Financial constraints, real options and corporate cash holdings

Cyrus A. Ramezani
Orfalea College of Business, California Polytechnic State University, San Luis Obispo, California, USA

Abstract

Purpose – A large body of empirical literature has identified the key drivers of corporate cash holdings. The extant literature posits that the existence of real options significantly influences a firm's demand for liquidity. The literature, however, has relied on indirect proxies to assess this influence. The purpose of this paper is to provide a direct method for assessing this hypothesis. It is posited that firms with valuable real options hold excess cash and liquid assets, relative to firms lacking such opportunities.

Design/methodology/approach – The author utilizes a procedure originally proposed by Copeland and Antikarov to identify firms with valuable real options. This procedure assumes that an option's value will rise with its underlying uncertainty and with firm's managerial flexibility, i.e. discretion over the timely exercise of the option. Without a large cash hoard, a firm with "in-the-money" real options may face "financing constraints" that result in foregone or delayed exercise of these options. The author extends the Copeland and Antikarov procedure to account for the firm's financing constraints. Using data from a large sample of US companies, new insights are presented on how managerial flexibility, financing constraints, and the value of the firm's real options drive its cash holdings to levels that may appear to be "irrational," if these factors are ignored.

Findings – Cash holdings are consistently higher for firms' valuable real options. All else being the same, financially unconstrained firms hold more cash. It is also shown that: an increase in a firm's weighted average cost of capital will lead to higher cash holdings; firms with higher market power (relative sales) hold less cash; and firms with less operational flexibility (higher fraction of fixed-to-total assets) hold less cash. Additional results are shown in the paper.

Research limitations/implications – The paper shows that the existence of valuable real options leads to an unambiguous increase in corporate cash holdings. Whether this addition to firm's cash holdings is capitalized into its equity price is an open and challenging question that deserves further study. Other promising areas for improving this line of research include: developing other measures of managerial flexibility; partitioning the volatility-flexibility into high, intermediate, and low categories (like the Kaplan and Zingales index); and expanding the analysis to cover a longer time period. The author believes that the results are robust and will be confirmed with these and other extensions.

Originality/value – This is the first paper that considers the effect of a firm's real options on its demand for liquid assets and cash.

Keywords United States of America, Corporate finances, Corporate strategy

Paper type Research paper

1. Introduction

Global corporate cash balances have risen significantly in recent decades, exceeding $3 trillion for all NYSE- and DASDAQ-listed companies in 2005. This unprecedented growth in corporate demand for liquidity is puzzling, particularly in light of capital markets innovations, which have significantly reduced both the required time and the

This paper benefited from extensive comments provided by the referee, the Editor, and several colleagues, particularly Alan Jung and Luc Soenen. Any remaining errors are the sole responsibility of the author.

0307-4358
DOI 10.1108/03074351111175074

costs of raising external funds. A large body of academic literature has attempted to explain this increase in corporate demand for liquidity[1]. The extant literature relies on the trade-off, the free cash flow, and the pecking order theories to explain the growing corporate demand for liquidity.

In a world with perfect capital markets, firms would hold no liquid assets. With market imperfections, such as informational asymmetry and agency problems, the firm holds an "optimal" level of cash that enables it to avoid excessive transaction costs and simultaneously use cash as a strategic tool to capitalize on its growth opportunities. Liquidity enables firms to invest without recourse to capital markets, thereby allowing the firm to avoid both implicit and explicit costs associated with raising external funds. Likewise, cash reserves reduce the cost of financial distress, as firms with higher reserves are more likely to meet their financial obligations; however, there are significant costs to a firm holding excessive cash, including low rate of return on cash holdings and adverse exposure to taxation. Optimality dictates that managers maximize the value of the firm by choosing that level of cash that balances these benefits and costs.

The free cash flow theory of Jensen (1986) suggests that managers prefer to hold excess cash (rather than distribute it to share holders) to pursue their own objectives to build empires and increase the size of the assets under their control. This leads to value destructive abuses of cash reserves by managers who advance their own pecuniary interests, often at the expense of the shareholders.

Under the pecking order theory of Myers and Majluf (1984), managers follow a financing hierarchy that minimizes transactions costs arising from informational asymmetries. The order of preference for financing investments favors internal funds, followed by issuance of debt and equity. The level of cash holding is therefore highly dependent on a firm's investment opportunities and the costs of raising external funds.

Recent important papers by Kim *et al.* (1998), Harford (1999) and Opler *et al.* (1999) attempted to empirically test these theories using data for a large cross-section of US firms. These studies identified a set of firm-specific variables that have been extensively analyzed in the subsequent body of empirical research. These variables measure the costs and benefits of cash holdings and serve as proxies for managerial motives, therefore providing the means to test the validity of these theories.

The extant literature investigates these issues using data for publicly traded firms from around the world (Minton and Schrand, 1999; Billett and Garfinkle, 2004; Ozkan and Ozkan, 2004; Mikkelson and Partch, 2002; Dittmar *et al.*, 2003). Harford *et al.* (2008), Dittmar and Mahrt-Smith (2007), Han and Qiu (2007) and Denis and Sibilkov (2009) survey recent developments in this literature, and Kalcheva and Lins (2007) and Lins *et al.* (2008) provide international comparisons of the determinants of demand for corporate cash holdings.

Starting with Opler *et al.* (1999), the empirical literature provides support for the trade-off theory and shows that corporate cash holdings rise with:

- the firm's investment opportunity set (growth opportunities);
- cash flow volatility and other measures of risk;
- lack of access to capital markets; and
- high costs of financial distress.

On the other hand, cash holdings decline with firm size and leverage.

The firm-specific control variables common to most studies include size; capital structure variables such as leverage; cash flow and its variability; level of working capital and capital expenditures; dividend distributions; insider and institutional ownership; measures of business risk; measures of the firm's access to capital markets, including its cost of raising outside funds; and proxies for the firm's growth opportunities – specifically, the market-to-book ratios (or Tobin's Q), expenditures on research and development (R&D), and expenditures on acquisitions[2].

Indeed, proxies for a firm's growth opportunities have been shown to be the most significant predictors of cash holdings, suggesting that demand for liquidity may be primarily driven by a firm's investment opportunities, rather than the other considerations noted above. This paper argues, however, that the evidence linking a firm's cash holdings to its investment opportunity set is indirect and subjective, and that this relationship warrants further empirical scrutiny, a gap we aim to fill. While all firms possess a variety of investment and growth opportunities, we posit that, all else being equal, firms with valuable investment opportunities will hold more cash, primarily because liquid assets enable the management to pursue investment opportunities in an efficient and timely manner.

Following standard practice in corporate finance, we assert that the value of any investment undertaken by the management is composed of the investment's static net present value (NPV) plus the value of the options that are embedded in that investment. The value of the embedded options, broadly referred to as real options, reflect the flexibilities that are afforded by that investment (the ability to expand, contract, abandon, alter, or stage decisions), the level of uncertainty associated with that investment (its underlying cash flow volatility) and whether that investment enhances the contingent nature of the firm's strategic decisions in a risky business environment (Amram and Kulatilaka, 1999).

Copeland and Antikarov (2001) assert that the value of the embedded real option(s) rises with the uncertainty of the underlying cash flows, as well as the managerial flexibility to optimally exercise these options: that is, as new information arrives and the uncertainty surrounding the investment decision is gradually resolved, managers with greater discretion may alter their original strategies so as to capitalize on favorable investment opportunities or to undertake actions that mitigate losses from adverse developments.

A critical assumption implicit in the Copeland and Antikarov (2001) assertion is that the firm possesses the necessary cash on hand to fund managers' decisions to optimally exercise embedded option(s), such as to expand, contract, abandon, alter, or stage investment(s). Alternatively, it is implicitly assumed that, absent its own cash holdings, the firm can tap resources from the capital markets in a timely and cost-effective manner to fund the exercise of its real option(s). Hence, the firm is assumed to face no financial constraints[3].

The influence of financial constraints on a firm's real and financial decisions has received much attention in the literature, focusing on the impact of financial constraints on investment decisions, rather than on the cash holdings decision. However, as Myers and Majluf (1984) have shown, in imperfect capital markets, investment decisions are constrained by the cost of external financing. Moreover, external sources of capital may be limited or non-existent, limiting a firm's investments to available internal resources. Hence, in imperfect capital markets, liquid assets offer a critical hedge, and hoarding large amounts of cash may be perfectly rational, particularly when the firm possesses valuable in-the-money real options that must be exercised strategically. Indeed, at the margin, excess cash holdings and managerial flexibility will likely increase the value of a financially constrained firm because it allows the firm to exercise its in-the-money real options that would otherwise expire.

