Is the relationship between investment and conditional cash flow volatility really ambiguous?*

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Abstract

Using a measure of conditional cash flow volatility, we explore the dynamic relationship between cash flow volatility and investment. For financially constrained (small and young) firms, we find current investment is negatively associated with both current and prior cash flow volatility. Importantly, our results suggest that financially constrained firms invest 23% less when faced with consistently high cash flow volatility. Interestingly, the relationship is not weakened in firms with high cash holdings. Lastly, within financially unconstrained firms, we find no evidence that cash flow volatility in financially unconstrained firms affects investment.

1 Introduction

In this paper, we address three questions. Firstly, what is the dynamic relationship, if any, between investment and cash flow volatility? Second, does the relationship between investment and cash flow volatility differ between financially constrained and unconstrained firms? Lastly, do cash holdings within a financially constrained firm affect the sensitivity of their investment decisions to cash flow volatility? Despite existing discussion on the dynamic link between investment and cash flow volatility in real option literature, to our knowledge these questions have not been explicitly addressed in the empirical literature.[1]

A possible reason for these open empirical questions is the difficulty in estimating a conditional cash flow volatility measure. Specifically, in the existing literature 'rolling methods' are used as a proxy for conditional volatility. These methods estimate volatility by calculating the scaled variance of cash flows over a fixed number of preceding years.[2] Because these rolling measures are constructed as averages over a number of years, these measures cannot be used to identify dynamic relationships between investment and cash flow at an annual frequency. To address the limitations of rolling measures, we follow De Veirman and Levin (2011) and construct a conditional operating cash flow volatility measure.[3] Because the measure estimates volatility independently each year it accounts for the cyclical changes that are not captured by rolling volatility measures.

The dynamic relationship between investment and cash flow volatility remains ambiguous according to existing literature. A major divide in the literature surrounds how the impact of cash flow volatility on investment differs between financially constrained and financially unconstrained firms. Real option models predict investment within financially constrained firms is more positively affected by cash flow volatility (Boyle and Guthrie, 2003; Hirth and Viswanatha, 2011). However, the financial flexibility literature and related empirical research suggest investment within financially constrained firms is negatively affected by cash flow volatility, contradicting the real options models (Minton and Schrand, 1999; Moyen, 2004; Almedia, Campello, and Weisbach, 2004). We develop five hypotheses from existing research. Initially, we posit a

[1]For example, Hirth and Viswanatha (2011) note the empirical relationship between cash flow volatility and investment whilst conditioning on cash holdings has not been addressed.

[2]For example, Jayaraman (2008) use 5 years, Minton and Schrand (1999) use 6 years, and Harford, Mansi, and Maxwell (2008) and Bates, Kahle, and Stulz (2009) use 10 years.

[3]We refer to the measure as 'conditional' as it captures changes in cash flow that are unexplained after conditioning on firm size, industry, time and interactions.

bidirectional association between cash flow volatility and investment. We then focus on the relationship between lagged cash flow volatility and current investment. Drawing upon the financial flexibility literature, we conjecture this relationship is negative within financially constrained firms and non-existent within financially unconstrained firms. Given cash holdings buffer a firm from cash flow shocks, we propose the strength of the relationship within financially constrained firms decreases with the level of firm cash holdings.

Our empirical findings suggest an economically important negative relationship between current investment and both prior and current cash flow volatility. Specifically, financially constrained firms invest 23% less when faced with consistently high cash flow volatility relative to equivalent firms facing consistently low cash flow volatility. Meanwhile, the effect of cash flow volatility on investment is negligible within financially unconstrained firms. Our results also indicate prior cash flow volatility is negatively associated with current investment while prior investment is negatively associated with current cash flow volatility. Lastly, we find the the strength of the observed negative relationship between cash flow volatility and investment within financially constrained firms, is positively associated with the level of cash holdings.

In our empirical design, we take advantage of the conditional volatility measure of Minton and Schrand (1999) and use Arellano and Bond dynamic panel estimation. In contrast to the cross sectional approach of Minton and Schrand (1999), our estimation method allows us to test and control for the dynamic inter-relationship between investment and cash flow volatility. To our knowledge, this is the first paper to test for the dynamics associated with investment and cash flow volatility. In addition, we are able develop hypotheses and test for questions posed by the real options literature.

In the real options literature, Boyle and Guthrie (2003) suggest the relationship between investment and cash flow volatility is positive within financially constrained firms and ambiguous within financially unconstrained firms. Our paper contributes to the literature by providing evidence directly contrary to the first of these predictions, finding the relationship between investment and cash flow volatility within financially constrained firms is substantially more negative than within financially unconstrained firms.

The findings of our paper broadly fit into the literature on financial flexibility. We extend the empirical study by Minton and Schrand (1999) by explicitly considering the role of financial constraints and cash holdings. Our empirical findings support Moyen (2004) who suggests financially constrained firms faced with cash flow volatility are less likely to invest cash flows, as well as Almedia, Campello, and Weisbach (2004) who find cash flow volatility has a relatively small impact on the investment decision within financially unconstrained firms. Lastly, our finding that cash holdings are positively associated with the relationship between investment and cash flow volatility within financially constrained firms is related to the finding of Harford, Mansi, and Maxwell (2008) that high cash holdings firms are characterised with high cash flow volatility.

Our paper is related to Comin and Philippon (2005) who look at the relationship between sales growth volatility and research & development expenditure. Our exploration of determinants of investment complement and add to research by Gala and Gomes (2012) by indicating the importance of financial constraint and cash holdings.

The paper proceeds as follows: Section 2 develops our hypotheses by examining the existing literature. Section 3 outlines the collection of our data. Section 4 illustrates our construction of key variables, and Section 5 examines the properties of the variables. Section 6 tests each of our hypotheses. Section 7 examines how our results may fit with existing real options literature. Section 8 reports some robustness checks, including the decomposition of the investment measure. Section 9 provides concluding remarks.

2 Development of hypotheses

Consider a firm with a risky investment opportunity. The current options for undertaking the investment include: i) fully undertake the investment, ii) partially undertake or stage the investment, or iii) delay the investment. If observed cash flow volatility is representative of uncertainty surrounding cash flows from the investment opportunity, the value of staging investment increases with cash flow volatility.[4] In this scenario staging of investment increases with cash flow volatility and therefore current investment levels decrease as a result of prior cash flow volatility, consistent with the model of Boyle and Guthrie (2003) in the absence of financial constraint. The findings of Minton and Schrand (1999), who empirically test the relationship, indicate a negative lagged relationship between cash flow volatility and investment in high cash

[4]The effect of the correlation between observed cash flows and volatility in the cash flows of future projects is discussed in more detail in Section 7.

flow firms, consistent with the basic real options model.[5] We put forward in our first hypothesis that the relationship discovered by Minton and Schrand (1999) is still present and observable.

Hypothesis 1: *Prior cash flow volatility is negatively associated with current investment.*

If the volatility of the estimated cash flows associated the investment is relatively small, the informational benefit from waiting will be small to the firm. Since the value of the real option to wait decreases, the firm is less likely to delay or stage the investment. Assuming the predicted low cash flow volatility is realised, the resulting relationship between prior investment and cash flow volatility is negative, as advanced in our second hypothesis.

Hypothesis 2: *Prior investment is negatively associated with current cash flow volatility.*

Does the relationship between investment and cash flow volatility differ between financially constrained and unconstrained firms? A financially constrained firm has limited access to external capital, and hence their ability to undertake investment is restricted. Moyen (2004) suggests financially constrained firms that face possible future cash shortfalls have an increased cash flow sensitivity,[6] and hence they build cash stocks rather than fund investments. At the extreme, Minton and Schrand (1999) note that firms facing increasing financial constraints may choose to forgo current investment. Under these conditions, financial constraints amplify the negative relationship between cash flow volatility and investment.

By definition, financially unconstrained firms can fully fund investments. Almedia, Campello, and Weisbach (2004) find there is no statistically significant relationship between cash levels and cash flow sensitivities within financially unconstrained firms. This is consistent with the explanation that financially unconstrained firms are unlikely to hold cash to guard against future shortfalls. Despite identifying a negative relationship between cash flow volatility and investment within their overall sample, Minton and Schrand (1999) find a weakened relationship for large firms, which according to evidence from Hadlock and Pierce (2010) tend to be financially unconstrained.

Real option models developed in Boyle and Guthrie (2003) and Hirth and Viswanatha (2011) capture the possibility that firms faced with cash flow volatility may delay current investment as opposed to forgoing it. Increased volatility in cash flows may represent increased

[5] Their testing is executed in a contemporaneous setting however their rolling volatility measure captures volatility over the previous five years, hence it is essentially a lagged variable in reference to current volatility.

[6] Cash flow sensitivity measures the inclination of a firm to save cash out of cash flows.

uncertainty, which generally implies the option to delay investment is more valuable to the firm. In contrast, the value of delaying investment may decrease as a result of cash flow volatility for a firm facing future financial constraints. The firm anticipates future cash shortfalls as a result of cash flow volatility, and if these shortfalls will restrict future investment the firm chooses current investment above optimal levels (Boyle and Guthrie, 2003). This effect implies a positive contemporaneous relationship between cash flow volatility and investment, leading to an ambiguous net relationship between previous cash flow volatility and current investment within financially constrained firms.

In contrast, there is no threat of cash shortfalls in financially unconstrained firms so cash flow volatility will not lead to over-investment. Provided volatility in observed cash flows impacts the volatility of the expected cash flows from the investment opportunity, the option to delay investment becomes more valuable with increasing cash flow volatility. Under these conditions, the model of Boyle and Guthrie (2003) predicts high cash flow volatility leads financially unconstrained firms to delay investment, implying a negative relationship between prior cash flow volatility and current investment. Hadlock and Pierce (2010) posit an alternative perspective, suggesting financially unconstrained (generally large and old) firms spread investment financing over longer periods of time which will decrease the strength of the relationship between current investment and cash flow volatility in these firms. Larger firms also benefit from the ability to spread investments over a range of projects and even industries, which may decrease the impact of observed cash flow volatility on investment opportunities as explored in Section 7.

In our third hypothesis, we posit the weight of the empirical evidence points to a negative relationship between prior cash flow volatility and current investment within financially constrained firms. Failure to identify this relationship would be consistent with the real options model of Boyle and Guthrie (2003), which suggest financially constrained firms over invest when faced with high cash flow volatility.

Hypothesis 3: *Within financially constrained firms, there is a negative relationship between prior cash flow volatility and current investment.*

In our fourth hypothesis, we put forward that the majority of evidence suggests that cash flow volatility does not affect investment within financially unconstrained firms. A negative relationship would suggest observed cash flow volatility has a material affect on the value of the option to delay investment within financially unconstrained firms.

Hypothesis 4: *Within financially unconstrained firms, cash flow volatility is not associated with investment.*

Cash holdings can provide a buffer against cash flow volatility in financially constrained firms; decreasing the likelihood of cash shortfalls which restrict the firms ability to undertake investment opportunities. The suggestion that cash holdings are important within financially constrained firms is supported by the finding of Bates, Kahle, and Stulz (2009) that small, young firms hold relatively more cash. Almedia, Campello, and Weisbach (2004) find that there is generally a positive and statistically significant cash flow sensitivity of cash for financially constrained firms, indicating the firms are inclined to save cash flows instead of funding investment. In their real option model, Boyle and Guthrie (2003) recognise the investment behaviour of a financially constrained firm converges toward that of a financially unconstrained firm if cash holdings are sufficiently high, suggesting the relationship between cash flow volatility and investment will be weaker. Therefore, we advance that the strength of the relationship between cash flow volatility and current investment decreases as cash holdings increase within financially constrained firms.

