Corporate Precautionary Cash Holdings[1]

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Abstract

This paper models the precautionary motive for a firm's cash holdings. A two-period investment model shows that the cash holdings of financially constrained firms are sensitive to cash flow volatility because financial constraints create an intertemporal trade-off between current and future investments. When future cash flow risk cannot be fully diversifiable, this intertemporal trade-off gives constrained firms the incentives of precautionary savings: they increase their cash holdings in response to increases in cash flow volatility. However, there is no systematic relationship between cash holdings and cash flow volatility for unconstrained firms. We test the empirical implications of our theory using quarterly information from a sample of U.S. publicly traded companies from 1997 to 2002, and find that the empirical evidence supports our theory.

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1 Introduction

Why do firms hold a large percentage of cash and cash equivalents in their assets even though there is an opportunity cost associated with cash and cash equivalent? According to Keynes (1936), there are two major benefits to cash holdings. First, a firm can save transaction costs by using cash to make payments without having to liquidating assets. Second, and possibly more important, a firm can reserve cash to hedge for the risk of future cash shortfalls; this is the precautionary motive for cash holdings.[1]

The transactional motive for cash holdings has been discussed at length in the literature. For example, Miller and Orr (1966) show that brokerage costs could induce firms to hold more liquid assets. Myers and Majluf (1984) argue that raising external financing is more costly than using internally generated funds in the presence of asymmetric informations and that it may be optimal for firms to hold a certain level of cash to meet the need for investment expenditures.

The precautionary motive for corporate cash holdings, however, has not been adequately modeled in the literature. It has been well documented empirically that cash flow volatility could affect a firm's cash-holding behavior. Opler, Pinkowitz, Stulz and Williamson (1999) present evidence that firms tend to hold more liquid assets if their industry average cash flow volatility is higher. Mikkelson and Partch (2003) further show that firms that persistently hold large cash reserves do not underperform when compared with their peer firms. These studies suggest that firms use internally generated funds to hedge against future cash flow uncertainty and to increase their cash holdings in response to increases in cash flow volatility. No previous theoretical study, however, has provided a direct analysis of the link between a firm's cash holdings, cash flow uncertainty and financial constraints. There exists, therefore, an open but important question: how do a firm's precautionary cash holdings, cash flow uncertainty, and financial constraints interact with one another?

[1] Agency costs could be another explanation for managers to hold cash that could easily be used for perquisite consumption. The empirical evidence in support of agency costs using the U.S. sample firms is generally weak (Opler, Pinkowitz, Stulz and Williamson, 1999).

The objective of this paper is to provide an analysis of corporate precautionary cash holdings. It has long been recognized in macroeconomics that the underlying rationales for household precautionary saving motives is the limited diversifiability of future uncertainty and the intertemporal consumption smoothing (see, e.g., Caballero, 1990; Dreze and Modigliani, 1972; and Leland 1968). Building on the insight of such research, we extend the theoretic model by Almeida, Campello and Weisbach (2004, hereinafter, ACW) to analyze the corporate precautionary cash holdings. In this model, a firm making decisions on investments over two periods cannot hedge future cash flow risk directly in the market but has to rely on cash reserves to hedge for future cash shortfalls. The objective of a firm is to maximize the present value of dividend payouts to investors. Solving for optimal corporate cash holdings and investments in such a setting allows us to capture the key driving forces of the precautionary motive in corporate cash holdings, that is, the limited diversifiability of future cash flow uncertainty and the intertemporal trade-off between current and future investments.

We analyze the role of financial constraints on precautionary corporate cash holdings. A firm is financially unconstrained if it has enough financing capacity to make the first-best investments in both periods regardless of the realization of the future cash flow. The first-best investment in each period is determined at the point where the (expected) marginal return on investments is equal to the marginal cost of borrowing. Therefore, optimal future investment is independent of optimal current investment. Since a financially unconstrained firm has enough financing capacity to make the first-best investments, one optimal financing policy can be replaced with an entirely different financing policy. Even if a financially constrained firm anticipates an increase in future cash flow volatility (i.e., a second-order stochastic dominated shift), it is still able to invest at the first-best level. Therefore, there is no systematic relationship between cash holdings, investment levels and future cash flow volatility. In other words, a financially unconstrained firm has no precautionary motive for cash holdings.

However, a financially constrained firm cannot make additional future investments without reducing current investments because it has exhausted all the external financing resources.[2] Therefore, the firm can invest more in the future only by holding more cash and by reducing current investments. When the marginal returns on investments are convex, an increase in future cash flow volatility makes the expected marginal return on future investments higher for given cash holdings.[3] Therefore, an increase in future cash flow volatility leads the constrained firm to be more prudent, to increase cash holdings for more future investment by decreasing current investment. This precautionary motive of cash holding creates a positive relationship between cash holdings and cash flow volatility and a negative relationship between current investments and cash flow volatility for a financially constrained firm.

A study by Kim, Mauer and Sherman (1998) also models a firm's optimal cash holdings and investment policy. There are, however, important differences between our paper and theirs. First, Kim, Mauer and Sherman (1998) do not generate the precautionary motive for cash holdings. They assume that current investments and cash holdings are substitutes for future liquidity needs. Consequently, the optimal decisions on current investments and cash holdings are decided by a static trade-off between current investments and cash holdings. In other words, their model does not consider the intertemporal trade-off between current and future investments. Their model predicts that only a financially unconstrained firm with an extra cash endowment - so that the marginal return on current investments is lower than the risk free rate - holds a positive amount of cash, while a financially constrained firm holds zero cash. Consequently, the motive for a firm to hold positive cash is due to an extra cash endowment, and not as a precautionary consideration.