This paper is among the first to empirically examine the influence of uncertainty, managerial flexibility, and financial constraints on demand for cash and liquid assets. Controlling for these factors, we show that the existence of real options provides the greatest justifications for corporate cash holdings. While uncertainty, financial constraints, and managerial flexibility influence demand for liquidity, we find that managerial flexibility has the largest impact on cash holdings. We therefore provide a direct confirmation of the Jensen's (1986) free cash flow theory.

2. Identifying firms with valuable real options

The traditional investment valuation models, particularly the NPV and internal rate of return analysis, are static in that they assume a fixed path for the future cash flows of a firm's investment projects. Moreover, the traditional models assume that managerial decisions are also static, where managers cannot alter their initial decisions in response to changes in uncertainty or shifts in the project's cash flow profile. The real options approach to valuation removes these assumptions, and shows that the value of an investment – and by extension the value of the entire firm – is comprised of the traditional static value associated with the assets in place, plus the value of the embedded options arising from the manager's ability to take such actions to expand successful projects; abandoning or altering value-destroying projects; staging investments so as to learn and benefit from the arrival of new information; and more generally take advantage of all flexibilities offered by an investment project in a dynamic world. Amram and Kulatilaka (1999), Copeland and Antikarov (2001) and Trigeorgis (1996) provide detailed explanations of options that may be embedded in real investment projects and present models for their valuation and optimal exercise.

To illustrate the link between real options, managerial flexibility, and cash holdings, consider the following simple but realistic scenario: suppose a firm, called XYZ, has the opportunity today to commit to a project that contains the embedded option to delay investment to an optimal future date, when the project's pay-offs will far exceed its costs. This opportunity may be the acquisition of raw land, which embeds the option to build later, or the filing of a patent application that creates the exclusive right to produce a product at the opportune time in the future.

Focusing on the patent example, suppose XYZ can spend C_0 today (t_0), to file a patent application for a new and novel production process. The patent gives XYZ the exclusive right to invest an amount I_s, to instantly install the new production process at time s in the future, where $t_0 \leq s \leq T$, and T is a fixed date in future when the patent expires. The value of this project – the present value of the expected future cash inflows from installing the new production process – will be denoted by V. Assume that the dynamics of V can be represented by the standard geometric Brownian motion, $dV/V = \alpha dt + \sigma d\omega$, where α is the mean rate of return and σ is the volatility of the return on this project and $d\omega$ is a Wiener process. Let r denote the risk-free rate and let $B_s = e^{rs}$ denote the future value at s of \$1 placed in the risk-free account at time t_0. Then, the present value of this project at time s, is given by

$NPV_s = V_s - I_s - C_0B_s = V_s - X_s$. XYZ's optimal decision rule for this project is to invest when its NPV is positive ($V > X$) and delay when its NPV is negative ($V < X$). The project may have a negative NPV at t_0 but it may still be a good project if XYZ waits to invest in the future. Note that there are costs associated with delaying the project, particularly when the NPV is positive. Assume that delaying the project will reduce the value of the investment by d_s percent over one waiting period that starts at s. Hence, installing the production process at s will generate a dividend rate equal to d_s.

Let $d_s = d$ and $I_s = I$ be constants. Then, acquiring the patent (raw land) is akin to acquiring an American call option on an asset with the underlying value V, dividend yield d, with the exercise price I, and maturity T. Applying standard option pricing theory, it is possible to find this patent's value and the optimal exercise time s^* for undertaking the investment in the new production process.

It is apparent from the foregoing that XYZ's cash holdings decision can adversely influence its ability to capitalize on this investment opportunity, particularly if it has no access to outside financing. First, XYZ's current cash holdings must be sufficient to cover the initial outlays to acquire the rights to this project, C_0. Second, sufficient liquid assets must be kept on hand to cover the possibly random cost of exercising the option, I_{s^*}, at a random future date, s^*. Note that at time s^*, when the project's NPV is positive, XYZ's cash holdings may be insufficient to cover I_{s^*}, causing a delay of at least one period and resulting in a minimum loss equal to $V_{s^*} \times d_{s^*}$. In that situation, the actual losses suffered by XYZ could be greater, as other firms may gain significant competitive advantage by undertaking similar investment projects.

To mitigate the risks associated with a shortfall in its funding, XYZ must determine its optimal cash holdings for every date, s, where $t_0 \leq s \leq T$. Without access to external financing, XYZ's cash holdings will rise with the project's NPV_{s^*} (i.e. more cash will be held if the project is expected to be deep in-the-money), as well as the project's dividend yield, d_{s^*} (the rate at which value is lost due to delay caused by insufficient liquid assets). Alternatively, XYZ can mitigate its shortfall risk by obtaining a secured line of credit (costly); by issuing bonds, equity, or other securities (costly, time consuming, and subject to undervaluation risk that may arise from adverse security-market conditions); and by entering partnerships and joint venture agreements to share the shortfall risk and, therefore, relax its financial constraints (risky and time consuming)[4].

Even when XYZ holds a large cash hoard (or faces no financial constraints), its management must possess sufficient managerial flexibility to execute investment decisions in an efficient and timely manner, as costly investment delays may be caused by a bureaucratic decision-making structure within the firm. Hence, insufficient cash holdings, external financial constraints, and/or an absence of managerial discretion will result in sub-optimal investment decisions, degrading the value of the firm's projects. Conversely, taking steps to remove financial constraints, hoarding cash, and increasing managerial discretion will ensure timely exercise of the firm's options and enhance the project's value.

Finally, it is possible to follow the above line of reasoning to demonstrate the importance of cash holdings, financial constraints, and managerial flexibility for the valuation of other types of real options embedded in the firm's investments (e.g. the option to expand, contract, alter, and so on). We note that the extant real option literature implicitly assumes that:

- The firms holds enough cash, and/or faces no financial constraints, so as to exercise investment options in a timely and value-maximizing manner.
- The firm's management possesses absolute discretion over whether to take advantage of operational contingencies that may arise by choosing the amount and timing of investments and the size of the firm's capital expenditures (the expenditures on investment activity serve as a proxy for managerial flexibility)[5].

In practice, all public firms possess a unique portfolio of real options that enable them to operate competitively within their respective industries. These options, however, are not equally valuable since the composition of hard assets and the structure of production costs vary widely within and across industries. We posit that after controlling for financial constraints and managerial flexibility, firms with valuable real options are more likely to hold excess cash (relative to their peers), primarily because liquid assets can be used to strategically exercise options that are most valuable (i.e. are deeper in-the-money).

To access the validity of this hypothesis, we need to distinguish firms with valuable real options from others. To achieve this objective, we separate firms into two distinct groups: firms with highest or lowest valued real options. We then examine the distribution of cash holdings for each group, while controlling for their financial constraints. Next, we estimate the standard time series and cross-section regression for each group, linking cash holdings to a common set of conditioning variables as identified in the literature (see Kim *et al.*, 1998; Opler *et al.*, 1999 and other references cited below).

As Copeland and Antikarov (2001) have shown, two key ingredients that enhance the value of real options are the volatility (risk) of the options' underlying cash flows and the firm's managerial flexibility[6]. As Table I shown, one can then think in terms of a two-by-two matrix with four quadrants, with low-option values corresponding to low volatility and limited managerial flexibility and high-option values corresponding to high volatility coupled with high managerial flexibility. The value of the other two quadrants lies within these two extremes.

Our first task is to describe the methodology we use to assign firms to each quadrant. As expected, there exists no universally accepted measure of underlying risk, managerial flexibility, or financial constraints. Hence, we consider a number of proxies for each.

2.1 The proxies for underlying risk

All else being equal, the value of real options is expected to rise with the volatility of its underlying cash flows. For example, the value of the option to delay rises with uncertainty, as delaying investment decisions enables the manager to exercise an

Table I. Value of real options versus managerial flexibility and uncertainty

Managerial flexibility	Underlying uncertainty: Low	Underlying uncertainty: High
Low	*Low value for real options.* Lack of volatility and managerial flexibility reduces value of real options	*Moderate (ambiguous).* High option value but lack of discretion to optimally exercise real options
High	*Ambiguous.* Low option value despite managerial flexibility	*High value for real options.* High degree of uncertainty and managerial flexibility enhance value of real options

investment option when it has a higher NPV. A firm may view its capacity or inventory choice (expansion option) with a similar perspective: keeping excess capacity or inventory permits the firm to lock in large profits during periods of peak demand, offsetting the costs associated with keeping excess capacity (inventory). The probability of experiencing peak demand is higher when the demand volatility is large. This analogy can be extended to firms that invest heavily in intangible assets that serve as a platform for future investments.

