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Can Changes in the Cost of Cash Resolve the Corporate Cash Puzzle?

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Abstract

To answer this question, we first create a measure of the opportunity costs of holding liquid assets as the wedge between the cost of capital and the return of firms' cash portfolio. Exploiting both cross-sectional and time-series variation of opportunity costs 1980-2011, we estimate a negative effect of opportunity costs on the cash-to-assets ratio of U.S. nonfinancial Compustat firms. We then use the estimate to predict changes in aggregate cash holdings for 1945-2013 and find that they closely match actual changes in cash holdings over that period. Differences in opportunity costs also explain cross-country differences and within-country time variation of cash-to-assets ratios in the five largest European economies and Japan. Our results make evident that current U.S. corporate cash holdings are not abnormal, neither in a historical nor in an international comparison.

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1 Introduction

What explains the secular variation in corporate cash holdings, and particularly the seemingly high cash holdings of U.S. firms at present time, compared to 1980?[1] A large literature has evolved around this question, involving policy makers, investors, and researchers. Policy makers wonder what they can do to make firms invest their cash in real projects instead of hoarding it and some investors believe they can increase firm value by forcing firms to reduce their cash holdings.[2] In response to this vivid debate, corporate finance researchers have investigated a wide range of explanations, which we review in detail in Section 2. These explanatinos include but are not limited to tax motives, increasing cash-flow volatility, increasing focus or decreasing diversification, and rising intangible capital. Figure 1(a) illustrates the common feature of these approaches in the context of the framework of Opler, Pinkowitz, Stulz, and Williamson (1999): the existing literature argues that the benefits of holding cash have increased in the last thirty years, either because the probability or the cost of running out of cash has increased. A typical implicit assumption in these approaches is that the cost of cash has not varied in significant ways over the same time period. This could be the case, for example if firms invested their liquid assets in accounts that return the risk-free rate, and if agency costs and taxes were the main reason why keeping cash inside the firm is costly to shareholders.

The present paper differs from these approaches in two main respects. First, we use a much longer time-series and greater breadth of data. Specifically, we point out that 1980 was a historical low in the time series of U.S. corporate cash holdings. In fact, liquid asset

[1] "Cash" here stands for the fraction of total assets held in any type of liquid asset, be it interest-bearing T-Bills or non-interest bearing currency.

[2] See, e.g., Sanchez and Yurdagul, 2013 on policy markers' perspective on corporate cash holdings. See, e.g., Carl Icahn's letter to Apple CEO Tim Cook in Steven Russolillo's recent article in the *Wall Street Journal* (Russolillo, October 24, 2013) on inverstors' persecptive on corporate cash holdings.

holdings as a share of total assets were significantly higher in the 1950s than they are now. Cash-to-asset ratios followed a secular downward trend until 1980, before trending upwards until present times. The "corporate cash puzzle" refers to the increase during the last 30 years of this time-series. Moreover, we document variation in corporate cash holdings within and across countries other than the U.S. The second main difference is conceptual. We investigate whether changes in the cost of holding liquid assets (as opposed to increases in the benefits of holding cash) can also explain the secular time-series variation in the level of liquid assets held by the nonfinancial corporate sector. Figure 1(b) illustrates that secular shifts in the marginal cost of holding liquid assets can theoretically explain secular trends in corporate cash holdings as well as shifts in the marginal benefits curve can. The focus of the paper is to explore whether there is quantitative support for the cost-based explanation not only in the data set used by the existing literature, but also in the expanded data set we consider.

We start by calculating the opportunity costs of holding cash as the spread between the nominal T-Bill rate (a measure of the cost of capital of the risk-free project "holding cash") and the return on the corporate sector's liquid asset portfolio. The main reason for the existence and time variation of this spread is that according to the Fed Flow of Funds, corporations hold a large fraction of their liquid assets portfolio in non-interest bearing currency (i.e., coins, or paper "cash") and non-interest bearing checking accounts, especially in the earlier parts of the sample. As discussed in section 3, this portfolio choice is likely driven by Regulation Q, but possibly also due to the cost and time needed to convert interest-bearing assets into cash before the advent of electronic payment technology. As a result of this portfolio choice, the return on the firm's cash portfolio is lower than the cost of capital for the project "holding cash," and corporate cash holdings are costly to the shareholders of the firm even absent agency or tax explanations. Formally, we calculate the opportunity

costs of holding cash as the T-Bill rate multiplied with the lagged and averaged fraction of non-interest bearing assets as a share of the total liquid assets portfolio. Because the cost of cash correlates with nominal interest rates while the return on non-interest bearing assets does not, the opportunity costs of holding cash covary positively with nominal interest rates. Interest rates were close to zero in 1945, peaked around 15% in 1980, and are back to close to zero nowadays. As a result, the opportunity costs of holding cash were much higher around 1980 than they were around 1950 or are today, and shareholder value maximizing corporate CFOs had much stronger incentives to economize on cash holdings around the year 1980 than either before or after.[3] Indeed, cash-to-asset ratios are negatively correlated with opportunity costs in the time series, as illustrated by Figures 4(a) and 4(b).