Hypothesis 5: *Within financially constrained firms, the strength of the negative relationship between cash flow volatility and investment decreases with the level of the firms' cash holdings.*

3 Data set

Using the Compustat North America Database, we take annual observations for all firms spanning 1965 to 2011. The sample provides 408,813 observations, representing 33,184 distinct firms. We drop all utilities and financial service companies (Standard industry codes 3000-3999 and 6000-6999 respectively). We also drop observations which include negative revenue, non-positive total assets or no stated year.

After constructing key variables, as detailed in Section 4, our sample consists of 172,176 observations with non-missing values for all key variables.[7] The observations span 16,228 unique

[7] Key variables are those which are used in testing Hypotheses 3-5, including *Log investment*$_{i,t}$, *Log DL OCF Volatility*$_{i,t}$, *SA index*$_{i,t}$, *Cash holdings*$_{i,t}$, *Sales growth*$_{i,t}$, *Sales-to-assets ratio*$_{i,t}$ and *Book-to-market ratio*$_{i,t}$.

firms. The properties of the constructed sample in relation to key variables are discussed in Section 5.

4 Variable construction

Table 1 provides the name, definition, construction method and data source of all constructed variables. The current section provides a more in-depth explanation on the construction of the volatility estimate and measure of financial constraint.

4.1 Conditional volatility measure

Cash flow volatility is constructed based on the *Operating cash flow*$_{i,t}$ variable. We follow the method of De Veirman and Levin (2011) and Keefe and Kieschnick (2012) to construct a conditional volatility measure. First, we estimate

$$\begin{aligned}\omega_{i,t} = \alpha + Year\vec{\beta_1} + Industry_i\vec{\beta_2} + SizeTercile_{i,t}\vec{\beta_3} + Year * Industry_i\vec{\beta_4} \\ + Year * SizeTercile_{i,t}\vec{\beta_5} + \epsilon_{i,t}\end{aligned} \tag{1}$$

where

i) $\omega_{i,t}$ represents *Cash flow growth*$_{i,t}$ from $t-1$ to t for firm i.

ii) $Year$ represents a matrix of year dummies with $\vec{\beta_1}$ the associated coefficient vector;

iii) $Industry$ represents a matrix of industry classification dummies based upon the five categories from Fama-French with $\vec{\beta_2}$ the associated coefficient vector;

iv) $SizeTercile$ represents a matrix of size tercile dummies based on total assets with $\vec{\beta_3}$ the associated coefficient vector;

v) $Year*Industry$ represents a matrix of interactions between the industry and year dummies and $\vec{\beta_4}$ the associated coefficient vector; and

vi) $Year * SizeTercile$ represents a matrix of interactions between the size and year dummies and $\vec{\beta_5}$ the associated coefficient vector.

The residual $\epsilon_{i,t}$ captures the deviation if firm i's growth in operating cash flows from the mean value after controlling for time, industry, size and related interactions. We utilise the regression errors, $\epsilon_{i,t}$, to estimate firm $i's$ conditional operating cash flow volatility at t as

$$\hat{\sigma}_{i,t} = \sqrt{\frac{\pi}{2}}|\epsilon_{i,t}|. \tag{2}$$

De Veirman and Levin (2011) show that $\hat{\sigma}_{i,t}$ is an unbiased estimator of the true conditional volatility. Throughout the paper, we refer to $\hat{\sigma}_{i,t}$ as $DL\ OCF\ Volatility_{i,t}$.

By using the residual $\epsilon_{i,t}$, the method of constructing $DL\ OCF\ Volatility_{i,t}$ implicitly defines volatility as the deviation of cash flows away from what can be explained by the time, industry, firm size or related interactions. This allows for cash flow trends over time, so a firm with increasing cash flows does not necessarily have volatile cash flows if the trend is industry wide or driven by time trends.

The distribution of the volatility estimates is shown in Figure 1a. We also explore a volatility measure constructed based on the natural logarithm of our estimates, $Log\ DL\ OCF\ Volatility_{i,t}$, constructed as $ln(DL\ OCF\ Volatility_{i,t}\ +1)$. The distribution of this measure is shown in Figure 1b. For testing Hypotheses 3-5 we construct a binary variable for high cash flow volatility by annually ranking all firms by $DL\ OCF\ Volatility_{i,t}$ and assigning the top tercile of firms a value of one for $High\ CFV\ Indicator_{i,t}$ and assigning the remaining firms a value of zero .

4.2 Financial constraint measure

We classify firms as either financially constrained or unconstrained using the proxies proposed by Hadlock and Pierce (2010), which are size and age. We follow their measures by taking size as the log of assets for each firm, and age as the current year minus the first year that the firm has a non-missing stock price on the Compustat file. From these measures we calculate the SA Index as follows:

$$SAIndex_{i,t} = (-0.737 * size_{i,t}) + (0.043 * size^2_{i,t}) - (0.040 * age_{i.t}) \tag{3}$$

Annually ranking all firms by $SA\ index_{i,t}$, the bottom tercile are classified as financially unconstrained and given a value of 1 for indicator variable $Financially\ unconstrained_{i,t}$. Likewise, all firms in the top tercile are given a value of 1 for indicator variable *Financially constrained*$_{i,t}$.

5 Summary statistics

Table 2 provides summary statistics of the key variables, including the number of observations, mean, standard deviation, maximum, minimum, skewness and kurtosis. Variables *Investment*$_{i,t}$, *DL OCF Volatility*$_{i,t}$, *Firm size*$_{i,t}$, *Firm age*$_{i,t}$, *Book-to-market ratio*$_{i,t}$, *Sales growth*$_{i,t}$, *Sales-to-assets ratio*$_{i,t}$, *Cash holdings*$_{i,t}$ and *Scaled operating cash flow*$_{i,t}$ have been winsorized at a 1% level.

The summary statistics of *Investment*$_{i,t}$ reveal the distributional characteristics of the variable depart from a normal distribution. Since *Investment*$_{i,t}$ is scaled by firms asset levels, the mean value of 0.1605 suggests the average firm invests over 16% of their asset value each year. This sample statistic may be inflated due to the large kurtosis and skewness in the data. The highly positive skewness indicates a 'fat tail' on the right hand side while the highly positive kurtosis represents the data has an extreme peak.

To improve the distributional features of the data we take the natural logarithm of the investment measure plus one, summarized in the variable *Log investment*$_{i,t}$. The skewness and kurtosis both reduce and the data appears to converge toward a normal distribution, as illustrated in Figure 2. The mean value of *Log investment*$_{i,t}$ is 0.1370, representing a slightly more reasonable investment level of 0.1468, or 14.7

To explore how the characteristics of financially constrained and unconstrained firms differ, Table 3 presents summary statistics on both subsamples. The mean investment level of financially unconstrained firms is 80% higher than financially constrained firms according to the *Log investment*$_{i,t}$ measure.[8] The standard deviation of *Log investment*$_{i,t}$ is more than twice as high in financially constrained firms, indicating their investment spending is a lot more volatile. Financially constrained firms also have lower operating cash flows on average and face higher cash flow volatility. Mean cash holdings are more than five times higher in financially constrained firms and again substantially more volatile.

[8] Mean investment in financially constrained is $e^{0.1835} - 1 = 0.2014$ and in financially unconstrained firms $e^{0.1052} - 1 = 0.1109$. The percentage difference is $100 * (\frac{0.2014-0.1109}{0.1109}) = 81.6\%$.

Table 4 summarizes the correlations between key variables constructed. Contemporaneous cash flow volatility and investment measures are positively correlated.[9] The impact of the natural logarithm transform of the investment and volatility measures on their correlations is very subtle, indicating the relationship between variables is preserved through this transform. Volatility measures are positively correlated with both $SA\ index_{i,t}$ and $Cash\ holdings_{i,t}$, indicating cash flow volatility is positively associated with financial constraint and cash holdings.

6 Testing

6.1 Hypotheses 1 & 2: The bidirectional relationship

To mitigate any omitted variable bias in future regressions, appropriate lag variables must be included. Therefore, we test for the bidirectional relationship between investment and cash flow volatility. Specifically, we test Hypotheses 1 and 2 using the Granger causality test. We adapt the method outlined by Gujarati (2003) to panel data using Arellano-Bond linear dynamic panel data estimation. Standard errors are clustered by firm and estimated using the sandwich estimator of variance.

Our testing is based around Equation (4).

$$loginv_{i,t} = c_i + \sum_{j=1}^{n} \alpha_j loginv_{i,t-j} + \sum_{j=1}^{n} \beta_j logvol_{i,t-j} + \epsilon_{i,t} \tag{4}$$

Hypothesis 1 suggests prior cash flow volatility is negatively associated with current investment. If this is not the case, knowing the value of lagged volatility provides no additional explanatory power in the prediction of current investment. In a Granger causality test setting, this translates to a test with H_0: Cash flow volatility does not Granger cause investment i.e. $H_0 : \sum_{j=1}^{n} \beta_j = 0$ and H_1 : Not H_0.

We test the joint significance of our beta estimates using a Wald chi-squared test. Panel A of Table 5 reports the regression results for different lag lengths. For each lag lenght, we reject H_0 at a 99% confidence level. The coefficients associated with lagged volatility are nega-

[9] Note this univariate correlation lacks appropriate control variables which are used in our multivariate tests executed in Section 6.

tive, indicating prior cash flow volatility is negatively associated with current investment which provides evidence consistent with Hypothesis 1.

The positive coefficients of lagged investment suggest investment spending in the previous period has a positive relationship on current investment spending. The large magnitude of the coefficients on the first lag of *Log investment*$_{i,t}$ indicate high first order autocorrelation is present, consistent with firms staging investments as predicted by the financial flexibility literature.

Similarly, we explore whether investment Granger causes cash flow volatility. The set up for the test closely matches the above and testing is based around Equation (5).

$$logvol_{i,t} = k_i + \sum_{j=1}^{n} \lambda_j logvol_{i,t-j} + \sum_{j=1}^{n} \delta_j loginv_{t-j} + \gamma_{i,t} \tag{5}$$

where $H_0 : \sum_{j=1}^{n} \delta_j = 0$ and H_1 : Not H_0.

Using the Wald chi-squared test, Panel B of Table 5 tests the joint significance of the δ_j estimates. These results lead to the rejection of H_0 at a 99% confidence level, implying cash flow volatility materially influences investment. The coefficient on lagged investment is negative suggesting higher prior investment is associated with lower current cash flow volatility, consistent with Hypothesis 2. The positive coefficient on lagged volatility suggests cash flow volatility has high first order correlation. The negative relationship identified in Hypothesis 2 is not analyzed in-depth within this paper, but may present an area for valuable future empirical research. [10]

A key inference from the Granger causality tests is the presence of first order autocorrelation in both *Log investment*$_{i,t}$ and *Log DL OCF Volatility*$_{i,t}$, which indicates the need to include lagged variables in subsequent regressions to avoid an omitted variable bias. Overall, the Granger causality tests provide evidence in support of Hypothesis 1, prior cash flow volatility is associated with lower current investment, as well as Hypothesis 2, prior investment is negatively associated with current cash flow volatility. These results provide a solid base for testing Hypotheses 3 and 4.

[10] In Section 8.2 we explore the robustness of these Granger causality tests. We discuss the correlation of regression errors, the use of variables that have not been log transformed and the appropriate number of lags to include.

6.2 Hypotheses 3 & 4: Conditioning on financial constraint

In this section, we test how the relationship between investment and cash flow volatility varies according to a firm's financial constraint. Hypothesis 3 suggests prior cash flow volatility is negatively associated with investment within financially constrained firms, whilst Hypothesis 4 suggests cash flow volatility is not associated with investment within financially unconstrained firms.