Second, our model generates sharply different empirical predictions from Kim, Mauer and Sherman (1998). Kim, Mauer and Sherman (1998) predict that the current investment

[2] Had the firm had more external financing resources, it would have invested more. The investment made by a financially constrained firm is typically lower than the first-best level.

[3] The role of the positive third derivative in generating precautionary savings was first derived by Leland (1968) in consumption literature and further analyzed by Sandmo (1970) and Dreze and Modigliani (1972).

is increasing in cash flow volatility. A recent empirical study by Minton and Schrand (1999) provides contradictory evidence to their prediction. Minton and Schrand (1999) show that higher cash flow volatility is associated with lower average levels of investments. In other words, investment is negatively related to cash flow volatility. Consistent with the findings in Minton and Schrand (1999), our model predicts that future cash flow volatility has a negative impact on current investments, while it has a positive impact on current cash holdings. Specifically, we show that if a firm is financially constrained, higher cash flow volatility induces it to increase its cash holdings and to voluntarily reduce its current investment level because of the intertemporal trade-off between current and future investments. Therefore, there is a positive relationship between cash holding and future cash flow volatility but a negative relationship between current investments and future cash flow volatility. Thus, our theory is consistent with extant empirical results and provides an explanation for the negative impact of future cash flow volatility on the firm's current investments.[4]

Our analysis builds on the recent study by ACW but addresses a fundamental issue that is ignored in their work: a firm's precautionary cash holding in response to cash flow uncertainty. Since ACW are interested in the effect of the changes in the level of cash flow on the firm's cash holdings, they assume that a firm can fully hedge any future cash flow risk at fair prices. As a result, a firm is concerned with only the expected value of future cash flow, not with the underlying uncertainty of future cash flow as a whole. This implies that, according to their model, even if future cash flow becomes more volatile, the firm would not change its cash holdings. Yet given the empirical studies mentioned above, which show that firms do adjust cash holdings in response to cash flow volatility, it seems reasonable to consider a firm's cash holdings in a situation where the full diversifiability of future cash flow risk is not possible. This is essentially the precautionary motive suggested by Keynes (1936), and the focus of our model. Our model predicts that financially constrained firms

[4]Another important difference is that Kim, Mauer and Sherman (1998) predict that future cash flow volatility affects only financially unconstrained firms but not financially constrained firms. Conversely, our model predict that cash flow volatility is relevant for financially constrained firms, but not for unconstrained firms.

on average will hold more cash than what is predicted by ACW for any given distribution of future cash flow. The additional cash holdings generated by our model comes exactly from the motive of precautionary savings.

We evaluate the prediction of our theory by investigating the cash holdings of a sample of publicly traded firms using the Compustat quarterly data from 1997 to 2002. We test the impact of firms' cash flow volatility on their cash holdings for two different groups of firms: financially constrained firms and financially unconstrained firms. We classify firm years into constrained and unconstrained observations, based on four financial constraint indices (firm size, dividend payout, debt rating and commercial rating). We find that the impact of cash flow volatility on a firm's cash holdings depends on a firm's financial constraint status. The financially constrained firm increases its cash holdings in response to an increase in cash flow volatility. In contrast, the cash holdings of financially unconstrained firms are not sensitive to cash flow volatility. Thus, the empirical evidence supports our theory.

The remainder of the paper proceeds as follows: Section 2 presents a theoretical analysis of the impact of cash flow volatility and financial constraints on a firm's cash holdings and investments. Section 3 tests the empirical prediction of the model. Section 4 concludes.

2 Theoretical Analysis

2.1 Model

Our model starts from the study by ACW which investigates the firm's cash-holding behavior in response to the changes in the expected value of future cash flow in the multi-period investment problem with a perfect external hedging market. To focus on the precautionary motive of cash holding, we assume away, for simplicity, the possibility of external hedging cash flow volatility through the market (e.g., option and future contracts). As in ACW, there are three periods. A firm faces an investment project in period 0. $G(y) \geq 0$ denotes the gross return on investment $y \geq 0$ in period 0. We assume that $G'(y) > 0$, $G''(y) < 0$, and $G'''(y) > 0$ for all $y \geq 0$. The firm has another investment project in period 1. When the firm invests $y \geq 0$ in period 1, the gross return on this investment is $H(y) \geq 0$. We assume that $H'(y) > 0$, $H''(y) < 0$ and $H'''(y) > 0$ for all $y \geq 0$. The gross returns on investments in periods 0 and 1 are realized in period 2. The positive third derivatives of G and H mean that the marginal gross return on investment is convex. Many plausible production functions, including the class of Cobb-Douglas production functions, have the positive third derivative.

The positive third derivative implies that an increase in uncertainty of cash flow in period 1 raises the expected marginal gross return on investment in period 1. As will be made clear later, the precautionary motive of cash holding arises due to the positive third derivatives of the marginal gross return functions and the absence of a perfect external hedging market. Given these assumptions, an increase in uncertainty of cash flow in period 1 leads a financially constrained firm to hold more cash, to be more prudent.

The firm faces the investment problems in the same physical environment as the one in ACW, except for the absence of a perfect external hedging market and the positive third derivatives of the marginal gross return functions. Here we briefly summarize the model in ACW in terms of continuous future cash flow. In period 0, the firm has an amount of cash $c_0 \geq 0$ that includes cash holdings carried over from previous periods and a cash flow generated from current operations. The cash flow in period 1 is denoted by $c_1 \geq 0$, and is random, following a probability distribution F on $[\underline{c}_1, \overline{c}_1] \subset \mathbb{R}_+$.