Modern firms possess a variety of real options with different underlying sources of risk, making it difficult to decide what measure should be used as the true underlying risk. For our purposes, we follow the common practice in the real option literature and use two variables that relate to the firm's revenues as broad proxies for the underlying risk(s). Specifically, at each point in time (*t*), we use quarterly data from the preceding five years to calculate the standard deviation of the firm's sales growth rate (denoted as V1) and its cash flow growth rate (V2)[7]. Growth rate facilitates comparisons across firms, and rolling mean and standard deviation smoothes the influence of transitory jumps in these variables. Similar measures have been widely used in the empirical corporate finance literature as proxies for firm-level risk.

The value of a financial option is influenced by the future volatility of returns on the underlying stock. Hence, for the purpose of option valuation, one must use a forward looking measure of the underlying volatility (e.g. implied volatility)[8]. This analogy also applies to real option valuation. However, our proposed measures of underlying volatility (V1 and V2) are based on historical data. This is, of course, unavoidable, since there is no market for real options that can be used to deduce an implied volatility associated with a firm's projects. Copeland and Antikarov (2001) propose a method for estimating the underlying volatility using the project's certainty-equivalent pay-offs. However, this approach also invokes strong assumptions and is subject to similar criticisms.

While it is common knowledge that systematic and nonsystematic factors influence real options' underlying cash flows, there exists no widely accepted technique for estimating future volatility of the cash flows generated by real investments. Accurate estimates of future volatility are critical for the valuation of real options, which is not the focus of our study. Our primary objective is to simply sort and categorize firms, as described above. For this purpose, the variation in historical sales and cash flow growth rate are reasonable estimates of expected future volatility.

The real options literature views equity as an option on the assets of the firm, and the total volatility of equity returns as the measure of the underlying risk. We decompose total volatility into its market and idiosyncratic components. We use the Beta (V3) to assign firms as high-low risk. For this purpose, at each (*t*), we estimate Beta using data for S&P-500 (the market index) and the 90-days Treasury Bill yield (risk-free rate) for the past 60 months[9]. Second, we use the residuals of CAPM, as a measure of the firm's idiosyncratic risks (V4) that is specific to the operations of the firm. This proposed decomposition enables us to separate the impact of market and idiosyncratic risks on the demand for liquidity.

2.2 The proxies for managerial flexibility

The value of a firm's real options is highly dependent upon the flexibility by which managers can execute optimal investment decisions, as well as the constraints they face in financing their investments. The literature uses a variety of variables as proxies for managerial control. These include managers' ownership stakes in the firm, institutional ownership, the composition of the board of directors, a firm's regulatory environment, and other factors that can bear on the autonomy of the managerial decision-making process. The influence of managerial control on cash holdings decision is unobserved, and the findings based on proxies are generally mixed. Kalcheva and Lins (2007), for example, find no relation between the percentage of managerial control and cash holdings (Tables IV and V).

Other authors use items from a firm's statement of cash flows, particularly capital expenditures and R&D, as proxies for managerial flexibility. Given our need to simply assign firms to quadrants of Table I, and the fact that our data do not contain managerial control variables, we use expenditures on investment activities (defined as the investment cash flow and denoted as F), as a broad proxy for managerial flexibility[10]. Investment cash flow measures expenditures on investment activities and is taken from the firm's statement of cash flows. Investment cash flow is deflated by sales to control for size. We improve on this measure by controlling for a firm's financial constraints.

2.3 The proxies for financial constraints

Empirically, a variety of classification schemes have been proposed to distinguish financially constrained and unconstrained firms. These include simple heuristics such as sorting firms based on size, dividend distributions, bond ratings, and WACC, as well as composite indexes such as the widely accepted KZ index proposed by Kaplan and Zingales (1997)[11]. A large and expanding body of empirical literature has used the KZ index and similar measures to investigate the impact of financial constraints on corporate decisions. However, it appears that few studies have analyzed the interaction between the firm's real options, its managerial flexibility, its financial constraints and its cash holdings.

Denis and Sibilkov (2009) consider the value of cash holdings for constrained and unconstrained firms. They show that cash holdings are more valuable for financially constrained firms. Moreover, they find that while higher cash holdings lead to higher investments by both types of firms, the marginal value of investment is greater for constrained firms. These authors conclude that higher cash holdings allow constrained firms to undertake valuable projects that would otherwise be bypassed. One aim of the present study is to confirm this finding using similar data, but to use an alternative approach that differentiates firms by the value of their investment opportunities.

Almeida *et al.* (2004) propose a model in which financially constrained firms with a limited capacity to raise external funds hold more cash as a hedge against shortfalls in future cash flows; however, for financially unconstrained firms with low-cost access to capital markets, the cash-holding decision becomes nearly irrelevant. These authors use pay-out ratio, firm size and bond ratings as proxies for financial constraints and to show that cash holdings and cash management policies are irrelevant for financially unconstrained firms. However, this finding is reversed when they use the KZ index. Again, the present study aims to reconcile these conflicting findings using similar data, but by carefully characterizing the firm's investment opportunities.

A variety of classification schemes have been proposed to distinguish financially constrained and unconstrained firms. These include sorting firms based on their financial characteristics (for example, size, dividend distributions, and bond rating) or a composite of such characteristics as captured by the KZ index. It is important to note that firms are not consistently ranked by all classification schemes and no consensus has emerged regarding the right method to sort firms. Absent such consensus, researchers report results for alternative schemes, a practice we adopt here, as well.

Given our focus on cash holdings, we adopt the widely used KZ index as our primary measure of financial constraints. We also use a firm's size, its return on investment (ROI), and its current ratio (CR) to test the robustness of our results[12]. The formula in Almeida *et al.* (2004) is used to construct the KZ index for the firms in our sample[13]. Firms in the bottom 30 percent of the KZ index (KZ30) are classified as financially unconstrained; the top 30 percent (KZ70) are classified as constrained; and the middle group (KZM) is assumed to be neither.

A widely used measure of a firm's performance is its ROI. In competitive industries, firms will not be able to earn an abnormal ROI (i.e. a ROI that significantly exceeds the firm's WACC): firms with abnormal ROI are able to pursue risky but highly profitable projects that raise their ROI without increasing their WACC. Such firms are considered to be financially unconstrained. We classify firms in the top 30 percent of ROI (ROI70) as financially unconstrained, the bottom 30 percent as constrained (ROI30), and the middle group (ROIM) as neither[14].

We use market capitalization as the measure of firm size (MV). Smaller firms are young, fast growing, and less known. Hence, they face significant external financing hurdles. To be consistent, we classify the firms in the bottom 30 percent of MV (MV30) as financially constrained; top 30 percent (MV70) are unconstrained; and the middle group (MVM) is assumed to be neither.

The CR measures liquidity, the firm's ability to meet current obligations using cash and current assets. Rating agencies attach significant importance to a firm's CR. It is generally assumed that the higher the CR, the more liquid the firm and the fewer financial constraints it faces. Again, to be consistent, the top 30 percent of CR (CR70) is classified as financially unconstrained; the bottom 30 percent (CR30) is constrained; and the middle group (CRM) is neither.

In addition to these measures, we include the firm's WACC, which measures the marginal after-tax WACC (both debt and equity). A firm's WACC is the required return on the firm as a whole and, as such, is often used internally by managers to determine the economic feasibility of expansionary opportunities and mergers. We anticipate that firms with a high WACC will tend to finance their projects with their liquid assets (lower opportunity cost) and are more likely to view cash holdings as a way to hedge the fluctuations in their WACC.

Finally, we use the firm's sales relative to its industry average (calculated at four-digit SIC level) as a proxy for its relative market power. Our aim is to control for the impact of market concentration and competition on the value of a firm's real options and, subsequently, its decision to hold cash[15].

3. Data and results

We consider the impact of real options and financial constraints on cash holdings in two steps. First, we examine the unconditional distribution of cash holdings for different combinations of real options and financial constraints. Next, we use a common set of data as conditioning variables (as in Opler *et al.*, 1999 and many other studies) to estimate the standard multivariate regression model that explains cash holdings for a constrained and an unconstrained firm, while accounting for the value of the firm's real options.