To test Hypothesis 3 we estimate the regression shown in Equation 6. Since our results in Section 6.1 indicate investment levels are highly autocorrelated, we include lagged investment as a control variable. The presence of this lagged variable in the regression leads us to again utilize the Arellano-Bond linear dynamic panel data estimation with robust standard errors clustered by firm.

$$
\begin{aligned}
loginv_{i,t} = \alpha_i + \nu_t + \beta_1 highCFV_{i,t} + \beta_2 l.highCFV_{i,t} + \beta_3 Cons_{i,t} + \delta_1 (HighCFV_{i,t} * Cons_{i,t}) \\
+ \delta_2 (l.highCFV_{i,t} * Cons_{i,t}) + \delta_3 (l.highCFV_{i,t} * highCFV_{i,t}) \\
+ \gamma_1 (highCFV_{i,t} * l.highCFV_{i,t} * Cons_{i,t}) + \sum_{j=1}^{n} c_j CONTROL^{j}_{i,t}
\end{aligned}
\tag{6}
$$

i) $loginv_{i,t}$ is the natural logarithm of investment levels of firm i at time t;

ii) α_i is a firm dummy to account for variance within a particular firm;

iii) ν_t is a time dummy to account for variance across the sampling period;

iv) $l.highCFV_{i,t}$ is an indicator variable which is one if firm i was in the top tercile of cash flow volatility in period $t-1$ and zero otherwise;

v) $highCFV_{i,t}$ is an indicator variable which is one if firm i is in the top tercile of cash flow volatility in period t and zero otherwise;

vi) $Cons_{i,t}$ is an indicator variable which is one if firm i is in the top tercile of financial constraint in period t and zero otherwise;

vii) $CONTROL_{i,t}$ includes one period lagged investment as discussed in Section 6.1 as well as: sales growth to account for realised firm growth, book-to-market ratio to proxy growth opportunities and sales-to-capital ratio to proxy firm productivity shocks.

In our third hypothesis, we posit that cash flow volatility impacts investment decisions within financially constrained firms, and so the expected level of investment varies when conditioning on cash flow volatility levels. The impact of current cash flow volatility on investment is explored when the $highCFV_{i,t}$ indicator changes from zero to one, captured by the term $\beta_1+\delta_1$. Similarly, the impact of prior cash flow volatility is captured in the parameters $\beta_2+\delta_2$. The overall impact of consistently high cash flow volatility on investment is captured in the marginal term generated when both $highCFV_{i,t}$ and $l.highCFV_{i,t}$ are equal to one, which is $\beta_1 + \beta_2 + \delta_1 + \delta_2 + \delta_3 + \gamma_1$. Based on our hypothesis, we expect this sum of coefficients to be statistically different from zero.

Table 6 provides estimation results of Equation (6). Column (4) of Table 6 presents the coefficients of the full specification. Column (4) shows the estimate $\beta_1 + \delta_1 = 0.0098$. This term captures the behaviour of a firm with high cash flow volatility in the current period, but not in the previous period, suggesting they invest more than a firm with consistently low cash flow volatility. The estimate $\beta_2 + \delta_2 =$ -0.0116 suggests financially constrained firms that faced high cash flow volatility last period but not in this period invest less than firms facing consistently low cash flow volatility. The economic importance of the coefficient, as discussed in Appendix A, suggests the magnitude of the decrease in investment is approximately 6%.[11] This evidence is consistent with our results in Section 6.1 as well as with Hypothesis 3.

Table 6 also reports that $\beta_1 + \beta_2 + \delta_1 + \delta_2 + \delta_3 + \gamma_1 =$ -0.0435. This suggests financially constrained firms with consistently high cash flow volatility invest 23% less than firms with consistently low volatility.[12] Therefore, our empirical findings strongly support Hypothesis 3 by showing a negative relationship between sustained cash flow volatility and investment within financially constrained firms. It is interesting to note that prior cash flow volatility appears to have a stronger affect on current investment decisions than contemporaneous cash flow volatility.

[11] E[A]=1.1977 for observations where Cons=1 and l.highCFV=0. The term $\beta_2 + \delta_2$ captures the increase in investment when l.highCFV=1 so from Equation (13) the relevant magnitude is $\frac{1.1977}{0.1977}(e^{-0.0116} - 1) = 0.0597$.

[12] E[A]=1.2193 for Cons=1, l.highCFV=0 and highCFV=0. Therefore, the economic importance of the term is $\frac{1.2193}{0.2193}(e^{-0.0435} - 1) = -0.2367$.

This may be because prior cash flow volatility is observable, and therefore more relevant to the decision process of both lenders to management.

Our fourth hypothesis suggests that within financially unconstrained firms, cash flow volatility does not impact investment decisions. If this is the case, conditional expectations of investment should be independent of prior or contemporaneous cash flow volatility. In order to test this relationship we estimate Equation (7).

$$
\begin{aligned}
loginv_{i,t} = \alpha_i + \nu_t + \beta_1 highCFV_{i,t} + \beta_2 l.highCFV_{i,t} + \beta_3 Uncons_{i,t} + \delta_1(HighCFV_{i,t} * Uncons_{i,t}) \\
+ \delta_2(l.highCFV_{i,t} * Uncons_{i,t}) + \delta_3(l.highCFV_{i,t} * highCFV_{i,t}) \\
+ \gamma_1(highCFV_{i,t} * l.highCFV_{i,t} * Uncons_{i,t}) + \sum_{j=1}^{n} c_j CONTROL^j_{i,t}
\end{aligned} \tag{7}
$$

where $Uncons_{i,t}$ is an indicator variable which is one if firm i is in the bottom tercile of financial constraint in period t and zero otherwise.

According to Hypothesis 4, cash flow volatility will not impact investment decisions in financially unconstrained firms and therefore the terms $\beta_1+\delta_1$, $\beta_2+\delta_2$ and $\beta_1+\beta_2+\delta_1+\delta_2+\delta_3+\gamma_1$ should all be close to zero.

The results in Table 7 are consistent with Hypothesis 4. Not only are the necessary terms statistically insignificant, but they are all of a smaller magnitude than for financially constrained firms. The term $\beta_1 + \beta_2 + \delta_1 + \delta_2 + \delta_3 + \gamma_1$=-0.0038 captures the impact of consistently high cash flow volatility on investment within financially unconstrained firms, suggesting financially unconstrained firms facing high cash flow volatility invest 2.7% less than those facing consistently low cash flow volatility.[13] This figure is not statistically different from zero at a 90% level and its magnitude is small relative to the case of financially constrained firms. Therefore, the statistical evidence does fully supports Hypothesis 4 as it suggests cash flow volatility does not materially affect investment decisions within financially unconstrained firms.

[13] E[A]=1.1642 for Uncons=1, l.highCFV=0 and highCFV=0. Therefore, the economic importance of the term is $\frac{1.1642}{0.1642}(e^{-0.0038} - 1) = -0.0269$.

6.3 Hypothesis 5: Conditioning on cash holdings

Do cash holdings within a financially constrained firm affect the sensitivity of their investment decisions to cash flow volatility? To answer this question we need to include an indicator variable that captures high cash holding firms into our testing regression. However, adding this indicator and appropriate interactions into the regression shown in Equation (6) results in serious collinearity issues. Given results from Sections 6.1 and 6.2 indicate lagged cash flow volatility has a strong influence on current investment, our subsequent testing will focus on the impact of previous cash flow volatility on investment, and hence we drop the contemporaneous indicator for high cash flow volatility from our regression equation. These transformations leave the regression for testing Hypothesis 5 as shown in Equation (8).

$$\begin{aligned} loginv_{i,t} = \alpha_i + \nu_t + \beta_1 l.highCFV_{i,t} + \beta_2 Cons_{i,t} + \beta_3 highCH_{i,t} + \delta_1 (l.highCFV_{i,t} * Cons_{i,t}) \\ + \delta_2 (l.highCFV_{i,t} * highCH_{i,t}) + \delta_3 (Cons_{i,t} * highCH_{i,t}) \\ + \gamma_1 (l.highCFV_{i,t} * Cons_{i,t} * highCH_{i,t}) + \sum_{j=1}^{n} c_j CONTROL^j_{i,t} \end{aligned} \tag{8}$$

where:

i) $loginv_{i,t}$ is the natural logarithm of investment levels of firm i at time t;

ii) α_i is a firm dummy to account for variance within a particular firm;

iii) ν_t is a time dummy to account for variance across the sampling period;

iv) $l.highCFV_{i,t}$ is an indicator variable which is one if firm i was in the top tercile of cash flow volatility in period $t-1$ and zero otherwise;

v) $Cons_{i,t}$ is an indicator variable which is one if firm i is in the top tercile of financial constraint in period t and zero otherwise;

vi) $highCH_{i,t}$ is the dummy variable which is one if firm i is in the top tercile of cash holdings period t and zero otherwise;

vii) $CONTROL_{i,t}$ includes one period lagged investment as well as sales growth, book-to-market ratio and sales-to-capital ratio.

As in Section 6.2 we utilize the Arellano-Bond linear dynamic panel data estimation, employing robust standard errors which cluster by firm.

A financially constrained firm with low cash holdings and high cash flow volatility has marginal expected investment of $\beta_1 + \delta_1$ relative to an equivalent firm facing low cash flow volatility.[14] Similarly, in high cash holdings firms this marginal expected investment is given by $\beta_1 + \delta_1 + \delta_2 + \gamma_1$.[15] Hypothesis 5 suggests the level of cash holdings impacts the relationship between investment and cash flow volatility. The difference in the impact cash flow volatility has on investment in firms with high cash holdings, relative to firms with low cash holdings is captured in the term $\delta_2 + \gamma_1$. We suggest this term is different from zero, and a positive value would indicate investment within firms with high cash holdings is less negatively affected by cash flow volatility, consistent with Hypothesis 5.

The results of the full regression are shown in Column (2) of Table 8. The results indicate a firm with low cash holdings is expected to invest 15.9% less when facing high cash flow volatility.[16] Meanwhile, a firm with high cash holdings is expected to invest 25% less when faced with high cash flow volatility.[17] The difference between these figures is represented by $\delta_2+\gamma_1$=-0.0217, which is statistically significant at a 99% confidence level. These results suggest that the investment of a firm with high cash holdings is more negatively affected by cash flow volatility than one with low cash holdings. This provides evidence contrary to Hypothesis 5, which was developed under the assumption high cash holding are able to buffer a firm against the negative effect of cash flow volatility.

Our inability to find statistical support for Hypothesis 5 does not completely reject the idea that cash holdings are an important mechanism for buffering against cash flow volatility in financially constrained firms. Kaplan and Zingales (1997) discuss the ambiguity between the classification of a high cash holdings firm as financially unconstrained due to their cash wealth, or financially constrained due to their need to hold high cash to avoid future distress. This indicates the characteristics of firms with high cash holdings may provide insight into our findings. Consistent with the prediction of Almedia, Campello, and Weisbach (2004),

[14] $(k_{i,t} + \beta_1 + \beta_2 + \delta_1) - (k_{i,t} + \beta_2)$

[15] $(k_{i,t} + \beta_1 + \beta_2 + \beta_3 + \delta_1 + \delta_2 + \delta_3 + \gamma_1) - (k_{i,t} + \beta_2 + \beta_3 + \delta_3)$.

[16] E[A]=1.1642 for Cons=1, l.highCFV=0 and highCH=0. Therefore, the economic importance of the term is $\frac{1.1719}{0.1719}(e^{-0.0235} - 1) = -0.1590$.

[17] E[A]=1.2131 for Cons=1, l.highCFV=0 and highCH=1. Therefore, the economic importance of the term is $\frac{1.2131}{0.2131}(e^{-0.0453} - 1) = -0.2521$.

Table 3 indicates financially constrained firms hold more cash and invest less than financially unconstrained firms.