Let $i_0 \geq 0$ be the investment made in period 0. Let $i_1(c_1) \geq 0$ denote the investment that the firm makes in period 1 when the cash flow in period 1 is c_1. The firm can liquidate the fixed proportion of investments in period 2 after the gross returns are realized. This proportion is given by some constant $q \in (0, 1)$. The liquidation value of assets that can be captured by creditors is given by $(1 - \tau)qi$, where $\tau \in (0, 1)$. Let $b_0 \geq 0$ be the amount of cash borrowed in period 0. In period 0, the borrowing constraint is $0 \leq b_0 \leq (1 - \tau)qi_0$. Interpret $b_1(c_1) \geq 0$ as the amount of cash borrowed in period 1 when the cash flow in period

1 is c_1. The borrowing constraint in period 1 is $0 \leq b_1(c_1) \leq (1-\tau)qi_1(c_1)$ for all $c_1 \geq 0$.

For simplicity, the gross return on holding cash is normalized to one. Let s be the amount of cash holdings carried over from period 0 to period 1. Let d_0 denote the dividend paid in period 0. It is equal to $d_0 = c_0 + b_0 - i_0 - s \geq 0$. The dividend paid in period 1 is denoted by d_1 and it is defined as $d_1 = c_1 + b_1(c_1) - i_1(c_1) + s \geq 0$. Let $g(i_0) = G(i_0) + qi_0$ and $h(i_1(c_1)) = H(i_1(c_1)) + qi_1(c_1)$. Note that g''' and h''' are positive since G''' and H''' are positive. The dividend paid in period 2 is denoted by d_2 and is equal to $d_2 = g(i_0) + h(i_1(c_1)) - b_0 - b_1(c_1)$. We assume that the discount factor is normalized to one. The firm's objective is to maximize the expected lifetime sum of all discounted dividends. With no agency problems, the firm's optimization problem obviously boils down to finding $\{b_0^*, b_1^*, i_0^*, i_1^*, s^*\}$ that maximizes the expected net present value (NPV) of the investments

$$g(i_0) - i_0 + \mathbb{E}\left[h(i_1(c_1)) - i_1(c_1)|F\right] \tag{1}$$

subject to the borrowing constraints and the non-negativity constraints for the dividends.

2.2 The Firm's Optimal Behavior

This section examines the firm's optimal behavior $\{b_0^*, b_1^*, i_0^*, i_1^*, s^*\}$ for the problem modeled in the previous section. The decision depends on the environment captured in the initial amount of cash c_0 and the probability distribution F of the cash flow in period 1. We also examine how changes in the firm's beliefs about the volatility of the cash flow in period 1 can affect the firm's cash holdings in period 0. We model changes in the volatility in c_1 through second-order stochastic dominance (mean-preserving spread). Consider two probability distributions, say F and Q, with the same mean. Let $[\underline{c}', \overline{c}']$ be the support of Q. Formally, Q is said to generate marginally more volatile cash flow than F if Q is second-order stochastically dominated by F and there exist small constants, $\underline{\epsilon} > 0$ and $\overline{\epsilon} > 0$, such that $[\underline{c}', \overline{c}'] \subset [\underline{c}_1 + \underline{\epsilon}, \overline{c}_1 + \overline{\epsilon}]$.

2.2.1 Unconstrained Firms

The firm is financially *unconstrained* if it has enough financing capacity to finance the first-best investments, which are determined by $g'(i_0^*) = 1$ and $h'(i_1^*(c_1)) = 1$. As ACW noted, the firm's ability to make first-best investments depends on an exogenous environment specified by initial cash, the uncertainty in the cash flow in period 1, investment opportunities and, most importantly, on the upper bound of borrowing amounts, which depends on τ. The unconstrained firm's investment level in period 1 is constant and independent of cash flow because unconstrained firms have enough financing capacity to finance the first-best investments.

We are interested in the unconstrained firm's cash-holding behavior when it anticipates a marginal increase in the volatility of future cash flow c_1. Note that under F, the unconstrained firm can find a financing policy for first-best investments. Suppose that the cash flow in period 1 becomes marginally more volatile. Since a financially unconstrained firm can make first-best investments in periods 0 and 1 without binding borrowing constraints, it can finance the first-best investment in period 1 either by saving a little bit more in period 0 or by borrowing a little bit more in period 1, while keeping the first-best investment in period 0. Therefore, we can find a continuum of financing policies that still induces the first-best investments. It implies that there is no systematic relationship between the financially unconstrained firm's optimal cash holding and marginal increases in cash flow volatility. This result is analogous to Modigliani and Miller's arguments, which suggest that financial policy is irrelevant to real decisions, so cash holding is indeterminate for unconstrained firms.