To facilitate comparison with previous studies, we use panel data that overlaps with the period covered in the studies cited above: it is during this period (1990-2000) that the "real options way of thinking" gained prominence and became the preferred systematic approach to valuation and strategic management of corporate investment opportunities (Amram and Kulatilaka, 1999; Copeland and Antikarov, 2001; Trigeorgis, 1996). Corporate leaders widely recognized that managerial decisions, including optimal investment in liquid assets, could enhance the value of the firm above and beyond the dollar added to their cash reserves.

The data for this study are taken from the annual and quarterly Compustat files spanning the period 1985 through 2000[16]. Our sample includes both active and inactive firms. This time period coincides with the wide acceptance of the real options theory as a strategic tool for managerial decision making. More importantly, this sample period facilitates comparison with other studies that rely on the same data period – in particular, Kim *et al.* (1998), Harford (1999), Opler *et al.* (1999), Almeida *et al.* (2004), and the recent paper by Denis and Sibilkov (2009), who also study the determinants of cash holdings for constrained and unconstrained firms.

Following standard practice in this literature, we exclude data for ADRs, financial firms, and utilities (regulated or otherwise), governmental and unclassifiable, as well as companies with annual net sales, total assets, and common equity less than $1 million. This leaves a sample consisting of 4,251 firms (24,141 firm-year observations). Tables II and III list all the variables used in this study and provide their precise definitions.

Cash holding measures	Definition
Cash/assets	Cash and liquid asset holdings divided by book value of assets net of cash
Cash/sales	Cash and liquid asset holdings divided by sale
Relative cash	Cash and liquid asset holdings divided the average cash holdings for the firms in the same four-digit SIC code by year
Cash difference	The difference between a firm's cash holdings and the average of cash holdings for the firms in the same four-digit SIC code by year
Volatility-flexibility measures	
Sales growth rate (V1)	Standard deviation of quarterly sales growth rate calculated form data for the preceding 20 quarters
Cash flow growth rate (V2)	Standard deviation of quarterly cash flow growth rate calculated form the data for the preceding 20 quarters
Beta (V3)	Firm's Beta estimated from the preceding 60 months' data
Idiosyncratic volatility (V4)	The standard deviation of the residual of CAPM, estimated using the preceding 60 months' data
Managerial flexibility (F)	Firm's investment cash flow divided by its sales
Financial constraint measures	
KZ index	Defined in the paper: KZ30 (bottom 30%), KZ70 (top 30%)
ROI	Income before extraordinary items divided by invested capital
MV (size)	The average of the past 12 months' MV of equity + average of the start and the end-of-the-year value of preferred stock + average of the start and the end-of-the-year book value of debt
CR	The book value of current assets divided by book value of current liabilities

Table II.
Definition of the dependent and sorting variables

Control variables	Definition
WACC	Firm's weighted average cost of capital (Compustat data)
Relative sales	Sales divided by sales average for firms in the same four-digit SIC code for that year
Industry volatility (% Ann)	Standard deviation of quarterly sales growth rate for firms in the same four-digit SIC code calculated form the preceding 20 quarters
Firm volatility (% Ann)	Standard deviation of the firm's monthly returns calculated from the preceding 60 months' data
Fixed assets	Value of the firm's property, plant, and equipment divided by the value of total assets
Acquisitions	Value of the firm's acquisitions divided by the value of total assets
Tobin's Q	Firm's (book value of assets − book value of equity + MV of equity) divided by book value of assets (market/book)
Real size	Logarithm of book value of assets
R&D	Expenditures on research and development divided by sales
Cash flow	Firm's (earnings before interest, taxes, and depreciation − interest expense − taxes − common dividends) divided by book value of assets net of cash
Net working capital	Firm's (current assets − current liabilities − cash) divided by book value of assets net of cash
Capital expenditure	Value of additions to property, plant, and equipment divided by book value of assets net of cash
Leverage	Total debt divided by book value of assets net of cash
Business segments	Dummy variable = 1 if the number of industry segments the firm operates within (1-10) is greater than 1
Dividend payout	Dummy variable = 1 if the common dividend is positive
Bond rating	Dummy variable = 1 if the firm has S&P bond rating
Persistence	Dummy variable = 1 if firm has data for more than five years
Time dummy	Dummy variable = 1 for years 1990 through 2000
Industry dummy	Dummy variable = 1 for different industries (two-digit SIC)

Table III.
Definition of the explanatory variables

We use the median value of the above volatility and flexibility measures to assign firms to four distinct quadrants of Table I: high volatility-high flexibility (HH), high volatility-low flexibility (HL), low volatility-high flexibility (LH), and low volatility-low flexibility (LL). For example, in each calendar year the median of the volatility of sales growth rate (V1) and the investment cash flow (F) are used to assign firms to each of the four quadrants, resulting in 16 unique data partitions labeled as HHViF, HLViF, LHViF, and LLViF, where i = 1, 2, 3, 4 identifies each volatility measure.

Following previous studies, we measure cash holdings as the ratio of cash and equivalent (marketable securities) to net assets, defined as the book value of total assets, net of cash and cash equivalents. Hereafter, we refer to this measure simply as cash holdings. To assess the sensitivity of our results, we also consider the ratio of cash to net sales, as well as to a firm's cash holdings in relation to its industry peers (the average of cash holdings for firms in the same four-digit SIC code).

3.1 The unconditional distribution of cash holdings

Table IV contains the data on the distributional characteristics of our measures of cash holdings for the entire sample and the quadrants of Table I. The data presented in the table indicate that, regardless of sorting scheme, firms with high volatility and high

Quadrant	Count	Cash/assets (%) Mean	SD	Cash/sales (%) Mean	SD	Relative cash Mean	SD	Cash difference Mean	SD
Entire sample	24,141	21.53	39.91	18.50	40.25	1.00	1.25	0.00	33.71
LLV1F	6,091	15.01	27.67	8.86	19.81	0.96	1.21	−2.33	25.32
LHV1F	5,981	18.45	33.68	15.33	27.17	0.9	1.12	−2.44	30.30
HLV1F	5,999	20.43	36.99	14.65	33.76	1.03	1.24	−0.23	31.67
HHV1F	6,070	32.18	54.14	35.09	61.68	1.11	1.42	4.96	44.09
LLV2F	5,304	17.12	32.06	10.64	24.79	1.05	1.27	0.02	27.39
LHV2F	6,769	22.83	43.59	21.64	44.33	0.98	1.24	1.32	35.66
HLV2F	6,786	18.16	33.27	12.58	29.89	0.95	1.18	−2.31	29.58
HHV2F	5,282	28.61	48.02	29.95	53.60	1.03	1.34	1.24	40.93
LLV3F	5,795	13.18	24.38	8.60	21.08	1.00	1.22	−1.30	22.37
LHV3F	6,287	14.56	30.12	14.37	30.33	0.84	1.10	−3.29	27.04
HLV3F	6,295	21.87	38.41	14.61	32.50	0.99	1.23	−1.27	33.42
HHV3F	5,764	37.15	55.73	37.18	60.84	1.18	1.44	6.29	46.72
LLV4F	5,726	12.86	23.29	8.28	19.56	1.00	1.21	−1.37	21.48
LHV4F	6,346	14.15	29.21	13.95	29.28	0.84	1.09	−3.41	26.33
HLV4F	6,364	22.06	38.84	14.84	33.19	0.99	1.23	−1.21	33.85
HHV4F	5,705	37.84	56.23	37.89	61.42	1.19	1.45	6.51	47.30

Table IV.
Distribution of cash holdings by the quadrants of the volatility and flexibility measures

flexibility hold significantly higher cash amounts (at times twice larger). Moreover, for firms in the HH quadrant, the distribution of cash holdings is more dispersed. As flexibility and risk decline, the value of a firms' real options declines, and the distribution of cash holdings changes in a manner consistent with the theory posited above. Considering the intermediate cases (LH and HL), we find that increases in flexibility, rather than risk, lead to higher cash holdings.

Table IV also indicates that the distribution of cash holdings for different combinations of flexibility and volatility are nearly identical (e.g. V1F versus V2F): our comprehensive regression analysis also confirms this fact. To save space, we will not report the results for every combination of the flexibility-volatility measure[17]. Instead, we will only report the results for the following sorting schemes: the volatility of sales growth rate (V1F), the firm's Beta (V3F), and the firm's idiosyncratic risk (V4F) combined with the firm's investment cash flows[18].

