [0.00]</td>
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<tr>
<td>( Lev_{t-1} )</td>
<td>-0.2681*** [0.00]</td>
<td>-0.4064*** [0.00]</td>
<td>-0.2238*** [0.00]</td>
<td>-0.3636*** [0.00]</td>
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<tr>
<td>( R&amp;D_{t-1} )</td>
<td>0.0214** [0.02]</td>
<td>0.0343*** [0.00]</td>
<td>0.0194 [0.50]</td>
<td>0.0328*** [0.00]</td>
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<tr>
<td><strong>Macro Controls:</strong></td>
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<tr>
<td>( CSI_{t-1} )</td>
<td>0.0139*** [0.00]</td>
<td>0.0154*** [0.00]</td>
<td>0.0106*** [0.00]</td>
<td>0.0137*** [0.00]</td>
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<tr>
<td>( AGDP_{t-1} )</td>
<td>-0.0034 [0.65]</td>
<td>-0.0397*** [0.00]</td>
<td>-0.0271*** [0.00]</td>
<td>-0.0488*** [0.00]</td>
<td></td>
</tr>
<tr>
<td>( Exp RET_{t-1} )</td>
<td>0.5662*** [0.00]</td>
<td>0.6891*** [0.00]</td>
<td>0.5933*** [0.00]</td>
<td>0.7081*** [0.00]</td>
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<tr>
<td><strong>Volatility &amp; Financing Constraints:</strong></td>
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<td></td>
<td></td>
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<tr>
<td>( Explidio VOL_{t-1} )</td>
<td>2.1041*** [0.00]</td>
<td>1.9192*** [0.00]</td>
<td>2.1450*** [0.00]</td>
<td>1.9118*** [0.00]</td>
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</tr>
<tr>
<td>( Z-Score_{t-1} )</td>
<td>-0.0000 [0.66]</td>
<td>-0.0000 [0.88]</td>
<td>-0.0000 [0.70]</td>
<td>-0.0000 [0.88]</td>
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<td>( Earn Vol_{t-1} )</td>
<td>0.2217*** [0.00]</td>
<td>0.4298** [0.01]</td>
<td>0.2053*** [0.00]</td>
<td>0.3799** [0.02]</td>
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<td><strong>Compensation:</strong></td>
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<td></td>
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<tr>
<td>( % Options_{t-1} )</td>
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<td>0.1619*** [0.00]</td>
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<td>0.1697*** [0.00]</td>
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<td><strong>Governance:</strong></td>
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<td></td>
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<tr>
<td>( CEO Ownership_{t-1} )</td>
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<td>0.0006 [0.25]</td>
<td>0.0006 [0.23]</td>
<td>0.0006 [0.23]</td>
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<tr>
<td>( DualRole_{t-1} )</td>
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<td>0.0370*** [0.01]</td>
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<tr>
<td>( # Directors_{t-1} )</td>
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<td>0.0498*** [0.00]</td>
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<td>0.0494*** [0.00]</td>
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<td>( % Indep Dir_{t-1} )</td>
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<td>-0.5295*** [0.00]</td>
<td>-0.4726*** [0.00]</td>
<td>-0.4726*** [0.00]</td>
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</table>

Observations: \( 59,223 \)  
R-squared: \( 0.1078 \)

***, **, * indicates significance at the 0.01, 0.05 and 0.10 level, respectively.
Table 6 – Alternative Investment on Ambiguity Regression Results