2.2.2 Constrained Firms

The firm is financially constrained if its investment levels are lower than the first-best levels because of borrowing constraints. A constrained firm cannot undertake all positive NPV projects. The cost of holding cash is today's forgone investment project. The benefit of holding cash is the increase in the firm's ability to finance future investment projects. As

ACW points out, forgoing a dividend payment in periods 0 and 1 is a zero NPV project and borrowing an additional dollar is also a zero NPV project. Therefore, it is optimal for the constrained firm not to pay any dividends in either period and to exhaust its borrowing capacity in periods 0 and 1. This implies that the investment levels are

$$i_0 = \frac{(c_0 - s)}{\lambda} \qquad \text{and} \qquad i_1(c_1) = \frac{(c_1 + s)}{\lambda}, \tag{2}$$

where $\lambda \equiv 1 - q + \tau q$. Therefore, the constrained firm's optimization problem is to find the cash holdings that maximize

$$g\left(\frac{c_0 - s}{\lambda}\right) - \frac{(c_0 - s)}{\lambda} + \mathbb{E}\left[h\left(\frac{c_1 + s}{\lambda}\right) - \frac{c_1 + s}{\lambda}\middle| F\right] \tag{3}$$

When a solution is interior, the optimal cash holdings $s^*(c_0, F)$ satisfy the following first-order condition:

$$g'\left(\frac{c_0 - s^*(c_0, F)}{\lambda}\right) = \mathbb{E}\left[h'\left(\frac{c_1 + s^*(c_0, F)}{\lambda}\right)\middle| F\right]. \tag{4}$$

There is a trade-off when the firm holds an additional dollar; it increases the marginal return on the investment in period 0 but decreases the expected marginal return on the investment in period 1. At the optimum, the marginal return on the investment in period 0 must be equal to the expected marginal return on the investment in period 1.

Let $s_h^*(c_0, F)$ be the constrained firm's optimal cash holdings for any c_0 and F in ACW, where a firm can fully hedge any future cash flow risk at fair prices. A firm in ACW only cares about the expected value of future cash flow, not the distribution of future cash flow as a whole, because a firm can fully hedge any future cash flow risk at fair prices. Therefore, $s_h^*(c_0, F)$ satisfies the first-order condition (ACW, p. 1784):

$$g'\left(\frac{c_0 - s_h^*(c_0, F)}{\lambda}\right) = h'\left(\frac{\mathbb{E}\left[c_1 | F\right] + s_h^*(c_0, F)}{\lambda}\right). \tag{5}$$

Proposition 1 points out the differences between our result and the one in ACW by showing that the constrained firm holds more cash when future cash flow risk is not fully hedged.

Proposition 1 *A financially constrained firm's optimal cash holdings satisfy* $s^*(c_0, F) > s_h^*(c_0, F)$ *for any* c_0 *and any non-degenerate probability distribution* F.

The intuition behind Proposition 1 can be easily explained by the convexity of $h'(\cdot)$. When $h'(\cdot)$ is convex, we have the following relationship by Jenson's inequality:

$$\mathbb{E}\left[h'\left(\frac{c_1+s}{\lambda}\right)\middle| F\right] > h'\left(\frac{\mathbb{E}\left[c_1|F\right]+s}{\lambda}\right), \tag{6}$$

for all s. From the first-order conditions (4) and (5), (6) directly implies that when future cash flow risk cannot be fully hedged, the financially constrained firm will hold more cash than what is predicted by ACW for any given distribution of future cash flow. This additional cash holdings,

$$s^*(c_0, F) - s_h^*(c_0, F), \tag{7}$$

is generated by *the motive of precautionary saving*s. Proposition 1 provides an important implication. If the financially constrained firm in fact could not fully hedge future cash risk, then the model in ACW would actually underestimate the financially constrained firm's optimal cash holdings and could not capture the effect of cash flow volatility on the financially constrained firm's optimal cash holdings because of the absence of precautionary savings in their model.

The difference between external hedging (e.g., future, options) and cash holdings is worth mentioning here. External hedging allows a firm to transfer resources from the good state to the bad state so it reduces the future cash flow volatility. However, cash holdings increase the level of the future cash by the same amount in every state of the future.[5]

[5] The constrained firm's investment levels are strictly lower than the first-best ones. So the firm would have invested more if possible. One possibility would be that a firm might borrow (b_0) today out of the existing assets that create the future cash flow. The firm then will be able to increase the current investment and also the future investment by carrying more cash to the future. However, the constrained firm's precautionary cash holdings in (7) will be still positive since it comes from the absence of perfect hedging. Also note that the increase in cash holdings does not decrease the future cash flow volatility since it increases the level of the future cash by the same amount in every state of the future.

For simplicity, we assumed away the external hedging market. Supposing that external hedging was partial in the sense that any increase in cash flow volatility can be partially, but not fully, eliminated, the nondiversifiable part of cash flow volatility will still create the motive of precautionary cash holdings for the constrained firm. Also, we assumed that future investment opportunity is the same in all future states of the world in our model, as in ACW. However, it is plausible that the future investment opportunity may co-vary positively with the future cash flow. If the correlation is high enough, the constrained firm's overall cash holdings might not be as much as predicted by our model or that of ACW, because the positive correlation implies that the need for future financing is positively correlated with the future cash flow (see Acharya, Almeida and Campello. 2005). Such a correlation will certainly affect the precautionary cash holdings. The additional amount of cash holding generated by the precautionary motive, as specified in (7), depends on the convexity of the marginal return function $h'(\cdot)$. This dependence would still hold in the environment with a correlation between investment opportunities and future cash flow. However, if the correlation makes the marginal return function less convex, then the additional amount of cash holding would be lower than (7). It would be higher if the correlation makes it more convex.[6]

Now we ask how the firm changes its optimal cash holdings when it believes that the volatility in the cash flow in period 1 will marginally increase. In ACW, an increase in future cash flow volatility in terms of second-order stochastic sense does not affect the financially constrained firm's optimal cash holdings. This is so because the firm in ACW can fully hedge any future cash flow risk and the second-order stochastic dominant cash flow is generated by a mean-preserving spread, that is, $\mathbb{E}[c_1|Q] = \mathbb{E}[c_1|F]$. However, Proposition 2 shows that when the firm cannot fully hedge future cash flow risk, an increase in cash flow volatility in the second-order stochastic sense will lead the financially constrained firm to hold more

[6] A more complex model is needed to incorporate the correlation between the future investment opportunities and the future cash flow into our framework in order to show the exact effect of the correlation on the precautionary cash holdings.

cash. This also comes directly from the motive of precautionary savings.