Table V shows the distribution of cash holdings under various classifications of financial constraints. As the table shows, the distribution of cash holdings across the classification schemes varies widely. For these data, we find that firms are not consistently classified across measures of financial constraint. This finding is common to most empirical studies that focus on the impact of financial constraints on corporate decisions (Almeida *et al.*, 2004; Denis and Sibilkov, 2009).

In particular, we find that unconstrained firms hold significantly higher levels of cash when the data are sorted by the KZ index or the CR. However, the distribution of cash holdings for these data partitions is very similar: we find that constrained firms hold significantly higher levels of cash when the data are sorted by ROI and MV. From our regression analysis, we find that firms with valuable real options hold more cash under all measures of financial constraint. Given this fact, we only report the results for the KZ index to save space[19].

	Cash/assets (%)			Cash/sales (%)			
	Mean	SD	Median	Mean	SD	Median	n
Entire sample	21.53	39.91	6.20	18.50	40.26	4.74	24,141
KZ index (middle 60%)	12.20	24.05	4.54	11.31	28.15	3.45	9,659
KZ30 (unconstrained)	46.21	55.51	25.4	37.39	56.47	15.94	7,241
KZ70 (constrained)	9.28	24.13	2.59	9.19	25.4	2.10	7,241
ROI (middle 60%)	14.53	29.59	3.91	12.76	28.92	3.22	9,650
ROI70 (unconstrained)	23.60	37.28	9.55	14.63	26.31	5.82	7,245
ROI30 (constrained)	28.78	51.28	7.70	30.01	58.33	6.43	7,246
MV (middle 60%)	24.47	44.04	6.87	21.06	44.80	5.12	9,652
MV70 (unconstrained)	13.92	28.63	4.15	12.10	28.66	3.31	7,243
MV30 (constrained)	25.21	42.67	8.66	21.48	42.97	6.29	7,246
CR (middle 60%)	13.46	24.30	5.17	10.51	22.94	3.64	9,651
CR70 (unconstrained)	46.61	58.35	24.94	40.48	60.34	17.12	7,247
CR30 (constrained)	7.17	13.94	3.10	7.15	18.96	2.43	7,243

Note: Under each measure of financial constraint, the sample is partitioned into constrained, unconstrained, and the middle group; the measures of financial constraint are the Kaplan and Zingales (KZ) index, return on investment (ROI), market value (MV), and current ratio (CR)

Table V. Distribution of cash holdings under different measures of financial constraint

3.2 The conditional distribution of cash holdings

As noted earlier, previous studies use a common set of firm attributes that the literature has identified as the key determinants of corporate demand for liquidity. We construct the control variables according to definitions provided by Opler *et al.* (1999) and subsequently used by other researchers cited above. Table III contains the precise definition for all the variables utilized.

Table VI provides information about the distributional characteristics of the control variables for the entire sample, as well as the means for data partitions based on the KZ index and selected combinations of volatility-flexibility sorting. Though the table only reports the means, we note that the distribution of these variables (range, variance, and higher moments) is significantly different across the data partitions.

While most mean values in Table VI are consistent with expectations, the distribution of the explanatory variables are very different for financially constrained and unconstrained firms, as well as the HH and LL sub-samples. Particularly, noteworthy variables are industry and firm-level volatility, Tobins' Q, size, working capital, capital expenditure, and leverage. These variables indicate significant differences between the HH and LL firm, as well as between the financially constrained and unconstrained firms. Overall, it seems reasonable to conclude that the univariate analysis supports the main hypothesis we advanced above, that firms with valuable real options are likely to hold larger cash reserves. However, we need to pursue this question using multivariate regression, which is the task we undertake next.

3.3 Multivariate analysis

To further investigate our hypothesized relationship, we estimate the standard model of corporate demand for liquidity. Our main innovation is to control for the existence of the firms' real options and its financial constraints. We estimate two distinct specifications using the same set of control variables. First, we use panel data for all

Table VI. Distribution of the explanatory variables by financial constraint and volatility-flexibility measures

	Sample Mean	Sample SD	The mean by KZ index KZM	KZ30 (U)	KZ70 (C)	The mean by sales growth LLV1F	HHV1F	The mean by Beta LLV3F	HHV3F	The mean by idiosyncratic LLV4F	HHV4F
WACC	0.12	0.02	0.12	0.10	0.13	0.11	0.12	0.11	0.12	0.11	0.12
Relative sales	13.69	22.98	16.67	14.83	8.59	17.01	10.09	21.66	6.71	22.35	6.12
Industry volatility (% Ann)	910.83	1,261.13	893.83	925.98	918.35	815.95	1,011.47	850.23	1,007.46	846.05	1,018.72
Firm volatility (% Ann)	57.53	32.11	52.42	59.85	62.02	51.52	65.74	37.58	76.19	34.92	78.15
Fixed assets	1.42	0.90	1.44	1.61	1.22	1.19	1.68	1.21	1.56	1.22	1.56
Acquisitions (%)	1.99	5.10	2.31	2.30	1.26	1.29	2.67	1.48	2.31	1.52	2.19
Tobin's Q	1.90	1.27	1.77	1.59	2.38	1.64	2.19	1.60	2.31	1.59	2.32
Real size	4.77	2.01	5.13	4.94	4.13	5.00	4.34	5.59	3.96	5.66	3.88
R&D (%)	5.21	14.35	3.56	3.22	9.40	2.27	10.35	1.47	12.00	1.38	12.26
Cash flow (%)	1.70	24.46	5.43	−1.31	−0.28	6.66	−6.68	7.05	−6.94	7.78	−7.65
Net working capital (%)	12.80	24.16	15.23	5.84	16.52	19.28	4.55	20.66	5.04	21.38	4.76
Capital expenditure (%)	7.77	6.81	7.71	7.36	8.25	5.68	9.74	5.75	9.95	5.78	9.95
Leverage (%)	30.08	52.93	20.26	72.80	0.47	27.57	33.86	25.68	30.06	25.20	30.04
Business segments	0.25	0.43	0.28	0.27	0.18	0.29	0.22	0.33	0.19	0.33	0.18
Dividend payout	0.33	0.47	0.39	0.29	0.28	0.41	0.21	0.57	0.08	0.59	0.06
Bond rating	0.10	0.30	0.16	0.10	0.02	0.11	0.06	0.16	0.01	0.17	0.01
Persistence	0.81	0.39	0.84	0.81	0.78	0.89	0.71	0.90	0.68	0.91	0.67
n (firms-years)	24,141		9,659	7,241	7,241	6,091	6,070	5,795	5,764	5,726	5,705

firms and include dummy variables signifying different quadrants of Table I, as well as indicators for financial constraints. Under this specification, each quadrant's dummy coefficient measures the impact of each classification on cash holdings while the effect of the control variables is forced to be the same across all quadrants[20]. Our model is specified as:

$$CH = \mu + \sum_{q=2}^{4} \delta_q D_q + \sum_{i=1}^{2} \varphi_i KZ_i + \sum_{j} \beta_j C_j + \sum_{y=1991}^{2000} \upsilon_y D_y + \sum_{k=1}^{10} \nu_k I_k + \varepsilon$$

where:

- CH is the logarithm of the firms adjusted cash holdings. The adjustment is achieved by dividing the cash holdings either by the firm's net assets (book value of assets net of cash) or by the firm's sales. Each element of CH represents a firm's cash holdings in a particular year (panel data).
- $D_q = 1$ for firms in the qth quadrant of real options' value and zero otherwise ($q =$ HH, HL, LH). The coefficient differentiating the quadrants is δ_q. It measures the difference in cash holdings across quadrants, after controlling for other factors. Our null hypothesis is that for each data-sorting scheme, firms in the HH, HL, and LH quadrants are no different from firms in the LL quadrant.
- φ_i measures the impact of the dummy variables for KZ30 and KZ70 with similar interpretation.
- C_j is the jth control variable and β_j measures its impact.
- D_y is a dummy variable for the year. $D_y = 1$ when $y = 1991, \ldots, 2000$ and zero otherwise. The influence of each year on CH is measured by υ_y.
- I_k is the industry dummy variable (two-digit SIC code) and ν_k measures its impact.
- μ is the regression intercept. It measures the conditional mean of the CH for the LL quadrant in year 1990 for firms in the KZM category with a two-digit SIC code in the 70-99 range.
- ε is the regression residual.