It is possible strategic cash flow saving decisions are made preemptively. For example, firms that are susceptible to cash flow shocks have high cash holdings to limit the affect of cash flow volatility on their ability to invest. Meanwhile, firms with low cash holdings are not as affected by cash flow volatility to begin with. Therefore the affect of cash flow volatility on the firms with high cash holdings appears to be larger, but it way be substantially less than the relationship if these firms had low cash holdings. The observed relationship between volatility and cash holdings provides evidence consistent with this explanation, and the findings of Harford, Mansi, and Maxwell (2008), as the mean of $Log\ DL\ OCF\ Volatility_{i,t}$ is 1.644 in firms with low cash holdings and 3.031 in firms with high cash holdings, suggesting high cash holdings firms are characterised with higher cash flow volatility.

7 Relating our findings to the real options literature

The results of our tests are not fully consistent with the basic predictions of the real options models discussed in Section 2. For example, we have found evidence contrary to the claim that investment within financially constrained firms is more positively affected by cash flow volatility than investment within financially unconstrained firms. We also found high cash holdings do not lead to the convergence of the investment behaviour between financially constrained and unconstrained firms facing cash flow volatility. In this section, we discuss how our conclusions may be consistent with the model of Boyle and Guthrie (2003) once the correlation between observed cash flows and growth opportunities is carefully considered.

In developing our initial hypotheses, we briefly mentioned the impact of the correlation between observed cash flow volatility and the volatility of the expected cash flows from the investment opportunity. The relationship is dependent on the correlation between observed cash flows and growth opportunities, and this is likely to vary according to the firm type. Since the extent to which firms investment decisions are affected by cash flow volatility will be influenced by this correlation, it is beneficial to explore whether this factor may play a role in driving the empirical relationships we observe.

Suppose observed cash flow volatility captures two major components: 'pure cash flow volatility' which is volatility in our current stream of cash flows, and 'growth option volatility' which is the increased uncertainty surrounding the cash flows of growth opportunities. The correlation between current cash flows and growth opportunities will determine the strength of 'growth option volatility' within the observed cash flow volatility.

Consider the case of financially constrained firms, typically small and young, where existing cash flows are likely to be strongly correlated with growth opportunities due to direct expansion. Since negative cash flow shocks will imply investment projects are less valuable, the firm is less likely to be restricted from undertaking a desirable investment due to their financial constraint. Therefore, pure cash flow volatility will not have a large impact on the firm's investment decision, whilst growth option volatility will have a strong influence. Also note that since the firm's financial constraint is not restrictive, the usefulness of cash holdings as a buffer is minimal. Increases in observed cash flow volatility will represent increased growth option volatility, so the firm may delay investment due to the increased value of the real option to wait. Therefore, if growth opportunities are strongly correlated with current cash flows, cash flow volatility will be negatively associated with investment, whilst cash holdings will have little affect on this relationship.

In financially unconstrained firms, which are typically large and old, sources of both current cash flows and future projects are likely to be more diverse. Therefore, current cash flows and growth opportunities will be less correlated. Cash flow shocks will not have a material impact on the ability of financially unconstrained firms to undertake investment, so pure cash flow volatility will not influence investment decisions. Also, observed cash flow volatility will be less correlated with growth option volatility, hence the impact of observed cash flow volatility on the value of delaying investment will be trivially small. Therefore, if the correlation between growth opportunities and current cash flows is low in financially unconstrained firms, there will be no observablel relationship between cash flow volatility and investment.

In order to give weight to this real option argument we must show cash flows today are positively correlated with growth opportunities within financially constrained firms, and much less correlated within financially unconstrained firms. As theory suggests market value is book value plus growth opportunities, then book-to-market ratio is a decreasing function of growth opportunities. Weak evidence in favour of the real options story is that financially unconstrained firms have a higher value of *Book-to-market* $ratio_{i,t}$ on average, as shown in Table 3, and the difference of 0.1327 is statistically significant at a 99% confidence level. However changes in cash flows are not significantly correlated with changes in growth opportunities, with a correlation coefficient between the changes in *Book-to-market* $ratio_{i,t}$ and changes in *Scaled operating cash* $flow_{i,t}$ of 0.0011 in financially constrained firms and -0.0032 in financially unconstrained firms. Both these figure are statistically insignificant and are close to zero in magnitude. When the relationship is tested on non-scaled cash flows, *Operating cash* $flow_{i,t}$, the correlations are unchanged. The results indicate changes in the observed cash flows of firms are not materially associated with changes in growth opportunities, regardless of the financial constraint of the firm. The evidence presented challenges the basic assumption of the alternative real options story, and hence leaves its legitimacy doubtful.

8 Robustness checks

8.1 Systematic volatility captured within volatility measure

By construction, the cash flow volatility measure *DL OCF* $Volatility_{i,t}$ attempts to capture firm idiosyncratic cash flow volatility. That is, volatility that cannot be explained by trends within years, industries or size groups. However, there is a possibility some systematic risk is captured within *DL OCF* $Volatility_{i,t}$ if material trends in cash flow volatility exist outside of the groups identified in its construction.

If systematic cash flow volatility was present, we would expect the relationship between *Log DL OCF* $Volatility_{i,t}$ and *Log* $investment_{i,t}$ to have a component invariant to the firm type. However, our identification of a distinctly different relationship within financially constrained and financially unconstrained firms indicates any invariant component within the relationship is minimal. This provides evidence consistent with the claim that our measure of cash flow volatility does not capture material amounts of systematic risk.

8.2 Granger causality test lags

In Section 6.1, we execute our Granger causality tests using measures transformed by the natural logarithm. For the purposes of comparison, Table 9 presents the results of the tests using non-transformed measures. The results show non-transformed measures also find evidence of Granger causality in both directions, indicating our findings do not rely on the use of natural logarithm transforms.

A requirement of the Granger causality test is that the errors of Equations 4 and 5 must be uncorrelated, that is $corr(\epsilon_{i,t}, \gamma_{i,t}) = 0$. The correlation coefficients are all under 0.21 for the regressions on log transformed measures. Using non-transformed measures the correlations are all above 0.25 and highly statistically significant which may lead to questions surrounding the validity of these tests. Therefore, we are further assured in our use of log transformed variables.

We identified the fact both Equations (4) and (5) have statistically significant first order autocorrelation. We also measure second order autocorrelation and find it is not statistically significant or economically important in either of the regressions. Determining the number of lags appropriate from which to draw our conclusions is a subjective decision. Wooldridge (2003) suggests "one or two" lags is appropriate for annual data. It appears the first lag terms have the strongest impact in terms of the size of their coefficients, though in most cases the second and third period lags are also statistically significant. Given we reject the null hypothesis in each case this decision does not impact our conclusions materially.

8.3 Decomposing the investment measure

The variable $Investment_{i,t}$ is constructed by combining measures of capital expenditure, research and development (R&D) expenditure and advertising expenditure. Although our conclusions are valid when referring to total levels of investment, it is possible the relationships identified vary across the investment types within the $Investment_{i,t}$ variable. To analyse this possibility we construct the variables *Log capital expenditure*$_{i,t}$, *Log R&D expenditure*$_{i,t}$ and*Log advertising expenditure*$_{i,t}$ in a method comparable to the construction of *Log investment*$_{i,t}$. We test the relationship between each of these investment components and cash flow volatility.

To ensure the fundamental negative relationship between investment and cash flow volatility holds across the investment measures, we execute the Granger causality test from Equation (4). The results, summarized in Table 10, reveal H_0 is rejected in all tests, which suggests cash flow volatility materially affects each of the investment measures. The first lagged coefficient on volatility is also negative in each case, implying a negative relationship comparable with the one observed in *Log investment*$_{i,t}$. The coefficient on volatility reveals cash flow volatility has the strongest affect on capital expenditure, relative to R&D and advertising.

To test if our conclusions regarding Hypotheses 3 differ with the type of investment we run the regression outlined in Equation (6), substituting the dependent variable *Log investment*$_{i,t}$ for the measures of capital expenditure, R&D and advertising, respectively. The results of these regressions are summarized in Table 11. For comparative purposes, the left hand column displays the results obtained using our original *Log investment*$_{i,t}$ measure.

The directions of coefficients on capital expenditure closely match the results from the *Log investment*$_{i,t}$ variable. The magnitude of $\beta_1+\beta_2+\delta_1+\delta_2+\delta_3+\gamma_1$ indicates capital expenditure is 25% lower in financially constrained firms facing consistently high cash flow volatility.[18] Both R&D and advertising expenditure also exhibit statistically significant negative relationships between investment and consistently high cash flow volatility.

In order to analyse Hypothesis 4, Table 12 presents the results of Equation (7) for each of the investment measures. For both R&D and advertising expenditure, the value of $\beta_1 + \beta_2 + \delta_1 + \delta_2 + \delta_3 + \gamma_1$ is statistically insignificant at a 95% level, consistent with Hypothesis 4. However, the figure is -0.0046 in the capital expenditure regression is statistically significant and suggests a financially unconstrained firm invests 4.6% less in capital expenditure when faced with consistently high cash flow volatility.[19]. Despite the significance of this finding, we note the magnitude is substantially smaller than in the case of financially constrained firms facing high cash flow volatility.

We conclude our findings are generally consistent with Hypothesis 3 and 4 within each of the components of investment. To examine the impact of cash holdings on the negative relationship relationship between investment and cash flow volatility we reestimate Equation (8) for each of the investment components. The results are presented in Table 13.

The impact of cash holdings on the relationship between cash flow volatility and investment is captured in the term $\delta_2 + \gamma_1$, as discussed in Section 6.3. The relationship between investment and cash flow volatility differs with cash holdings most in the case of R&D, where cash flow volatility has a much more negative impact on R&D for firms with high cash holdings.

[18] E[A]=1.1292 for Cons=1, l.highCFV=0 and highCFV=0. Therefore, the economic importance of the term is $\frac{1.1292}{0.1292}(e^{-0.0292}-1) = -0.2515$.

[19] E[A]=1.0994 for Cons=1, l.highCFV=0 and highCFV=0. Therefore, the economic importance of the term is $\frac{1.0994}{0.0994}(e^{-0.0042}-1) = -0.0464$.

Meanwhile, in the cases of capital expenditure and advertising, the affect of cash flow volatility is not statistically different between high and low cash holding firms at a 95% level. Overall, the evidence found using the components of $Investment_{i,t}$ is consistent with our original finding that a high level of cash holdings does not indicate a lesser impact of cash flow volatility on investment within financially constrained firms. The limitations in interpreting this result are again revealed in light of the findings of Brown and Petersen (2011), who analyse the role of cash holdings in smoothing R&D expenditure and find financially constrained firms use cash to buffer against volatility. This would indicate firms with high cash holdings do so because they face severe cash flows volatility, and hence a stronger observed negative relationship with R&D.

Overall, our results generally hold across the individual components of investment. The strength and magnitude of our results vary across the investment measures, highlighting the heterogeneous nature of investment spending. Since the constructed variable $Log\ investment_{i,t}$ represents real investment outflows to the firm, we suggest the results based on this measure capture relationships that are relevant to existing firms, and therefore represents a valid measure on which to base conclusions. Further exploration into the affect of cash flow volatility on individual components of investment spending such as capital expenditure, R&D and advertising, presents a broad and interesting area for future research.

9 Conclusion

Our paper provides valuable insight into the relationship between conditional cash flow volatility and investment. We are the first to use the De Veirman and Levin measure of conditional cash flow volatility in a corporate finance setting and initially find evidence that suggests investment and cash flow volatility exhibit a bidirectional relationship. We find, first, that prior cash flow volatility is negatively associated with current investment, and second, prior investment is negatively associated with current cash flow volatility.