Proposition 2 *Suppose that a probability distribution Q on the cash flow in period 1 induces a more volatile cash flow in period 1 than does the probability distribution F. Let $s^*(c_0, Q)$ be the optimal cash holdings when c_0 is the initial cash flow and Q is the probability distribution of the cash flow in period 1. If $s^*(c_0, F) \in (0, c_0)$, then $s^*(c_0, Q) > s^*(c_0, F)$.*

Proof. See Appendix.

The key intuition behind Proposition 2 is that the marginal return function $h'(\cdot)$ on investment in period 1 is a convex function. Given the original level of cash holdings $s^*(c_0, F)$ and the convex marginal return function, more volatile cash flow generated by Q increases the expected marginal return on investments in period 1 relative to the marginal return on investments in period 0:

$$\mathbb{E}\left[h'\left(\frac{c_1 + s^*(c_0, F)}{\lambda}\right)\middle| Q\right] > \mathbb{E}\left[h'\left(\frac{c_1 + s^*(c_0, F)}{\lambda}\right)\middle| F\right].$$

From the first-order condition in (4), we can easily see that the firm wants to invest more in period 1 to equalize marginal returns on investments across periods. Since a constrained firm cannot borrow more to increase the investment in period 1, it must save more in period 0 in the form of increased cash holdings. As (2) shows, there is a negative relationship between cash holdings and current investment, but a positive relationship between cash holdings and future investment for the constrained firm. Since Proposition 2 shows that a marginal increase in the volatility of future cash flow leads to an increase in the constrained firm's cash holdings, it implies that a marginal increase in the volatility of future cash flow leads to a decrease in current investment but to an increase in future investment for the constrained firm.

3 Empirical Analysis

The theoretical analysis generates a testable empirical implication for a firm's optimal cash holdings in response to a change in cash flow volatility: cash holdings of financially constrained firms increase in the presence of greater cash flow volatility, while cash holdings of financially unconstrained firms are not affected by cash flow volatility. To test our theory, we examine a sample of publicly traded firms using Compustat quarterly data from 1997 to 2002. There is an important advantage to using quarterly data over annual data in testing the impact of cash flow volatility on cash holdings. The high frequency of quarterly data allows us to have more observations to measure the volatility of cash flow within a shorter period. For example, to calculate the coefficient of variation in cash flow for four years, quarterly data have 16 observations, while annual data offer only 4 observations. To obtain 16 observations using annual data, one needs to use 16 years of data. Moreover, a firm's characteristics could change dramatically in 16 years, and cash flow volatility calculated using 16 years observations might have low explanatory power regarding the firm's current cash-holding decisions.

To test the impact of cash flow volatility on financially constrained and unconstrained firms, we first follow the approach of ACW and separate firms into financially constrained and unconstrained groups based on four indices.[7] The first index is the dividend payout ratio. Firms are assigned to the financially constrained group if they have not paid out dividends during the sample period. Firms belong to the financially unconstrained group if they paid out dividends in certain years. The second index is firm size. Firms are ranked based on their asset sizes from 1997 to 2002, and they are assigned to the financially constrained (unconstrained) group if they are in the bottom (top) quartile of the size distribution. The third index is bond ratings. Financially unconstrained firms are those whose bonds have

[7] ACW also used the Kaplan and Zingales (1997) index as a financial constraints index and found that the KZ index is negatively correlated with other indices. There has been an ongoing debate as to which measurement should be used to define financially constrainted status (see Fazzari, Hubbard and Petersen, 1988; and Kaplan and Zingales, 1997). Given the results in ACW, we exclude the KZ index in our analysis.

been rated during the sample period, while financially constrained firms are those whose bonds have never been rated during the sample period. The final index is commercial paper ratings. Financially unconstrained firms are those whose commercial papers have been rated during the sample period, while financially constrained firms are those whose commercial papers have never been rated during the sample period.

[Table 1 about here]

Table 1 reports the number of firm-year observations in each group. The number of observations in each group reflects the correlation of observations among different classification criteria. Consistent with the results of ACW, there is a positive relationship among the observations separated by the four criteria of financial constraints. For example, most small (large) firms lack (have) bond ratings. Also, most small (large) firms have low (high) payouts.