This table reports the results obtained from our estimation of quarterly data by OLS, where I/A (capital expenditures scaled by total assets) is the dependent variable. VP is the variance premium calculated over the last month of the prior quarter. DISP is the dispersion in quarterly corporate profit forecasts from the Survey of Professional Forecaster. Sales Growth is the change in sales over the quarter scaled by assets. CFO is the cash flows from operations reported in the statement of cash flow scaled by total assets. Cash is cash and cash equivalents scaled by total assets. Lev is the sum of short-term debt and long-term debt scaled by total assets. Size is the natural logarithm of the market value of equity. Age is the age of the firm in years. CSI is the last reported level of the quarterly Consumer Sentiment Index constructed by the Michigan Consumer Research Center at the beginning of each fiscal quarter. ΔGDP is the percentage change in seasonally adjusted real GDP over the calendar quarter with the maximum overlap with each fiscal quarter. ExpRET is the value-weighted market return over the following fiscal quarter. ExpldioVOL is firm specific conditional volatility for the following quarter. Z-Score is the inverse of the Altman Z-score ratio (Altman, 1968). EarnVol is the standard deviation of EBIT scaled by total assets calculated over the prior 12 quarters. %Options is the ratio of the Black-Scholes value of options granted/total compensation. CEO Ownership is the number of shares owned by the CEO scaled by total common shares outstanding. DualRole is an indicator variable that takes a value of one for firms where the CEO is also the president of the board, and zero otherwise. #Directors is the number of shares owned by the CEO scaled by total common shares outstanding. %IndepDir is the number of independent directors scaled by the total number directors on the board. All variables are regressed on CEO and time fixed effects in a first stage regression, then these demeaned variables are used in the main analysis. The standard errors are clustered by firm and quarter (Petersen, 2009).

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Predictions</th>
<th>Coef</th>
<th>[p-value]</th>
<th>Coef</th>
<th>[p-value]</th>
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<td>I/A_{t-4}</td>
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<td>ExpldioVOL_{t-1}</td>
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<td>-0.0000</td>
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<td>0.01</td>
<td>0.0008***</td>
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<td>Governance:</td>
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<td>0.21</td>
<td>-0.0005</td>
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</table>

Observations  40,601  41,345  
R-squared  0.2113  0.2112

***, **, * indicates significance at the 0.01, 0.05 and 0.10 level, respectively.
Table 7 – Alternative Cash Holdings on Ambiguity Regression Results

This table reports the results obtained from our estimation of quarterly data by GMM, where Cash (cash and cash equivalents scaled by total assets) is the dependent variable. VP is the variance premium calculated over the last month of the prior quarter. DISP is the dispersion in quarterly corporate profit forecasts from the Survey of Professional Forecaster. CFO is the cash flows from operations reported in the statement of cash flow scaled by total assets. Liquidity is current asset minus current liabilities and total cash scaled by total assets. Leverage is the sum of short-term debt and long-term debt scaled by total assets. Q is the market value of assets scaled by the book value of assets. Size is the natural logarithm of the market value of equity. Dividend is an indicator variable set to one if the firm paid a dividend in the quarter, zero otherwise. CSI is the last reported level of the quarterly Consumer Sentiment Index constructed by the Michigan Consumer Research Center at the beginning of each fiscal quarter. ΔGDP is the percentage change in seasonally-adjusted real GDP over the calendar quarter with the maximum overlap with each fiscal quarter. ExpRET is the value-weighted market return over the following fiscal quarter. ExpldioVol is firm specific conditional volatility for the following quarter. Z-Score is the inverse of the Altman Z-score ratio (Altman, 1968). EarnVol is the standard deviation of EBIT, scaled by total assets calculated over the prior 12 quarters. %Options is the ratio of the Black-Scholes value of options granted/Total compensation. CEO Ownership is the number of shares owned by the CEO, scaled by total common shares outstanding. DualRole is an indicator variable that takes a value of one for firms where the CEO is also the president of the board, and zero otherwise. #Directors is the number of independent directors scaled by the total number directors on the board. All variables are regressed on CEO and time fixed effects in a first stage regression, then these demeaned variables are used in the main analysis. The standard errors are clustered by firm and quarter (Petersen, 2009).

<table>
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<tr>
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<th>[p-value]</th>
<th>Coef</th>
<th>[p-value]</th>
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<td>Casht-1</td>
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<td>Sizet</td>
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<td>CSIt</td>
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<td>[0.80]</td>
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<td>[0.05]</td>
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<td>-0.0024*</td>
<td>[0.09]</td>
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<td>-0.0127**</td>
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<td>-0.0154**</td>
<td>[0.01]</td>
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</tbody>
</table>

Hansen J-Stat [p-value] 0.6759 0.3077
Observations 32,203 33,461

***, **, * indicates significance at the 0.01, 0.05 and 0.10 level, respectively.