Our results indicate the relationship between cash flow volatility and investment is strongly related to the financial constraints faced by the firm. Within financially constrained firms, high levels of cash flow volatility are associated with lower levels of investment. This negative relationship is not weakened in firms with increased levels of cash holdings, counter to the models developed by Boyle and Guthrie (2003) and Hirth and Viswanatha (2011). Additionally, within financially unconstrained firms the association between cash flow volatility and investment is negligible.

The findings of this paper go some way to resolving on-going debate on whether the relationship between cash flow volatility and investment is really ambiguous. By extending the empirical tests of Minton and Schrand (1999) we offer additional interpretations after conditioning on financial constraints and cash holdings. We conclude the relationship between cash flow volatility and investment is generally negative and not ambiguous.

Some questions remain open at the conclusion of this paper, and may provide areas for future research. An exploration into the impact of investment on cash flow volatility may be a valuable contribution to the literature given we found indications of a negative relationship. Further analysis into how the affect of cash flow volatility varies across different categories of investment could provide insight into the nature of the investment decisions faced by management.

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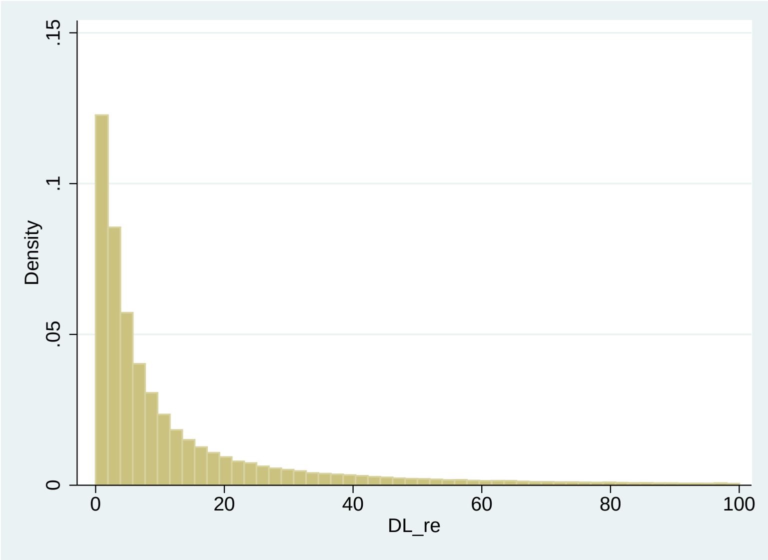
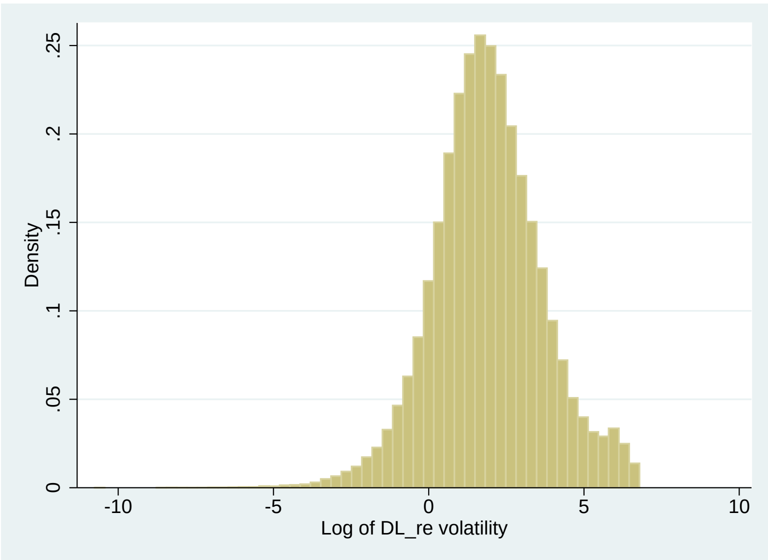
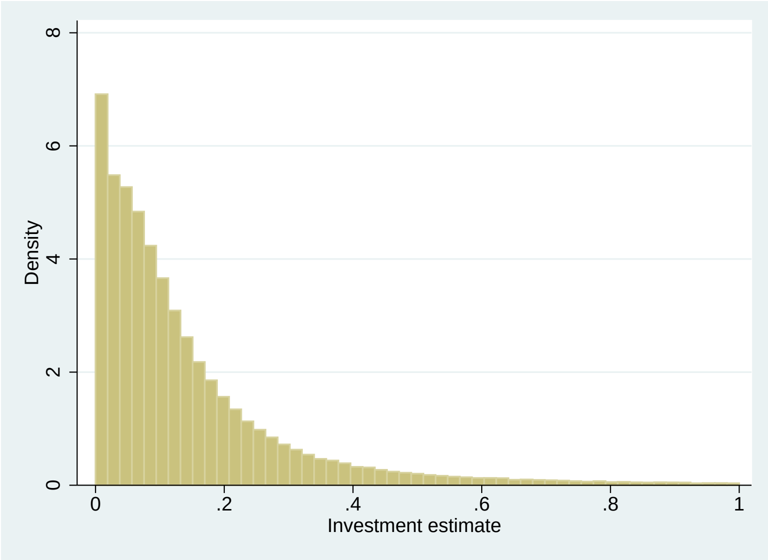


(a) The distribution of *DL OCF Volatility*$_{i,t}$ for all observations with volatility between 0 and 100, representing 93% of our sample.

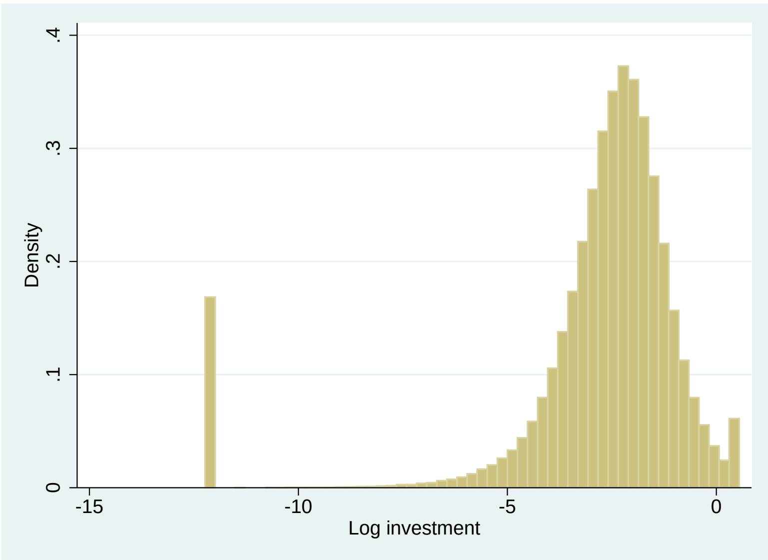


(b) The distribution of *Log DL OCF Volatility*$_{i,t}$ for all observations in our data set

Figure 1: **Distribution of volatility measures**
The figures show the distribution on our conditional operating cash flow volatility estimates.



(a) The distribution of $Investment_{i,t}$ for all observations with investment levels between 0 and 1, representing 93% of our sample.



(b) The distribution of $Log\ investment_{i,t}$ for all observations in our data set

Figure 2: **Distribution of investment measures**
The figures show the distribution on our investment measures.

Table 1: **Summary of variables**
A summary of the variables used throughout the paper including the method of construction for each and the source of data

Variable	Definition	Construction	Data Sources
Book-to-market ratio$_{i,t}$	Total value of common equity divided by the number of ordinary shares multiplied by the end-of-year market price	ceq/(prcc_f*csho)	Compustat
Cash holdings$_{i,t}$	Cash and short-term investment divided by net assets. (From Minton and Schrand (1999))	che/(at-che)	Compustat
Cash flow growth$_{i,t}$	The change in operating cash flows scaled by beginning of period revenue.	(*Operating cash flow*$_{i,t}$- l.*Operating cash flow*$_{i,t}$)/l.revt	Constructed
DL OCF Volatility$_{i,t}$	The De Veirman & Levin estimate for firm specific cash flow volatility at time t for firm i, constructed with random effects.	In Section 4.1	Constructed
Financially constrained$_{i,t}$	Indicator variable: One if firm i is in the top tercile of financial constraint in year t.	Constructed from *SA index*$_{i,t}$	Constructed
Firm age$_{i,t}$	The number of years firm i has had data in Compustat.	fyear-First year in Compustat	Compustat
Firm size$_{i,t}$	Natural logarithm of total assets (From Hadlock and Pierce (2010)).	log(at)	Compustat
High CH Indicator$_{i,t}$	Indicator variable: One for firm i if in the top tercile of cash holding in year t.	Constructed from *Cash holdings*$_{i,t}$	Constructed
High CFV Indicator$_{i,t}$	Indicator variable: One for firm i if in the top tercile of cash flow volatility in year t.	Constructed from *DL OCF Volatility*$_{i,t}$	Constructed
Industry$_i$	Sector of firm as classified using the Fama & French 5 Sector economy.	Classification using sic code	Compustat
Investment$_{i,t}$	Firm i investment in capital expenditure, advertising and R&D expenditure, scaled by beginning of year assets.	(capx+xad+ xrd)/l.at	Compustat
Log advertising expenditure$_{i,t}$	The natural logarithm of advertising expenditure plus one, scaled by beginning of period total assets. Takes the minimum observed value if xad is zero.	ln((xad+1)/l.at). If age=1, ln((xad+1)/at)	Compustat
Log capital expenditure$_{i,t}$	The natural logarithm of capital expenditure, scaled by beginning of period total assets. Takes the minimum observed value if capx is zero.	ln(capx/l.at). If age=1, ln(capx/at)	Compustat
Log book-to-market ratio$_{i,t}$	The natural logarithm of *Book-to-market ratio*$_{i,t}$ plus one.	ln(*Book-to-market ratio*$_{i,t}$ +1)	Constructed
Log DL OCF Volatility$_{i,t}$	The natural logarithm of *DL OCF Volatility*$_{i,t}$ plus one.	ln(*DL OCF Volatility*$_{i,t}$ +1)	Constructed
Log investment$_{i,t}$	The natural logarithm of *Investment*$_{i,t}$ plus one. Takes the minimum observed value if *Investment*$_{i,t}$ is zero.	ln((*Investment*$_{i,t}$ +1)/l.at). If age=1, ln((*Investment*$_{i,t}$ +1)/at)	Constructed

Table 1 – continued from previous page

Variable	**Definition**	**Construction**	**Data Sources**
Log R&D expenditure$_{i,t}$	The natural logarithm of research and development expenditure plus one, scaled by beginning of period total assets. Takes the minimum observed value if xrd is zero.	ln((xrd+1)/l.at). If age=1, ln((xrd+1)/at).	Compustat
Log sales growth$_{i,t}$	The natural logarithm of *Sales growth*$_{i,t}$ plus one, less the minimum observed value.	ln(*Sales growth*$_{i,t}$-min(*Sales growth*$_{i,t}$)+1)	Constructed
Log sales-to-assets ratio$_{i,t}$	The natural logarithm of *Sales-to-assets ratio*$_{i,t}$ plus one.	ln(*Sales-to-assets ratio*$_{i,t}$ +1)	Constructed
Operating cash flow$_{i,t}$	Operating income before depreciation less interest expense, income taxes and dividends. (Bates, Kahle, and Stulz, 2009)	oibdp - xint - txt - dvc	Compustat
SA index$_{i,t}$	Value of the SA Index of financial constrain, as constructed by Hadlock and Pierce (2010).	In Section 4.2	Constructed
Sales growth$_{i,t}$	Change in total revenues divided by previous periods revenue.	100*(revt-l.revt)/l.revt	Compustat
Sales-to-assets ratio$_{i,t}$	Sales divided by total assets.	sale/l.cat	Compustat
Scaled operating cash flow$_{i,t}$	Operating cash flow scaled by beginning of period assets.	*Operating cash flow*$_{i,t}$/l.at. If age=1, *Operating cash flow*$_{i,t}$/at	Compustat

Table 2: **Summary statistics of variables**

Summary statistics are reported on key constructed variables. *Observations* reports the number of observations. *Std Dev.* reports the standard deviation of the sample. *Max* reports the maximum observation observed, while *Min* reports the minimum observation.