We then estimate the following dynamic panel cash holdings model for financially constrained and unconstrained firms respectively,

$$CASH_{i,t} = b_0+b_1CVCF_{i,t-1}+b_2CF_{i,t}+b_3SIZE_{i,t-1}+b_4Q_{i,t-1}+b_5LEV_{i,t-1}+\sum_{j=1}^{3} a_jCASH_{i,t-j}+Y_t+V_i+\varepsilon_{i,t} \quad (8)$$

where the dependent variable, $CASH_{i,t}$, is firm i's cash holding at time t and is measured by the cash and cash equivalent (data item 36) normalized by total assets of the firm (data item 44). Because we are using quarterly information, cash holdings could be highly persistent among quarters. We include lagged one to three quarter cash holdings as explanatory variables. The explanatory variable of particular interest to this study is cash flow volatility, $CVCF_{i,t}$, which is defined as the coefficient of variation in a firm's quarterly cash flow over the past four years (16 quarters). The coefficient of variation is the standard deviation of operating cash flow scaled by the absolute value of the mean over the same period. For example, to measure the cash flow volatility for a firm at the end of the first quarter of 1998, we calculate the coefficient of variation of the cash flow from the first quarter of 1994 to the cash flow in the fourth quarter of 1997. This measurement has been used by Albrecht and Richardson (1990); Michelson, Jordan-Wagner, and Wootton (1995); and Minton and Schrand (1999). A firm is included in the sample for a given quarter if it has at least 12 quarters of non-missing observations during the past 16 quarters.

Other control variables are conventional and have been shown in the previous literature to have significant explanatory power on the cash-holding decisions of firms: cash flow, $CF_{i,t}$, is computed quarterly as the sum of earnings before extraordinary items (data item 8) and depreciation (data item 5) normalized by the total assets (data item 44) at the beginning of the quarter. Tobin's Q, $Q_{i,t-1}$, is measured by total assets plus the market value of equity (data item 61 $\times$ data item 68) minus the book value of equity (data item 60) divided by total assets. Tobin's Q captures the growth opportunities of a firm. Firms with greater growth opportunities may have higher cash reserves in order to capture future growth opportunities. Firm size, $SIZE_{i,t-1}$, is measured by the natural logarithm of total assets. Since there are potential economies of scale in cash management, large firms may have a lower cash-to-assets ratio than small firms. Leverage level, $LEV_{i,t-1}$, is measured by long-term debt (data item 51) divided by total assets. Firms with higher leverage levels might need to save more cash to meet future debt payments. Y_t is a dummy variable indicating different years-quarters and captures quarterly and yearly effects. V_i is an individual firm effect and is assumed to be constant over time.

[Table 2 about here]

Table 2 presents summary statistics of the variables used in the regressions. We exclude financial firms. All variables below or higher than the 1st and 99th percentiles are deleted to avoid problems with outliers. The summary statistics show that, on average, the sample firms hold 8.4% of their assets in cash and cash equivalents. The average Tobin's Q is 1.704, suggesting that the firms sampled have relatively good growth prospects in the sample period.

[Table 3 about here]

To estimate equation (8), we apply the generalized method of moments (GMM), developed by Arellano and Bond (1991). This method first differences the data to eliminate the firm fixed effect, and then utilizes lagged values of the regressors as instruments. The consistency of estimates is subject to the validity of instruments that depends on the absence of higher-order serial correlations in the error terms. Table 3 reports the GMM estimation results. The significance of coefficients is calculated using the asymptotic standard errors robust to general cross-section and time series heteroskedasticity, as suggested in Arellano and Bond (1991). The last two columns in Table 3 report Z-statistics for first- and second-order serial correlations, $R(1)$ and $R(2)$. The results indicate that there is only first-order serial correlation but no second-order serial correlation.[8] An inspection of Table 3 reveals that cash flow volatility has a significantly positive impact on the cash holdings of financially constrained firms. In contrast, the coefficient on cash flow volatility is insignificant for unconstrained firms. The estimated coefficients on cash flow volatility for financially constrained firms are around 0.001. These estimates imply that for an increase of one unit of standard deviation of cash flow, the cash to total assets ratio of average financially constrained firms will increase by 0.017.[9] Given that the average cash to total assets ratio is 0.084 in our sample, the result suggests that the effect of cash flow volatility on the cash holdings of financially constrained firms is economically significant. Thus, the empirical results indicate differences in cash holding behavior between financially constrained and unconstrained firms in their response to the changes in cash flow volatility, and support the predictions of our model.

[8] Another specification test, the Sargent over-identifying test, tends to over-reject, and its asymptotic distribution is unknown in the presence of heteroskedasticity (Arellano and Bond, 1991). Thus the Sargent test is not used here.

[9] This is calculated in the following way: since the volatility of cash flow is measured by the coefficient of variation of cash flow defined as the standard deviation of cash flow scaled by the absolute value of the mean of cash flow, the estimated coefficient of 0.001 on cash flow volatility should be interpreted as 0.001*(standard deviation of cash flow/absolute value of the mean of cash flow). The average absolute value of the mean of cash flow in our sample is 0.06; thus the result suggests that the effect of one unit of standard deviation of cash flow on cash holdings is equal to 0.017 (0.001/0.06).

4 Conclusion

This paper provides an analysis of the interaction between a firm's financial constraints, cash holdings and cash flow volatility. It was shown that the impact of cash flow volatility on a firm's cash holdings depends on its financial constraints. A financially constrained firm increases its cash holdings in response to an increase in cash flow volatility. In contrast, there is no systematic relationship between cash holding and cash flow volatility for unconstrained firms. The empirical implication of our theory is that there is a significantly positive relationship between cash flow volatility and cash holding among financially constrained firms, while the cash flow volatility - cash holding relationship is insignificant among financially unconstrained firms. We tested the implication of our theory using a large sample of publicly traded firms from 1997 to 2002 and found supportive empirical results.