The control variables, as defined in Table V, are common to most studies of demand for corporate cash holdings. Briefly, volatility variables measure the impact of risk on cash holdings. The logarithm of a firm's total assets is used as a proxy for firm size. The Tobin's Q is used as a proxy for the likelihood that a firm will have valuable investment projects in the future[21]. R&D expenditures (deflated by sales) are believed to correlate with the costs of financial distress (Opler *et al.*, 1999) and cause managers to hold higher cash reserves. Harford (1999) has shown that excess cash holdings lead to value-destroying acquisitions. The expenditures on acquisitions (deflated by net assets) are included to capture this effect. Working capital is seen as a reserve of liquid asset substitutes. A firm's cash holdings are expected to be negatively affected by the amount of liquid-asset substitutes (Ferreira and Vilela, 2004). Leverage is added following the finding in Myers (1993), which shows that debt-to-equity ratio tends to be lower in high-growth industries, even when the need for external capital may be the greatest. The bond rating (dummy) is a proxy for a firm's access to credit markets.

In addition to the common variables used in previous studies, we include a firm's WACC as a measure of its financial position, and the ratio of fixed assets to total assets as a measure of the firm's asset composition. All else being equal, we expect that the lower this ratio – that is, the smaller the fraction of a firm's assets tied into property, plant, and equipment – the more its flexibility to invest in valuable real options. The competitive environment in which a firm operates has a significant bearing on its demand for liquidity. We use relative sales, which is a rough measure of market power, as a proxy for the degree of concentration in a firm's industry.

Finally, recall that our data includes both active and inactive firms (those that dropped from the sample for a variety of reasons, including bankruptcy, mergers, and the like). To assess the influence of potential survivorship bias, we create a dummy variable that equals one for firms with five or more years of data. Admittedly, this is a low-tech method of accounting for survivorship bias. However, it does provide a simple control for this important phenomenon.

As noted, all dollar-denominated variables are deflated by the value of net assets (or sales). This normalization achieves two important objectives: first, a firm's assets in place, rather than its excess short-term cash holdings, is an important determinant of its long-term performance. Looking at dollar values-per-unit of net assets (or sales) is, therefore, a more appropriate way of comparing firms. Second, deflating by net assets (or sales) increases the likelihood that the regression residuals have a constant variance (a simple method for correcting for heteroskedasticity). Hence, the assumptions underlying the regression model are less likely to be violated and the estimated coefficients will be unbiased[22].

3.4 Regression results

The proposed regression model is estimated with panel data procedures using Stata. Tables VII-IX contain the estimated regression coefficients for the above specifications. Before focusing on a specific table, we note that the majority of the estimated coefficients are highly statistically significant (above a 99-percent confidence level), and the adjusted R-squares are consistent with those reported in the literature. All regressions include dummy variables for years and industries (these coefficients are not reported to save space)[23]. The sign and significance of most variables common to previous studies (column 1 in Tables VII and VIII) are confirmed with our sample data. We therefore focus our discussion on the variables that directly bear on our proposed hypothesis.

Table VII contains the regression results when the dependent variable is the logarithm of cash holdings. Table VIII uses the same control variables, but the dependent variable is the logarithm of the ratio of cash-holdings-to-sales. In both tables, dummy variables distinguish firms in different quadrants of Table I and dummy variables for the KZ index are added. We also estimated these models using relative and difference-of-industry cash holdings (Table II). Given the similarities, we will not report those regression results.

The results in Tables VII and VIII can be summarized as follows: cash holdings are consistently higher for firms in the HH quadrant across all volatility-flexibility measures. Turning to the KZ index, all else being the same, unconstrained firms hold more cash, which seems somewhat counter intuitive. Still, this finding is consistent with the results in Almeida *et al.* (2004) and Denis and Sibilkov (2009). Using ROIs, MV, or CR,

Table VII. Determinants of cash/asset ratio

Variable	Sign	Standard model	V1F	V3F	V4F
HH			0.098**	0.391***	0.403***
HL			0.089**	0.173***	0.190***
LH			−0.041	−0.251***	−0.243***
Unconstrained firm (KZ30)			1.063***	1.056***	1.055***
Constrained firm (KZ70)			−0.326***	−0.327***	−0.327***
WACC		31.690***	16.951***	16.792***	17.026***
Relative sales		−0.005***	−0.004***	−0.004***	−0.004***
Industry volatility (% Ann)	+***	0.000***	0.000***	0.000***	0.000***
Firm volatility (% Ann)	+***	−0.001	0.000	−0.002***	−0.003***
Fixed assets		−0.126***	−0.074***	−0.058***	−0.057***
Acquisitions (%)	−***	−0.022***	−0.013***	−0.013***	−0.013***
Tobin's Q	+***	0.104***	0.095***	0.096***	0.096***
Real size	+***	−0.012	0.007	0.018**	0.018**
R&D (%)	+***	0.031***	0.028***	0.026***	0.026***
Cash flow (%)	+***	0.003***	0.002***	0.002***	0.002***
Net working capital (%)	−***	−0.006***	−0.006***	−0.006***	−0.006***
Capital expenditure (%)	−/+***	0.013***	0.013***	0.013***	0.013***
Leverage (%)	−***	−0.003***	0.000**	0.001**	0.001**
Business segments	−*	−0.005	0.032	0.032	0.031
Dividend payout	−/+***	−0.066**	−0.115***	−0.035	−0.030
Bond rating	−***	−0.442***	−0.285***	−0.270***	−0.271***
Persistence		−0.018	0.006	0.021	0.024
Constant		−2.062***	−0.711***	−0.711***	−0.754***
R^2	0.22	0.29	0.34	0.344	0.344

Notes: Significance levels at: *90-95 percent, **95-99 percent, and ***above 99 percent; the table reports regression results for the standard specification of demand for liquidity; the dependent variable is the logarithm of cash holdings divided by book value of assets net of cash; the first column reports the sign and significance of the explanatory variables as reported in previous studies starting with Opler *et al.* (1999); other columns show the results for different combinations of volatility-flexibility measures; the explanatory variables are constructed as defined in Table III; all regression models include dummies for the years and the firms' industry (two-digit SIC), with correction for heteroskedasticity using robust standard errors; the sample size in all regressions is 24,141

we found that unconstrained firms hold less cash but the results for the quadrants of Table I remain unchanged. Moreover, few coefficients in the regression model changed in a discernable way.

These tables also show that:

- an increase in a firm's WACC will lead to higher cash holdings;
- firms with higher market power (relative sales) hold less cash;
- firms with a higher fraction of fixed-to-total assets, hold less cash; and
- the rest of the control variables confirm the findings in previous studies though the magnitudes of the coefficients are not the same (Opler *et al.*, 1999).

In summary, cash holdings rise with industry risk and are expected to rise with firm-level risk. As Shin and Stulz (2000) and others have shown, the value of a firm's real options is expected to rise with the level of its idiosyncratic risk. Our results, however, do not confirm this conjecture, as the sign and significance of the coefficient

Table VIII. Determinants of cash/sales ratio

Variable	Sign	Standard model	V1F	V3F	V4F
HH			0.784***	0.965***	0.975***
HL			0.230***	0.236***	0.256***
LH			0.457***	0.288***	0.301***
Unconstrained firm (KZ30)			0.910***	0.902***	0.900***
Constrained firm (KZ70)			−0.167***	−0.165***	−0.165***
WACC		23.691***	11.586***	11.574***	11.840***
Relative sales		−0.007***	−0.006***	−0.006***	−0.006***
Industry volatility (% Ann)	+***	0.000***	0.000***	0.000***	0.000***
Firm volatility (% Ann)	+***	0.000	0.000	−0.002***	−0.002***
Fixed assets		0.077***	0.053***	0.064***	0.065***
Acquisitions (%)	−***	−0.006***	−0.004*	−0.004*	−0.004*
Tobin's Q	+***	0.102***	0.079***	0.079***	0.079***
Real size	+***	0.073***	0.082***	0.088***	0.088***
R&D (%)	+***	0.034***	0.029***	0.028***	0.028***
Cash flow (%)	+***	−0.001*	−0.001**	−0.002***	−0.002***
Net working capital (%)	−***	−0.006***	−0.005***	−0.005***	−0.005***
Capital expenditure (%)	−/+***	0.006***	0.003*	0.002	0.002
Leverage (%)	−***	−0.007***	−0.005***	−0.004***	−0.004***
Business segments	−*	0.020	0.059**	0.059**	0.059**
Dividend payout	−/+***	−0.159***	−0.166***	−0.084***	−0.079***
Bond rating	−***	−0.527***	−0.397***	−0.383***	−0.384***
Persistence		−0.129***	−0.050*	−0.044	−0.042
Constant		−0.939***	−0.157	−0.059	−0.107
R^2	0.22	0.336	0.379	0.382	0.382

Notes: Significance levels at: *90-95 percent, **95-99 percent, and ***above 99 percent; the table reports regression results for the standard specification of demand for liquidity; the dependent variable is the logarithm of cash holdings divided by sales; the first column reports the sign and significance of the explanatory variables as reported in previous studies, starting with Opler *et al.* (1999); other columns show the results for different combinations of volatility-flexibility measures; the explanatory variables are constructed as defined in Table III; all regression models include dummies for the years and the firms' industry (two-digit SIC), with correction for heteroskedasticity using robust standard errors; the sample size in all regressions is 24,141

of the firm-level risk indicates. The diversity of a firm's operations, as measured by the number of business segments it operates in, reduces cash holdings. Together, these results suggest that firms maintain cash reserves not so much to hedge against idiosyncratic risk, but rather as a hedge against industry risk.