Variable	Observations	Mean	Std Dev.	Max	Min	Skewness	Kurtosis
$Investment_{i,t}$	172,176	0.1605	0.2100	1.730	0.0000	4.074	25.47
$Log\ investment_{i,t}$	172,176	0.1370	0.1436	1.004	0.0000	2.775	13.70
$DL\ OCF\ Volatility_{i,t}$	172,176	27.32	77.53	874.0	0.0000	5.695	40.10
$Log\ DL\ OCF\ Volatility_{i,t}$	172,176	2.146	1.342	6.774	0.0000	0.8301	3.494
$Firm\ size_{i,t}$	172,176	4.565	2.149	10.00	-1.871	0.3321	2.779
$Firm\ age_{i,t}$	172,176	13.37	11.19	49.00	1.000	1.248	4.075
$Book\text{-}to\text{-}market\ ratio_{i,t}$	172,176	0.8268	0.7949	4.721	0.0252	2.380	10.18
$Sales\ growth_{i,t}$	172,176	0.2500	0.7775	5.971	-0.8924	5.051	34.32
$Sales\text{-}to\text{-}assets\ ratio_{i,t}$	172,176	1.513	1.122	6.965	0.0000	1.934	8.665
$SA\ index_{i,t}$	172,176	-2.804	0.9850	1.489	-5.118	0.1287	3.081
$Cash\ holdings_{i,t}$	172,176	0.4135	1.173	10.43	0.0000	6.100	45.99
$Scaled\ operating\ cash\ flow_{i,t}$	172,176	0.0109	0.3719	0.4470	-5.271	-8.607	104.0

Table 3: **Summary statistics of variables by financial constraint**
Summary statistics are reported according to the financial constraint in each observation. Figures in the left columns refer to the summary statistics of financially unconstrained firms ($\textit{Financially unconstrained}_{i,t} = 1$) and figures in the right (shaded) columns refer to financially constrained firms ($\textit{Financially constrained}_{i,t} = 1$). *Observations* reports the number of observations.

	Observations		Mean		Standard deviation	
	Uncons	Cons	Uncons	Cons	Uncons	Cons
$\textit{Log investment}_{i,t}$	78,986	78,949	0.1052	0.1835	0.0885	0.2261
$\textit{Log DL OCF Volatility}_{i,t}$	77,377	59,946	1.644	3.031	0.9915	1.550
$\textit{Book-to-market ratio}_{i,t}$	71,494	43,933	0.8339	0.7012	0.721	0.8491
$\textit{Scaled operating cash flow}_{i,t}$	78,516	77,910	0.0767	-0.4107	0.0975	1.118
$\textit{Cash holdings}_{i,t}$	78,905	78,270	0.1618	0.8162	0.4701	1.966
$\textit{Firm size}_{i,t}$	78,986	78,949	6.350	1.561	1.617	1.379
$\textit{Firm age}_{i,t}$	78,986	78,949	20.89	5.394	12.22	5.778

Table 4: **Correlation between variables**

The correlation coefficient between key variables is reported. The number of observations within the correlation calculation is dependent on the number of observations of the relevant variables, as shown in Table 2.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) $Investment_{i,t}$	1.0000											
(2) $Log\ investment_{i,t}$	0.9853	1.0000										
(3) $DL\ OCF\ Volatility_{i,t}$	0.3265	0.3111	1.0000									
(4) $Log\ DL\ OCF\ Volatility_{i,t}$	0.3014	0.2974	0.6877	1.0000								
(5) $Firm\ size_{i,t}$	-0.1211	-0.1167	-0.2107	-0.2769	1.0000							
(6) $Firm\ age_{i,t}$	-0.1993	-0.2072	-0.1565	-0.2154	0.4557	1.0000						
(7) $Book\text{-}to\text{-}market\ ratio_{i,t}$	-0.2197	-0.2440	-0.1114	-0.1506	-0.0720	0.0306	1.0000					
(8) $Sales\ growth_{i,t}$	0.3284	0.3207	0.4411	0.3165	-0.0773	-0.1686	-0.1468	1.0000				
(9) $Sales\text{-}to\text{-}assets\ ratio_{i,t}$	0.0663	0.0597	-0.2016	-0.3054	-0.0766	-0.0391	-0.0200	0.1446	1.0000			
(10) $SA\ index_{i,t}$	0.1739	0.1725	0.2479	0.3274	-0.8917	-0.7371	0.0115	0.1288	0.0389	1.0000		
(11) $Cash\ holdings_{i,t}$	0.2660	0.2615	0.3762	0.3533	-0.1298	-0.1356	-0.1112	0.1087	-0.1629	0.1528	1.0000	
(12) $Scaled\ operating\ cash\ flow_{i,t}$	-0.4080	-0.3553	-0.5204	-0.3862	0.2165	0.1158	0.0504	-0.1796	0.1333	-0.2414	-0.3267	1.0000

Table 5: **Granger causality test results using log transformations**
The table presents results of the Granger causality tests from Section 6.1. *Total # lags* indicates the number of lags included in the regression (n), while *Lag #* indicates the specific lag variable the row presents statistics on. *Coef* reports the coefficient from the regression. *Joint p-value* presents the p-value for the joint significance of the lags included, and the outcome of the test is expressed in *Reject* H_0.
Panel A presents the results of the Granger causality test expressed in Equation (4), with H_0: Volatility does not Granger cause investment.
Panel B presents the results of the Granger causality test expressed in Equation (5), with H_0: Investment does not Granger cause volatility.
(*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

Panel A: Regressing volatility on investment

		Log investment$_{i,t}$ lags	*Log DL OCF Volatility*$_{i,t}$ lags		
Total # lags	lag#	Coef	Coef	Joint p-value	Reject H_0?
3	1	0.3929***	-0.0048***	0.0000	Yes
	2	0.0507***	-0.0026***		
	3	0.0263***	-0.0022***		
2	1	0.3436***	-0.0046***	0.0000	Yes
	2	0.0414***	-0.0021***		
1	1	0.3833***	-0.0043***	0.0000	Yes

Panel B: Regressing investment on volatility

		Log DL OCF Volatility$_{i,t}$ lags	*Log investment*$_{i,t}$ lags		
Total # lags	lag#	Coef	Coef	Joint p-value	Reject H_0?
3	1	0.1471***	-0.1476***	0.0000	Yes
	2	0.0467***	-0.0133		
	3	0.0241***	0.1114		
2	1	0.1530***	-0.1259***	0.0029	Yes
	2	0.0421***	-0.0138		
1	1	0.1396***	-0.0612*	0.0525	Yes

Table 6: **Regression results from Equation (6): Financially constrained firms**

The table reports the cross sectional regression results from Equation (6), regressing *Log investment*$_{i,t}$ against several indicator variables. The regression takes the form:

$$loginv_{i,t} = \alpha_i + \nu_t + \beta_1 highCFV_{i,t} + \beta_2 l.highCFV_{i,t} + \beta_3 Cons_{i,t} + \delta_1 (HighCFV_{i,t} * Cons_{i,t}) + \delta_2 (l.highCFV_{i,t} * Cons_{i,t}) + \delta_3 (l.highCFV_{i,t} * highCFV_{i,t}) + \gamma_1 (highCFV_{i,t} * l.highCFV_{i,t} * Cons_{i,t}) + \sum_{j=1}^{n} c_j CONTROL_{i,t}^{j}$$

highCFV, and the lagged value l.highCFV, refer to the value of *High CFV Indicator*$_{i,t}$. Cons represents the indicator variable *Financially constrained*$_{i,t}$. Interaction terms are identified with an underscore. l.loginv represents the lagged value of *Log investment*$_{i,t}$. The natural logarithms of *Sales growth*$_{i,t}$, *Sales-to-assets ratio*$_{i,t}$, and *Book-to-market ratio*$_{i,t}$ have been included as control variables. Year indicators are included in the regression but their coefficients have not been reported. The second section of the table shows the value of coefficient combinations important in testing our hypotheses, as outlined in Section 6.2. These figures are reported as significant if we reject the hypothesis that the sum of appropriate coefficients is equal to zero. The bottom section of the table presents properties of the regression, where the Wald chi-squared stat and p-value relate to the test of the joint significance of all coefficients. (*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

		Dependent Variable: *Log investment*$_{i,t}$			
Regressor	**Coefficient**	**(1)**	**(2)**	**(3)**	**(4)**
highCFV	β_1	0.0042***	0.0069***	0.0053***	0.0049***
l.highCFV	β_2		-0.0081***		-0.0067***
Cons	β_3			-0.0085***	-0.0031
highCFV_Cons	δ_1			-0.0034*	0.0048*
l.highCFV_Cons	δ_2				-0.0049**
l.highCFV_highCFV	δ_3		-0.0247***		-0.013***
l.highCFV_highCFV_Cons	γ_1				-0.0286***
l.loginv	c_1	0.3289***	0.331***	0.3301***	0.3319***
Log sales growth$_{i,t}$	c_2	-0.0398***	-0.0399***	-0.0399***	-0.0403***
Log sales-to-assets ratio$_{i,t}$	c_3	0.3148***	0.3114***	0.3142***	0.3099***
Log book-to-market ratio$_{i,t}$	c_4	-0.0148***	-0.0143***	-0.0152***	-0.0147***
$\beta_1 + \delta_1$					0.0098
$\beta_2 + \delta_2$					-0.0116***
$\beta_1 + \beta_2 + \delta_1 + \delta_2 + \delta_3 + \gamma_1$					-0.0435***
Number of Observations		153,310	153,310	153,310	153,310
Number of Firms		14,722	14,722	14,722	14,722
Year Dummies		Yes	Yes	Yes	Yes
Wal chi-squared stat		10,970	11,107	11,000	11,204
p-value		0.0000	0.0000	0.0000	0.0000

Table 7: **Regression results from Equation (7): Financially unconstrained firms**

The table reports the cross sectional regression results from Equation (7), regressing *Log investment*$_{i,t}$ against several indicator variables. The regression takes the form:

$$loginv_{i,t} = \alpha_i + \nu_t + \beta_1 highCFV_{i,t} + \beta_2 l.highCFV_{i,t} + \beta_3 Uncons_{i,t} + \delta_1(HighCFV_{i,t} * Uncons_{i,t}) + \delta_2(l.highCFV_{i,t} * Uncons_{i,t}) + \delta_3(l.highCFV_{i,t} * highCFV_{i,t}) + \gamma_1(highCFV_{i,t} * l.highCFV_{i,t} * Uncons_{i,t}) + \sum_{j=1}^{n} c_j CONTROL_{i,t}^{j}$$

highCFV, and the lagged value l.highCFV, refer to the value of *High CFV Indicator*$_{i,t}$. Uncons represents the indicator variable *Financially unconstrained*$_{i,t}$. Interaction terms are identified with an underscore. l.loginv represents the lagged value of *Log investment*$_{i,t}$. The natural logarithms of *Sales growth*$_{i,t}$, *Sales-to-assets ratio*$_{i,t}$, and *Book-to-market ratio*$_{i,t}$ have been included as control variables. Year indicators are included in the regression but their coefficients have not been reported. The second section of the table shows the value of coefficient combinations important in testing our hypotheses, as outlined in Section 6.2. These figures are reported as significant if we reject the hypothesis that the sum of appropriate coefficients is equal to zero. The bottom section of the table presents properties of the regression, where the Wald chi-squared stat and p-value relate to the test of the joint significance of all coefficients. (*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