This paper contributes to the extant literature in several important dimensions: first, to our knowledge, this paper provides a first analysis of the precautionary motive for firms' cash holdings proposed by Keynes (1936). It shows how a firm's optimal cash holdings change in the presence of cash flow volatility. Second, our theory has implications for the impact of cash flow volatility on a firm's investment. We provide a theoretical explanation for the existence of a negative relationship between current investment and cash flow volatility. Finally, this paper extends our knowledge of the impact of financial constraints on a firm's investment and saving behavior. It has been demonstrated in the literature that financial constraints could affect the link between cash flow and investment (Fazzari et al., 1988 and Kaplan and Zingales, 1997) and the link between cash holding and cash flow (ACW). Our theory shows that financial constraints could also affect the link between cash flow volatility, cash holdings and investments.

For simplicity, the model in this paper assumed away hedging. However, a firm may, in practice, hedge future cash flow uncertainty to certain degree. In fact, our theory implies that a decrease in future cash flow uncertainty by hedging will reduce the incentive for the precautionary cash holdings. Therefore, hedging and precautionary cash holdings can be thought of as substitutes, and the optimal hedging and precautionary cash holdings will be determined at the point where the marginal benefit of one extra dollar for hedging is the same as the marginal benefit of one extra dollar for precautionary cash holdings. The trade-off between hedging and precautionary cash holdings may also depend on how much the future investment opportunity is correlated with the future cash flow. The line of inquiry is interesting, and we leave it for our future research.

APPENDIX

A marginally more volatile cash flow can be constructed as follows. Choose a very small $\epsilon' \in [-s^*(c_0, F) - \underline{c}_1, 0]$ and a very small $\epsilon'' > 0$. Construct a probability distribution Q for c_1 which is a mean-preserving spread of F by using a conditional probability distribution $M(\cdot|c_1)$ with zero mean such that the support of $M(\cdot|c_1)$ is $[\underline{x}(c_1), \overline{x}(c_1)] \subset [\epsilon', \epsilon'']$ for all $c_1 \in [\underline{c}_1, \overline{c}_1]$. Let $[\underline{c}', \overline{c}']$ be the support of Q. $s^*(c_0, F) \in (0, c_0)$ implies that the optimal cash holding is an interior solution to the problem (3) given (c_0, F). Therefore, (4) holds.

Suppose that the firm still chooses to hold $s^*(c_0, F)$ given (c_0, Q). Since $\underline{x}(c_1) > \epsilon' > -s^*(c_0, F) - \underline{c}_1$ for all $c_1 \in [\underline{c}_1, \overline{c}_1]$, we have $\underline{c}' + s^*(c_0, F) = \min_{c_1} [c_1 + \underline{x}(c_1)] + s^*(c_0, F)$. In other words, $s^*(c_0, F)$ always induces a positive investment in period 1, regardless of the cash flow realized from Q. Then, we have

$$
\begin{aligned}
& \int_{\underline{c}'}^{\overline{c}'} h'\left(\frac{c_1' + s^*(c_0, F)}{\lambda}\right) dQ(c_1') \qquad (9) \\
= & \int_{\underline{c}}^{\overline{c}} \left(\int_{\underline{x}(c_1)}^{\overline{x}(c_1)} h'\left(\frac{c_1 + x + s^*(c_0, F)}{\lambda}\right) dM(x|c_1)\right) dF(c_1) \\
> & \int_{\underline{c}}^{\overline{c}} h'\left(\frac{c_1 + s^*(c_0, F)}{\lambda} + \int_{\underline{x}(c_1)}^{\overline{x}(c_1)} \frac{x}{\lambda} dM(x|c_1)\right) dF(c_1) \\
= & \int_{\underline{c}}^{\overline{c}} h'\left(\frac{c_1 + s^*(c_0, F)}{\lambda}\right) dF(c_1).
\end{aligned}
$$

The first equality comes from the definition of Q. The inequality holds because of $h''' > 0$. The last equality comes from the fact that the mean of x from the probability distribution Q is zero. The inequality in (9) and (4) implies that

$$
g'\left(\frac{c_0 - s^*(c_0, F)}{\lambda}\right) < \mathbb{E}\left[h'\left(\frac{c_1 + s^*(c_0, F)}{\lambda}\right) \middle| Q\right]
$$

Since the expected marginal return on the investment in period 1 is greater than the marginal return on the investment in period 0 at $s = s^*(c_0, F)$ given (c_0, Q), $s^*(c_0, Q)$ must be greater than $s^*(c_0, F)$. QED

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Table 1

Cross-Classification of Constraint Types

This table displays firm-year cross-classification for the four criteria (dividend payout ratio; firm size; bond ratings; and commercial paper ratings) used to categorize firm-years as either financially constrained or unconstrained. The letter A stands for constrained firms and B stands for unconstrained firms in each row/column. The sampled firms are non-financial firms in the Compustat quarterly industrial data. The sample period is 1997 through 2002.

		Dividend Payout Ratio		Firm Size		Bond Ratings		CP Ratings	
		A	B	A	B	A	B	A	B
Dividend Payout Ratio	A (constrained)	15,110							
	B (unconstrained)		18,507						
Firm Size	A (constrained)	5,723	2,546	8,267					
	B (unconstrained)	1,695	6,833		8,529				
Bond Ratings	A (constrained)	6,261	6,598	8,114	639	14,773			
	B (unconstrained)	8,512	12,246	414	7,630		18,844		
CP Ratings	A (constrained)	14,756	354	8,269	3,409	14,711	12,106	6,800	
	B (unconstrained)	12,061	6,446	0	5,119	62	6,738		26,817

Table 2

Description of Variables for the 1997-2002 Compustat Quarterly Sample

This table provides summary statistics of the variables used in the empirical tests. The sample is the Compustat quarterly data over the 1997-2002 period. $CASH_{i,t}$ is firm i's cash holding at time t. $CVCF_{i,t}$ is the coefficient of the variation in a firm's quarterly cash flow over the past four years (16 quarters). $CF_{i,t}$ is the firm's cash flow at time t. $Q_{i,t-1}$ is Tobin's Q at time t-1. $SIZE_{i,t-1}$ is the natural logarithm of total assets. $LEV_{i,t-1}$ is the firm's leverage. The number of observations is 33,617.