The impact of a firm's investment opportunities (Tobin's Q, fixed-to-net assets, R&D, and acquisitions) conforms to the results in previous studies. In particular, Tobin's Q remains significant even after controlling for the values of real options. R&D expenditure, often viewed as a measure of the potential for financial-distress costs, significantly and positively influences cash holdings. Leverage is expected to reduce cash holdings, though once we introduce proxies for real options and financial constraints, this relationship is not consistently observed. Not surprisingly, firms with dividend payouts and access to capital markets (bond rating) hold less cash. Finally, the dummy variable for survivorship (firms that remain in the sample for at least five years) is mostly insignificant.

Table IX. Determinants of cash/sales ratio

Variable	KZM	V1F KZ30 (U)	KZ70 (C)	KZM	V4F KZ30 (U)	KZ70 (C)
HH	0.697***	0.880***	0.839***	0.923***	1.108***	0.928***
HL	0.292***	0.160**	0.340***	0.304***	0.344***	0.218**
LH	0.348***	0.736***	0.482***	0.196***	0.663***	0.316***
WACC	−0.007	22.935***	−0.123	0.483	23.427***	0.147
Relative sales	−0.006***	−0.009***	−0.006***	−0.006***	−0.009***	−0.005***
Industry volatility (% Ann)	0.000***	0.000*	0.000**	0.000***	0.000	0.000**
Firm volatility (% Ann)	0.002**	−0.001	0.001	−0.001	−0.003***	−0.001
Fixed assets	0.006	−0.004	0.113***	0.021	0.009	0.111***
Acquisitions (%)	−0.002	−0.006	0.004	−0.003	−0.006	0.004
Tobin's Q	0.134***	0.051***	0.087***	0.138***	0.051***	0.091***
Real size	0.080***	0.029**	0.137***	0.088***	0.036***	0.141***
R&D (%)	0.035***	0.022***	0.032***	0.033***	0.021***	0.031***
Cash flow (%)	−0.001	−0.003***	−0.005***	−0.002	−0.003***	−0.006***
Net working capital (%)	−0.012***	−0.002***	−0.008***	−0.012***	−0.002***	−0.008***
Capital expenditure (%)	−0.003	0.009***	0.008**	−0.004	0.008***	0.007**
Leverage (%)	−0.042***	0.022***	−0.005***	−0.041***	0.022***	−0.005***
Business Segments	0.138***	−0.103**	0.122**	0.131***	−0.100**	0.122**
Dividend payout	−0.208***	−0.021	−0.331***	−0.125***	0.071	−0.259***
Bond rating	−0.221***	−0.344***	−0.506***	−0.217***	−0.350***	−0.485***
Persistence	0.016	−0.074*	−0.064	0.010	−0.071	−0.047
Constant	2.361***	−1.143***	0.793***	2.387***	−1.237***	0.893***
R^2	0.276	0.337	0.252	0.279	0.340	0.252
n (firms-years)	9,659	7,241	7,241	9,659	7,241	7,241

Notes: Significance levels at: *90-95 percent, **95-99 percent, and ***above 99 percent; the table reports regression results for the standard specification of demand for liquidity after the data are sorted for financial constraints and by the quadrants of volatility-flexibility; results for V2F and V3F combinations are similar and not reported to save space; the dependent variable is the logarithm of cash holdings divided by sales; all regressions models include dummies for the years and the firms' industry (two-digit SIC), with correction for heteroskedasticity using robust standard errors

When comparing coefficients across the volatility-flexibility partitions (Table VIII), it appears that for firms in the intermediate case (HL and LH), managerial flexibility rather than volatility is the main driver of corporate cash holdings. The implication is that firms with high managerial flexibility will hold large cash reserves but this is the case even though a firm's real options are not valuable. This result provides direct support for Jensen's (1986) free cash flow hypothesis, which asserts that a self-interested manager (an empire builder) prefers to retain excess liquidity rather than distribute cash to share holders as dividends.

3.5 Robustness tests

As a test for the robustness of our regression results, we estimate the proposed model for the constrained, unconstrained, and the intermediate group of firms based on the KZ index. Table IX presents our findings for two volatility-flexibility combinations; the coefficients for other combinations are nearly identical and are dropped to save space.

The results in Table IX are striking: first, firms with valuable real options (HH) hold more cash, whether they are classified as financially constrained, unconstrained, or neither; this provides strong confirmation that our findings are independent of how the data are partitioned. It appears that even within the HH quartile, the financially unconstrained firms hold more cash. This is consistent with the results from the KZ index coefficients reported in Tables VII and VIII. The evidence supporting the free cash flow hypothesis remains intact, and is, indeed, further strengthened. All else being the same, unconstrained firms with LH nearly hold as much cash as firms with HH. This provides additional confirmation of the free cash flow hypothesis.

Other regression coefficients are similar to the specifications reported in Table VIII. Notable changes are:

- a firm's WACC is only a significant driver of cash holdings for the unconstrained firms;
- a fixed-asset ratio is only significant for the constrained firms;
- acquisition becomes statistically insignificant for all data partitions; and
- the impact of leverage on cash holdings is positive for unconstrained firms and negative for the constrained firms.

4. Summary and conclusion

A large body of empirical literature has identified the key drivers of corporate cash holdings. The extant literature has hypothesized that the existence of real options significantly influences demand for liquidity. The literature has relied on indirect proxies to assess this influence. In this study, we provided a direct method for assessing the influence of valuable real options on cash holdings. We showed that the volatility and flexibility that enhance real options' value leads to a higher demand for liquidity. We used a simple methodology to separate firms with valuable real options from the rest of the sample. We also studied how financial constraints, interacting with the existence of real options, influence demand for liquidity. Our approach enabled us to delineate the influence of growth options, while controlling for financial constraints and other factors considered in the literature.

Our analysis shows that the existence of real options provides the greatest justifications for corporate cash holdings. While both risk and flexibility influence demand for liquidity, we find that flexibility leads to a higher cash holdings. This is a direct confirmation of Jensen's (1986) free cash flow theory. We have shown that the existence of valuable real options leads to an unambiguous increase in corporate cash holdings. Whether this addition to a firm's cash holdings is capitalized into its equity price is an open and challenging question that deserves further study. Other promising areas for improving this line of research include:

- developing other measures of managerial flexibility;
- partitioning the volatility-flexibility into high, intermediate, and low categories (like the KZ index); and
- expanding the analysis to cover a longer time period.

We believe that our results are robust and will be confirmed with these and other extensions.

Notes

1. Recent research is cited below. It is interesting to note that an online search of the Social Science Research Network (www.ssrn.com) using key words "corporate cash holdings" and limited to the last five years returns over 100 papers. This is commensurate with the recent rise in corporate cash holdings!
2. A variety of other exogenous variables has been shown to influence corporate liquidity demand across the globe. These include the character of a country's legal system and its law enforcement (Ferreira and Vilela, 2004); outside ownership structure and monitoring (Ozkan and Ozkan, 2004); bank (creditors') power (Pinkowitz and Williamson, 2001); and measures of overall corporate governance (Harford *et al.*, 2008). Another strand of this literature investigates the impact of additions to cash reserves on the firm's market value (MV) (Denis and Sibilkov, 2009).
3. Note that financial constraints may increase the project's effective weighted average cost of capital (WACC) and reduce the size of investment. Cossin and Hricko (2001) show that undervaluation risk arises from delays in obtaining outside financing. In a closely related paper, Ramezani and Soenen (2007) investigate the link between a firm's real options and its cash holdings. However, these authors also do not consider the important role financial constraints play in corporate demand for liquidity.
4. Cossin and Hricko (2001) considered the relationship between real options and cash holdings in a simpler version of the theoretical model presented here. In their model, optimal cash holding is determined by equating the cost of cash holding with its benefits when raising external funds takes time, is costly, and when firms face undervaluation risk if they issue new securities.
5. By absolute discretion, we mean the right and ability to decide exactly what should be done at the optimal exercise time.
6. Copeland and Antikarov (2001) assume the firm faces no financial constraints.
7. Cash flow is income (after all expenses and taxes but before dividends) plus depreciation.
8. For financial options, the volatility implied by actual option prices is used as an estimate of future volatility.
9. We use CAPM as a tool to decompose total volatility. The standard CAPM is sufficient for this purpose, but multi-factor models should be used for asset pricing purposes. We take the usual steps to ensure the consistency of the CAPM regression, including correction for first-order auto correlation.