		Dependent Variable: *Log investment*$_{i,t}$			
Regressor	**Coefficient**	**(1)**	**(2)**	**(3)**	**(4)**
highCFV	β_1	0.0042***	0.0069***	0.005***	0.0093***
l.highCFV	β_2		-0.0081***		-0.0098***
Uncons	β_3			0.0024	-0.002
highCFV_Uncons	δ_1			-0.0027*	-0.0092***
l.highCFV_Uncons	δ_2				0.0064***
l.highCFV_highCFV	δ_3		-0.0247***		-0.0306***
l.highCFV_highCFV_Uncons	γ_1				0.0301***
l.loginv	c_1	0.3289***	0.331***	0.3291***	0.3317***
Log sales growth$_{i,t}$	c_2	-0.0398***	-0.0399***	-0.0398***	-0.0401***
Log sales-to-assets ratio$_{i,t}$	c_3	0.3148***	0.3114***	0.3146***	0.3104***
Log book-to-market ratio$_{i,t}$	c_4	-0.0148***	-0.0143***	-0.0148***	-0.0142***
$\beta_1 + \delta_1$					0.0001
$\beta_2 + \delta_2$					-0.0034***
$\beta_1 + \beta_2 + \delta_1 + \delta_2 + \delta_3 + \gamma_1$					-0.0038
Number of Observations		153,310	153,310	153,310	153,310
Number of Firms		14,722	14,722	14,722	14,722
Year Dummies		Yes	Yes	Yes	Yes
Wal chi-squared stat		10,970	11,107	11,066	11,237
p-value		0.0000	0.0000	0.0000	0.0000

Table 8: **Regression results from Equation (8): Cash holdings**

The table reports the cross sectional regression results from Equation (8), regressing *Log investment*$_{i,t}$ against several indicator variables. The regression takes the form:

$$loginv_{i,t} = \alpha_i + \nu_t + \beta_1 l.highCFV_{i,t} + \beta_2 Cons_{i,t} + \beta_3 highCH_{i,t} + \delta_1(l.highCFV_{i,t} * Cons_{i,t}) + \delta_2(l.highCFV_{i,t} * highCH_{i,t}) + \delta_3(Cons_{i,t} * highCH_{i,t}) + \gamma_1(l.highCFV_{i,t} * Cons_{i,t} * highCH_{i,t}) + \sum_{j=1}^{n} c_j CONTROL^j_{i,t}$$

l.highCFV represents the lagged value of *High CFV Indicator*$_{i,t}$. Cons represents the indicator variable *Financially constrained*$_{i,t}$. highCH represents the variable *High CH Indicator*$_{i,t}$. Interaction terms are identified with an underscore. l.loginv represents the lagged value of the *Log investment*$_{i,t}$. The natural logarithms of *Sales growth*$_{i,t}$, *Sales-to-assets ratio*$_{i,t}$, and *Book-to-market ratio*$_{i,t}$ have been included as control variables. Year indicators are included in the regression but their coefficients have not been reported. The second section of the table shows the value of coefficient combinations important in testing our hypotheses, as outlined in Section 6.3. These figures are reported as significant if we reject the hypothesis that the sum of appropriate coefficients is equal to zero. The bottom section of the table presents properties of the regression, where the Wald chi-squared stat and p-value relate to the test of the joint significance of all coefficients. (*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

		Dependent Variable:	
		Log investment$_{i,t}$	
Regressor	**Coefficient**	**(1)**	**(2)**
l.highCFV	β_1	-0.0146***	-0.0086***
Cons	β_2		-0.013***
highCH	β_3	0.0011	-0.0031***
l.highCFV_Cons	δ_1		-0.015***
l.highCFV_highCH	δ_2	-0.0092***	-0.0063***
Cons_highCH	δ_3		0.0199***
l.highCFV_Cons_highCH	γ_1		-0.0153***
l.loginv	c_1	0.3322***	0.332***
Log sales growth$_{i,t}$	c_2	-0.0402***	0.0008
Log sales-to-assets ratio$_{i,t}$	c_3	0.3119***	0.084***
Log book-to-market ratio$_{i,t}$	c_4	-0.0147***	-0.006***
$\beta_1 + \delta_1$			-0.0236***
$\beta_1 + \delta_1 + \delta_2 + \gamma_1$			-0.0453***
$\delta_2 + \gamma_1$			-0.0217***
Number of Observations		153,310	153,310
Number of Firms		14,722	14,722
Year Dummies		Yes	Yes
Wald chi squared stat		11,166	10,230
p-value		0.0000	0.0000

Table 9: **Granger causality test results using non-transformed variables**
The table presents results of the Granger causality tests from Section 6.1 executed using variables $Investment_{i,t}$ and $DL\ OCF\ Volatility_{i,t}$ in place of the log transformed measures $Log\ investment_{i,t}$ and $Log\ DL\ OCF\ Volatility_{i,t}$ respectively. *Total # lags* indicates the number of lags included in the regression, while *Lag #* indicates the specific lag variable the row presents statistics on. *Coef* reports the coefficient from the regression. *Joint p-value* presents the p-value for the joint significance of the lags included, and the outcome of the test is expressed in *Reject* H_0.
Panel A presents the results of the Granger causality test expressed in Equation (4), with H_0: Volatility does not Granger cause investment.
Panel B presents the results of the Granger causality test expressed in Equation (5), with H_0: Investment does not Granger cause volatility.
(*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

Panel A: Regressing volatility on investment

		$Investment_{i,t}$ lags	$DL\ OCF\ Volatility_{i,t}$ lags		
Total # lags	lag#	Coef	Coef	Joint p-value	Reject H_0 ?
3	1	0.3365***	-0.0002***	0.0000	Yes
	2	0.0539***	-0.0001***		
	3	0.0226***	0.0000**		
2	1	0.2927***	-0.0002***	0.0000	Yes
	2	0.0436***	-0.0001***		
1	1	0.3352***	-0.0002***	0.0000	Yes

Panel B: Regressing investment on volatility

		$DL\ OCF\ Volatility_{i,t}$ lags	$Investment_{i,t}$ lags		
Total # lags	lag#	Coef	Coef	Joint p-value	Reject H_0?
3	1	0.1989***	-11.358***	0.0003	Yes
	2	0.0277**	-7.9315***		
	3	0.0312***	-1.9221		
2	1	0.2011***	-12.151***	0.0000	Yes
	2	0.0331***	-4.4377**		
1	1	0.2233***	-7.4426***	0.0029	Yes

Table 10: **Granger causality test results for alternative measures of investment**

The table presents results of the Granger causality test expressed in Equation 4, with H_0: Volatility does not Granger cause investment, executed for different each of the investment measures *Log investment*$_{i,t}$, *Log capital expenditure*$_{i,t}$, *Log R&D expenditure*$_{i,t}$ and *Log advertising expenditure*$_{i,t}$. *Total # lags* indicates the number of lags included in the regression, while *Lag #* indicates the specific lag variable the row presents statistics on. *Coef* reports the coefficient from the regression. *Joint p-value* presents the p-value for the joint significance of the lags included, and the outcome of the test is expressed in *Reject* H_0. (*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

		Investment measure: *Log investment*$_{i,t}$				Investment measure: *Log capital expenditure*$_{i,t}$			
		Investment lags	Volatility lags			Investment lags	Volatility lags		
Total # lags	lag#	Coef	Coef	Joint p-value	Reject H_0?	Coef	Coef	Joint p-value	Reject H_0?
3	1	0.3929***	-0.0048***	0.0000	Yes	0.2913***	-0.0040***	0.0000	Yes
	2	0.0507***	-0.0026***			0.0506***	-0.0022***		
	3	0.0263	-0.0022***			0.0174***	-0.0014***		
2	1	0.3463***	-0.0046***	0.0000	Yes	0.2836***	-0.0038***	0.0000	Yes
	2	0.0414***	-0.0021***			0.0458***	-0.0023***		
1	1	0.3833***	-0.0043***	0.0000	Yes	0.2481***	-0.0030***	0.0000	Yes

		Investment measure: *Log R&D expenditure*$_{i,t}$				Investment measure: *Log advertising expenditure*$_{i,t}$			
		Investment lags	Volatility lags			Investment lags	Volatility lags		
Total # lags	lag#	Coef	Coef	Joint p-value	Reject H_0?	Coef	Coef	Joint p-value	Reject H_0?
3	1	0.2082***	-0.0009***	0.0012	Yes	0.3956***	-0.0007***	0.0000	Yes
	2	-0.0112	-0.0004			0.0400**	-0.0005***		
	3	0.0283	-0.008***			0.0163*	-0.0000		
2	1	0.1699***	-0.0007***	0.0113	Yes	0.3646***	-0.0008***	0.0000	Yes
	2	0.0007	0.0001			0.0299***	-0.0005***		
1	1	0.2157***	-0.0013***	0.0000	Yes	0.2597***	-0.0005***	0.0001	Yes

Table 11: **Regression results from Equation (6) for alternative measures of investment**
The table reports the cross sectional regression results of from Equation (6), using alternative measures of investment. *Investment* represents our constructed investment variable *Log investment*$_{i,t}$, *CapExp.* represents *Log capital expenditure*$_{i,t}$, *R&D* represents *Log R&D expenditure*$_{i,t}$ and *Advertising* represents *Log advertising expenditure*$_{i,t}$. The regression takes the form:

$$loginv_{i,t} = \alpha_i + \nu_t + \beta_1 highCFV_{i,t} + \beta_2 l.highCFV_{i,t} + \beta_3 Cons_{i,t} + \delta_1(HighCFV_{i,t} * Cons_{i,t}) + \delta_2(l.highCFV_{i,t} * Cons_{i,t}) + \delta_3(l.highCFV_{i,t} * highCFV_{i,t}) + \gamma_1(highCFV_{i,t} * l.highCFV_{i,t} * Cons_{i,t}) + \sum_{j=1}^{n} c_j CONTROL^j_{i,t}$$

where *Log investment*$_{i,t}$ is substituted for the appropriate dependent variable. highCFV, and the lagged value l.highCFV, refer to the value of *High CFV Indicator*$_{i,t}$. Cons represents the indicator variable *Financially constrained*$_{i,t}$. Interaction terms are identified with an underscore. l.DepVar represents the lagged value of the dependent variable. The natural logarithms of *Sales growth*$_{i,t}$, *Sales-to-assets ratio*$_{i,t}$, and *Book-to-market ratio*$_{i,t}$ have been included as control variables. Year indicators are included in the regression but their coefficients have not been reported. The second section of the table shows the value of coefficient combinations important in testing our hypotheses, as outlined in Section 6.2. These figures are reported as significant if we reject the hypothesis that the sum of appropriate coefficients is equal to zero. The bottom section of the table presents properties of the regression, where the Wald chi-squared stat and p-value relate to the test of the joint significance of all coefficients. (*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