Variables	Mean	Std.	25^{th} Percentile	Median	75^{th} Percentile
$CASH_{i,t}$	0.084	0.126	0.012	0.033	0.099
$CVCF_{i,t}$	1.161	2.384	0.257	0.469	1.020
$CF_{i,t}$	0.021	0.033	0.013	0.023	0.035
$SIZE_{i,t-1}$	6.654	1.888	5.492	6.759	7.919
$Q_{i,t-1}$	1.704	1.193	1.054	1.314	1.879
$LEV_{i,t-1}$	0.227	0.182	0.086	0.212	0.348

Table 3

Cash Flow Volatility and Cash Holdings

This table displays results for GMM estimations of dynamic panel regression models for financially constrained and unconstrained firms, respectively. The specification of the model is

$$CASH_{i,t} = b_0 + b_1 CVCF_{i,t-1} + b_2 Q_{i,t-1} + b_3 CF_{i,t} + b_4 SIZE_{i,t-1} + b_5 LEV_{i,t-1} + \sum_{j=1}^{3} a_j CASH_{i,t-j} + Y_t + V_i + \varepsilon_{i,t}$$

where the dependent variable, $CASH_{i,t}$ is firm i's cash holding at time t. $CVCF_{i,t}$ is the coefficient of variation in a firm's quarterly cash flow over the past four years (16 quarters). $CF_{i,t}$ is firm i's cash flow at time t. $Q_{i,t-1}$ is Tobin's Q at time t-1. $SIZE_{i,t-1}$ is the natural logarithm of total assets. $LEV_{i,t-1}$ is a firm's leverage level. $CASH_{i,t-j}$, is firm i's cash holding at time t-j. Y_t is the quarterly dummies. V_i is the firm's individual effect. The sampled firms are non-financial firms in the Compustat quarterly industrial data. The sample period is 1997 through 2002. Firm-year observations are divided into financially constrained and unconstrained observations based on four criteria: dividend payout, firm size, bond rating and commercial paper ratings. z-statistics of coefficients are in parentheses and are calculated using the asymptotic standard errors robust to general cross-section and time series. R(1) and R(2) are z-statistics for first- and second-order serial correlation in the first-differenced residuals. *, **, and *** represent significance at the 10%, 5% and 1% levels, respectively.

Table 3

(Continued)

	CVCF$_{i,t-1}$	CF$_{i,t}$	SIZE$_{i,t-1}$	Q$_{i,t-1}$	LEV$_{i,t-1}$	Cash$_{i,t-1}$	Cash$_{i,t-2}$	Cash$_{i,t-3}$	R(1)	R(2)
Financial Constraints Criteria										
1. Dividend Payout Ratio										
Constrained firms	0.0010** (2.22)	0.1266*** (3.40)	-0.0112 (-1.44)	-0.0015 (-0.74)	0.0042 (0.24)	0.4412*** (7.61)	0.0330 (1.33)	-0.0086 (-0.41)	-8.53	0.07
Unconstrained firms	0.0008 (1.18)	0.1495*** (3.47)	-0.0179*** (-3.11)	0.0039** (-1.92)	0.0078 (0.46)	0.4557*** (8.08)	0.0037 (0.12)	0.0284 (-1.10)	-8.67	0.74
2. Firm Size										
Constrained firms	0.0014** (2.26)	0.0768** (2.45)	-0.0160 (-1.30)	0.0024 (0.90)	0.0129 (0.57)	0.5369*** (9.61)	0.0375 (1.09)	-0.003 (-0.01)	-6.82	0.27
Unconstrained firms	-0.0010 (-1.06)	0.2258** (2.62)	-0.0073 (-1.40)	-0.0014 (-0.46)	-0.0017 (-0.08)	0.3810*** (5.91)	0.0555* (1.79)	-0.0475 (-1.58)	-7.49	0.25
3. Bond Ratings										
Constrained firms	0.0010** (2.03)	0.1240*** (3.16)	0.0032 (0.36)	0.0031 (1.42)	0.0085 (0.53)	0.4997*** (9.32)	0.0220 (0.79)	0.0161 (0.77)	-8.75	0.82
Unconstrained firms	0.0008 (1.18)	0.1495*** ((3.49)	-0.0179*** (-3.11)	-0.0040* (-1.90)	0.0078 (0.46)	0.4557*** (8.08)	0.0037 (0.12)	-0.0284 (-1.10)	-8.67	0.74
4. Commercial Paper Ratings										
Constrained firms	0.0009** (2.16)	0.1339*** (4.06)	-0.0113* (-1.72)	-0.0015 (-0.80)	0.0087 (0.65)	0.4992*** (10.44)	0.0203 (0.91)	0.0079 (0.44)	-10.73	0.94
Unconstrained firms	-0.0003 (-0.53)	0.1040** (2.26)	-0.0033 (-0.53)	0.0022 (0.77)	0.0123** (0.51)	0.3227*** (3.19)	-0.0246 (-0.74)	-0.0544* (-1.75)	-5.07	1.35