10. We also considered investment cash flow deflated by net assets, but obtained identical results.
11. Another important composite measure of financial constraint is the Whited and Wu (2006) index.
12. We also use a firm's WACC as a control variable in our regression models.
13. The KZ index = −1.002*(cash flow/net assets) + 0.283*(market/book) + 3.139*(debt/equity) − 39.368*(dividends/net assets) − 1.315*(cash/net assets).
14. We use the Compustat figures for market capitalization, CR, and ROI.
15. A more appropriate means for controlling for market concentration may be to use a composite proxy such as the Herfindahl index.
16. The data for the period spanning 1985-1990 are used to calculate volatility and flexibility measures that are used to sort the data. Regression models are based on the data for the period 1990-2000.
17. However, these results and other tests in support of the robustness of our results are available upon request.
18. These combinations of flexibility-volatility proxies result in the greatest differences in the distribution of cash holdings cross the quartiles. The results for other combinations are available from the authors upon request.
19. Again these results are can be seen in a longer version of this paper, which is available upon request.
20. As a second alternative, we estimated the regression model for each quadrant separately. We obtained nearly identical results but will not report them here to save space.
21. It is common to measure the likelihood that a firm will have positive NPV projects in the future by the market-to-book ratio. However, the market-to-book ratio is based on common equity and ignores the preferred stock and long-term debt. Following other authors, we calculate Tobin's Q by adding the latter values to common equity and then deflate by the book value of a firm's assets.
22. Without this normalization, the variance of the regression residual will be a function of firm size. Statistical tests indicate that after this normalization and with the inclusion of size and industry dummies, the residuals are nearly homoscedastic. We also performed other "diagnostic tests" and were not able to reject the standard OLS assumptions. Finally, we ran cross-sectional regressions by year and then averaged the coefficients as suggested by Fama and MacBeth (1973). The results were identical to those reported below.
23. We estimated the models using the panel data procedures (*xtreg)* in Stata. The differences between the *Fixed Effects*, the *Random Effect*, the *Population Averaged*, and the OLS regressions were minor and would not change our conclusions in any way. This is not surprising as our model includes a large number of dummies for industries and time. We, therefore, report the simpler-to-interpret OLS results after making corrections for heteroskedasticity and robust standard errors.

References

Almeida, H., Campello, M. and Weisbach, M.S. (2004), "The cash flow sensitivity of cash", *Journal of Finance*, Vol. 59 No. 4, pp. 1777-804.

Amram, M. and Kulatilaka, N. (1999), *Real Options: Managing Strategic Investment in an Uncertain World*, Harvard Business School, Boston, MA.

Billett, M. and Garfinkle, J. (2004), "Financial flexibility and the cost of external finance for US bank holding companies", *Journal of Money, Credit and Banking*, Vol. 36 No. 5, pp. 827-52.

Copeland, T. and Antikarov, V. (2001), *Real Options: A Practitioner's Guide*, Texere, New York, NY.

Cossin, D. and Hricko, T. (2001), "The benefits of holding cash: a real options approach", *Journal of Managerial Finance*, Vol. 27, pp. 11-25.

Denis, D. and Sibilkov, V. (2009), "Financial constraints, investment, and the value of cash holdings", *Review of Financial Studies*, May, Online version.

Dittmar, A. and Mahrt-Smith, J. (2007), "Corporate governance and the value of cash holdings", *Journal of Financial Economics*, Vol. 83 No. 3, pp. 599-634.

Dittmar, A., Mahrt-Smith, J. and Servaes, H. (2003), "International corporate governance and corporate cash holdings", *Journal of Financial and Quantitative Analysis*, Vol. 38 No. 1, pp. 111-33.

Fama, E.F. and MacBeth, J.D. (1973), "Risk, return, and equilibrium: empirical tests", *Journal of Political Economy*, Vol. 81, pp. 607-36.

Ferreira, M.A. and Vilela, A. (2004), "Why do firms hold cash? Evidence from EMU", *European Financial Management*, Vol. 10, pp. 295-319.

Han, S. and Qiu, J. (2007), "Corporate precautionary cash holdings", *Journal of Corporate Finance*, Vol. 13 No. 1, pp. 43-57.

Harford, J. (1999), "Corporate cash reserves and acquisitions", *Journal of Finance*, Vol. 54, pp. 1969-97.

Harford, J., Mansi, S.A. and Maxwell, W.F. (2008), "Shareholder rights and corporate cash holdings", *Journal of Financial Economics*, Vol. 87 No. 3, pp. 535-55.

Jensen, M. (1986), "Agency costs of free cash flow, corporate finance and takeovers", *American Economic Review*, Vol. 76, pp. 323-9.

Kalcheva, I. and Lins, K. (2007), "International evidence on cash holdings and expected managerial agency problems", *Review of Financial Studies*, Vol. 20, pp. 1087-112.

Kaplan, S. and Zingales, L. (1997), "Do investment cash flow sensitive provide useful measure of financial constraints?", *Quarterly Journal of Economics*, Vol. 112 No. 1, pp. 169-215.

Kim, C., Mauer, D.C. and Sherman, A.E. (1998), "The determinants of corporate liquidity: theory and evidence", *Journal of Financial and Quantitative Analysis*, Vol. 33, pp. 335-59.

Lins, K., Servaes, H. and Tufano, P. (2008), "What drives corporate liquidity? An international survey of cash holdings and lines of credit", available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=971178

Mikkelson, W. and Partch, M. (2002), "Do persistent large cash reserves hinder performance?", *Journal of Financial and Quantitative Analysis*, Vol. 38, pp. 275-94.

Minton, B.A. and Schrand, C. (1999), "The impact of cash flow volatility on discretionary investment and the costs of debt and equity financing", *Journal of Financial Economics*, Vol. 54, pp. 423-60.

Myers, S.C. (1993), "Still searching for optimal capital structure", *Journal of Applied Corporate Finance*, Spring, pp. 4-14.

Myers, S.C. and Majluf, N. (1984), "Corporate financing and investment decisions when firms have information that investors do not have", *Journal of Financial Economics*, Vol. 13, pp. 187-211.

Opler, T., Pinkowitz, L., Stulz, R. and Williamson, R. (1999), "The determinants and implications of corporate cash holdings", *Journal of Financial Economics*, Vol. 52, pp. 3-46.

Ozkan, A. and Ozkan, N. (2004), "Corporate cash holdings: an empirical investigation of UK companies", *Journal of Banking & Finance*, Vol. 28 No. 9, pp. 2103-34.

Pinkowitz, L. and Williamson, R. (2001), "Bank power and cash holdings: evidence from Japan", *Review of Financial Studies*, Vol. 14, pp. 1059-82.

Ramezani, C.A. and Soenen, L. (2007), "The impact of real options on corporate cash holdings", paper presented at the 2007 FMA Annual Meeting, Orlando, FL, available at: http://69.175.2.130/~finman/Orlando/Papers/Ramezani-Soenen.pdf

Shin, H. and Stulz, R. (2000), "Firm value, risk, and growth opportunities", NBER Working Papers 7808, National Bureau of Economic Research, Inc., Cambridge, MA.

Trigeorgis, L. (1996), *Real Options: Managerial Flexibility and Strategy in Resource Allocation*, The MIT Press, Cambridge, MA.

Whited, T. and Wu, G. (2006), "Financial constraints risk", *Review of Financial Studies*, Vol. 19 No. 2, pp. 531-59.

Further reading

La Porta, R., Lopez-de-Silanes, F., Shleifer, A. and Vishny, R.W. (1997), "Legal determinants of external finance", *Journal of Finance*, Vol. 52, pp. 1131-50.

Corresponding author

Cyrus A. Ramezani can be contacted at: cramezan@calpoly.edu