		Dependent Variable:			
		Investment	*CapExp.*	*R&D*	*Advertising*
highCFV	β_1	0.0049***	0.0043***	0.0015**	0.0009**
l.highCFV	β_2	-0.0067***	-0.0034***	-0.0029***	-0.0006**
Cons	β_3	-0.0031	-0.0034	0.0039**	0.0009
highCFV_Cons	δ_1	0.0048*	0.0043*	0.0069***	-0.0001
l.highCFV_Cons	δ_2	-0.0049**	-0.0018	-0.0028**	-0.0008
l.highCFV_highCFV	δ_3	-0.013***	-0.0093***	-0.0083***	-0.0026***
l.highCFV_highCFV_Cons	γ_1	-0.0286***	-0.0234***	-0.0163***	-0.0053***
l.loginv	c_1	0.3319***	0.1471***	0.2835***	0.2194***
Log sales growth$_{i,t}$	c_2	-0.0403***	-0.0203***	-0.0307***	-0.0094***
Log sales-to-assets ratio$_{i,t}$	c_3	0.3099***	0.2122***	0.1457***	0.0561***
Log book-to-market ratio$_{i,t}$	c_4	-0.0147***	-0.0182***	0.0034**	-0.0024*
$\beta_1 + \delta_1$		0.0098	0.0086***	0.0084***	0.0008
$\beta_2 + \delta_2$		-0.0116***	-0.0052***	-0.0057***	-0.0013*
$\beta_1 + \beta_2 + \delta_1 + \delta_2 + \delta_3 + \gamma_1$		-0.0435***	-0.0292***	-0.022***	-0.0085***
Number of Observations		153,310	153,310	153,310	153,310
Number of Firms		14,722	14,722	14,722	14,722
Year Dummies		Yes	Yes	Yes	Yes
Wal chi-squared stat		11,204	4,325	1,566	1,310
p-value		0.0000	0.0000	0.0000	0.0000

Table 12: **Regression results from Equation (7) for alternative measures of investment**
The table reports the cross sectional regression results of from Equation (7), using alternative measures of investment. *Investment* represents our constructed investment variable *Log investment*$_{i,t}$, *CapExp.* represents *Log capital expenditure*$_{i,t}$, *R&D* represents *Log R&D expenditure*$_{i,t}$ and *Advertising* represents *Log advertising expenditure*$_{i,t}$. The regression takes the form:

$$loginv_{i,t} = \alpha_i + \nu_t + \beta_1 highCFV_{i,t} + \beta_2 l.highCFV_{i,t} + \beta_3 Uncons_{i,t} + \delta_1(HighCFV_{i,t} * Uncons_{i,t}) + \delta_2(l.highCFV_{i,t} * Uncons_{i,t}) + \delta_3(l.highCFV_{i,t} * highCFV_{i,t}) + \gamma_1(highCFV_{i,t} * l.highCFV_{i,t} * Uncons_{i,t}) + \sum_{j=1}^{n} c_j CONTROL^j_{i,t}$$

where *Log investment*$_{i,t}$ is substituted for the appropriate dependent variable. highCFV, and the lagged value l.highCFV, refer to the value of *High CFV Indicator*$_{i,t}$. Uncons represents the indicator variable *Financially unconstrained*$_{i,t}$. Interaction terms are identified with an underscore. l.DepVar represents the lagged value of the dependent variable. The natural logarithms of *Sales growth*$_{i,t}$, *Sales-to-assets ratio*$_{i,t}$, and *Book-to-market ratio*$_{i,t}$ have been included as control variables. Year indicators are included in the regression but their coefficients have not been reported. The second section of the table shows the value of coefficient combinations important in testing our hypotheses, as outlined in Section 6.2. These figures are reported as significant if we reject the hypothesis that the sum of appropriate coefficients is equal to zero. The bottom section of the table presents properties of the regression, where the Wald chi-squared stat and p-value relate to the test of the joint significance of all coefficients. (*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

		Dependent Variable:			
		Investment	*CapExp.*	*R&D*	*Advertising*
highCFV	β_1	0.0093***	0.0083***	0.006***	0.0014***
l.highCFV	β_2	-0.0098***	-0.004***	-0.0048***	-0.0009**
Uncons	β_3	-0.002	-0.0024	-0.0038***	-0.0019**
highCFV_Uncons	δ_1	-0.0092***	-0.0082***	-0.0079***	-0.0016***
l.highCFV_Uncons	δ_2	0.0064***	0.0009	0.0039***	0.0005
l.highCFV_highCFV	δ_3	-0.0306***	-0.0232***	-0.0188***	-0.0062***
l.highCFV_highCFV_Uncons	γ_1	0.0301***	0.0216***	0.0192***	0.0069***
l.loginv	c_1	0.3317***	0.1467***	0.284***	0.2193***
Log sales growth$_{i,t}$	c_2	-0.0401***	-0.0201***	-0.0307***	-0.0093***
Log sales-to-assets ratio$_{i,t}$	c_3	0.3104***	0.2128***	0.1457***	0.0562***
Log book-to-market ratio$_{i,t}$	c_4	-0.0142***	-0.0178***	0.0034**	-0.0023*
$\beta_1 + \delta_1$		0.0001	0	-0.0019***	-0.0002
$\beta_2 + \delta_2$		-0.0034***	-0.0031***	-0.0009	-0.0004
$\beta_1 + \beta_2 + \delta_1 + \delta_2 + \delta_3 + \gamma_1$		-0.0038	-0.0046**	-0.0024*	0.0001
Number of Observations		153,310	153,310	153,310	153,310
Number of Firms		14,722	14,722	14,722	14,722
Year Dummies		Yes	Yes	Yes	Yes
Wal chi-squared stat		11,237	4,374	1,573	1,309
p-value		0.0000	0.0000	0.0000	0.0000

Table 13: **Regression results from Equation (8) for alternative measures of investment**
The table reports the cross sectional regression results of from Equation (8) using alternative measures of investment. *Investment* represents our constructed investment variable *Log investment*$_{i,t}$, *CapExp.* represents *Log capital expenditure*$_{i,t}$, *R&D* represents *Log R&D expenditure*$_{i,t}$ and *Advertising* represents *Log advertising expenditure*$_{i,t}$. The regression takes the form:

$$loginv_{i,t} = \alpha_i + \nu_t + \beta_1 l.highCFV_{i,t} + \beta_2 Cons_{i,t} + \beta_3 highCH_{i,t} + \delta_1(l.highCFV_{i,t} * Cons_{i,t}) + \delta_2(l.highCFV_{i,t} * highCH_{i,t}) + \delta_3(Cons_{i,t} * highCH_{i,t}) + \gamma_1(l.highCFV_{i,t} * Cons_{i,t} * highCH_{i,t}) + \sum_{j=1}^{n} c_j CONTROL_{i,t}^{j}$$

where *Log investment*$_{i,t}$ is substituted for the appropriate dependent variable. l.highCFV represents the lagged value of *High CFV Indicator*$_{i,t}$. Cons represents the indicator variable *Financially constrained*$_{i,t}$. highCH represents the variable *High CH Indicator*$_{i,t}$. Interaction terms are identified with an underscore. l.DepVar represents the lagged value of the dependent variable. The natural logarithms of *Sales growth*$_{i,t}$, *Sales-to-assets ratio*$_{i,t}$, and *Book-to-market ratio*$_{i,t}$ have been included as control variables. Year indicators are included in the regression but their coefficients have not been reported. The second section of the table shows the value of coefficient combinations important in testing our hypotheses, as outlined in Section 6.3. These figures are reported as significant if we reject the hypothesis that the sum of appropriate coefficients is equal to zero. The bottom section of the table presents properties of the regression, where the Wald chi-squared stat and p-value relate to the test of the joint significance of all coefficients. (*), (**) and (***) indicate the figure is significant at a 90%, 95% or 99% confidence level respectively.

		Dependent Variable:			
		Investment	*CapExp.*	*R&D*	*Advertising*
l.highCFV	β_1	-0.0086***	-0.007***	-0.0011**	-0.0007**
Cons	β_2	-0.013***	-0.0075**	-0.0007	-0.0012
highCH	β_3	-0.0031***	-0.0063***	0.0028***	0.0012***
l.highCFV_Cons	δ_1	-0.015***	-0.0133***	-0.0067***	-0.0025**
l.highCFV_highCH	δ_2	-0.0063***	-0.0001	-0.0117***	-0.0017**
Cons_highCH	δ_3	0.0199***	0.0118***	0.0158***	0.0032**
l.highCFV_Cons_highCH	γ_1	-0.0153***	-0.0039	-0.0114***	-0.0016
l.loginv	c_1	0.332***	0.1474***	0.2838***	0.2192***
Log sales growth$_{i,t}$	c_2	0.0008	-0.0205***	-0.0305***	-0.0093***
Log sales-to-assets ratio$_{i,t}$	c_3	0.084***	0.2127***	0.1444***	0.0559***
Log book-to-market ratio$_{i,t}$	c_4	-0.006***	-0.0187***	0.0033**	-0.0024*
$\beta_1 + \delta_1$		-0.0236***	-0.0202***	-0.0078***	-0.0032***
$\beta_1 + \delta_1 + \delta_2 + \gamma_1$		-0.0453***	-0.0242***	-0.0309***	-0.0065***
$\delta_2 + \gamma_1$		-0.0217***	-0.004	-0.0231***	-0.0033*
Number of Observations		153,310	153,310	153,310	153,310
Number of Firms		14,722	14,722	14,722	14,722
Year Dummies		Yes	Yes	Yes	Yes
Wal chi-squared stat		10,230	4,409	1,561	1,305
p-value		0.0000	0.0000	0.0000	0.0000

A Economic importance

In this appendix, we show how to interpret the economic importance of the coefficient associated with an indicator variable in a semi-log model and where the dependent variable is transformed using the log of one plus the variable. For example, let I_t be the value of a continuous variable at time t and D_t be an indicator variable at time t. Now consider the following regression with a transformed variable

$$\ln(1 + I_t) = \alpha + \beta \ln(1 + I_{t-1}) + \delta D_t + \epsilon. \tag{9}$$

Because (9) represents the conditional expectation of the $\ln(1 + I_t)$, we drop the residual term and re-express (9) as

$$I_t = \exp\left(\alpha + \beta \ln(1 + I_{t-1}) + \delta D_t\right) - 1 \tag{10}$$

Using (10), we express percentage change in I_t from switching the indicator D_t from zero to one as

$$\frac{I_t^{D=1}}{I_t^{D=0}} - 1 = \frac{\exp\left(\alpha + \beta \ln(1 + I_{t-1}) + \delta\right) - 1}{\exp\left(\alpha + \beta \ln(1 + I_{t-1})\right) - 1} - 1 \tag{11}$$

where clearly the LHS of (11) represents the percentage change in investment. To focus on the effect of δ on investment, we let $A = \exp\left(\alpha + \beta \ln(1 + I_{t-1})\right)$ and re-arrange (11) as

$$\frac{I_t^{D=1}}{I_t^{D=0}} - 1 = \frac{A \exp(\delta) - 1}{A - 1} - \frac{A - 1}{A - 1}. \tag{12}$$

We simplify (12) to

$$\frac{I_t^{D=1}}{I_t^{D=0}} - 1 = \frac{A}{A - 1}(\exp(\delta) - 1) \tag{13}$$

where the term $(\exp(\delta) - 1)$ represents the percentage change in I_t in a standard semi-log model with an indicator variable. In summary, to find the economic effect of the indicator variable D_t on a percentage change in I_t, we adjust the standard semi-log expression $(\exp(\delta) - 1)$ by $\frac{A}{A-1}$. In order to estimate the economic significance of variables we must estimate the term A. If D_t is the variable of interest and Equation (9) is fitted, let $ln\widehat{(1 + I_t^{D=0})}$ be the associated estimates for observations where D_t is equal to zero.

$$\hat{\alpha} + \hat{\beta} ln(1 + I_{t-1}) = ln\widehat{(1 + I_t)} \tag{14}$$

From these estimates we can infer a value for A, approximating the intercept of observations with $D_t = 0$.

$$\begin{aligned} E[A] &= E[e^{\hat{\alpha} + \hat{\beta} ln(1 + I_{t-1})}] \\ &= E[ln\widehat{(1 + I_t)}] \\ &= mean[ln\widehat{(1 + I_t)}] \end{aligned} \tag{15}$$

Given the estimate of A we can calculate the relevant economic significance of the indicator variable D_t using Equation (13).