We provide three sets of formal analyses to establish a robust inverse relationship between corporate cash holdings and opportunity costs that is large enough to explain the secular variation in corporate cash holdings. First, we run a time-series estimation of Compustat firm-level cash holdings as a function of the opportunity costs of holding cash for U.S. firms using data from 1980 to 2011. These regressions are similar to traditional money demand

[3]Note that economizing on non-interest bearing assets by a stragety of re-balancing into interest-bearing assets yet holding total liquid asset holding constant instead of the strategy of reducing total liquid asset holdings was not an option due to regulatory constraints. Note also that tax explanations are less likely to explain the secular variation in liquid asset holdings. It is true that the wedge between corporate and personal income taxes on interest income, as discussed in Graham (2000) and Faulkender and Wang (2006), does create a reason for a cost of holding cash. Any tax disadvantage scales linearly with the level of nominal interest rates as well. However, marginal federal tax rates on personal income were much *higher* than the corporate tax rate from 1945 until the mid-1980s, then were roughly equal, and dropped considerably below the corporate tax rate only with the 2003 tax cuts, creating a wedge with the right sign. This monotic decrease in the wedge of personal minus corporate tax rates can of course not explain the non-monotic pattern of cash holdings between 1945 and 2013. In the cross-section, the effect of personal and corporate taxes on firms' optimal cash holdings is difficult to assess because of the complications from calculating the effective marginal tax rate of both corporations and individuals, state-level differences in income taxes and a not perfectly observable geographical distribution of stockholders, etc. Lastly, tax explanations affect only the portion of cash invested in interest-bearing assets, and are therefore, while important nowadays, by construction a second-order effect in the early parts of the sample, compared to the costs of holding cash arising from corporations investing in non-interest bearing assets.

studies (see Meltzer, 1963b, and Mulligan, 1997). A key difference is that we estimate the effect of opportunity costs on cash holdings, rather than the effect of interest rates alone. Another key difference is that we control for possibly non-linear time trends. The latter implies that our identification comes from variation of cash holdings and opportunity costs around their trend and not from the secular time trend in opportunity costs or cash that we will later attempt to predict. We also control for firm-fixed effects and variables identified by the corporate finance literature to drive cash holdings (Bates, Kahle, and Stulz, 2009). We estimate that a one percentage-point decline in opportunity costs increases average cash to asset ratios by approximately 13%. To investigate the power of these estimates to explain the dynamics of U.S. corporate cash holdings, we apply our estimates to the observed changes in opportunity costs to calculate the predicted changes in the aggregate cash ratio. These predictions assume that only opportunity costs changed; all other factors are held constant. We find that changes in opportunity costs can explain most of the secular variation in corporate cash holdings not only in-sample (1980-2011), but for the entire period 1945-2013.

While the opportunity costs measure that is employed above as an explanatory variable is a macroeconomic variable, and is therefore unlikely to be affected by individual firms' corporate financial policies, we cannot exclude the possibility that some omitted variable drives both opportunity costs and cash holdings in the time-series. The following set of cross-sectional analyses eliminates this possibility by replacing the time-trend controls with time-fixed effects in the manner of typical corporate finance studies. We construct a measure of opportunity costs that exploits variation across firms in the ratio of non-interest bearing to total liquid asset holdings (Compustat *CH* over *CHE*) in out-of-sample years. We use it to run various instrumental variable (IV) and difference-in-differences tests. All results indicate that cash holdings of firms that in the past tended hold most of their cash in currency

and checking accounts (for example, retail firms – presumably for operational reasons) are more sensitive to changes in interest rates than the cash holdings of firms that hold more of their cash in interest-bearing assets. In fact, firms with below-median holdings of cash in non-interest bearing accounts (i.e., above-median holdings of cash in interest bearing accounts) did not increase their cash holdings at all from 1980-2011; the lowest quintile of firms by non-interest bearing liquid assets as a share of total liquid assets even substantially reduced their cash-to-asset ratios despite the decrease in nominal interest rates, possibly due to innovations in payments technology which decreased the transactions demand for cash. The cross-sectional results not only confirm the time-series estimates qualitatively. Notably, the cross-sectional estimates are quantitatively similar to the estimates obtained in the time-series regressions. Of course, it would be a rather curious coincidence if an omitted variable different from the one hypothesized to bias the time-series estimates biased these cross-sectional results in such ways as to produce such strikingly similar estimates. Nevertheless, we provide a third set of analyses that, while being interesting in its own right, also further reduces endogeneity concerns.

The third set of results repeats the above analyses for the five largest European economies and Japan between 1996 and 2011. Because nominal interest rates change at different times across countries, and because the fraction of liquid assets held in non-interest bearing assets also varies across countries, we are able to include both year- and firm-fixed effects in panel regressions; we show that differences in average opportunity costs explain differences in average cash ratios across countries very well; and we show that changes in opportunity costs over time can also explain to some extent changes in the cash ratio over time within these countries. Notably, the regression coefficients in the cross-country analysis and for the within-country estimates are similar to those obtained in the U.S.-only analyses. Moreover,

we find that the results from a pooled panel regression using year fixed effects and those using a cubic time trend are similar, suggesting that the U.S.-only time-series estimates are less likely to be driven by an omitted variable.

To summarize, while Pinkowitz, Stulz, and Williamson (2013) argue that "the high cash holdings of U.S. firms before the crisis are a U.S.-specific puzzle", we find that once the effect of opportunity costs is taken into consideration, current U.S. cash holdings do not seem abnormal in the context of either a long-term or international perspective, or both. In particular, current U.S. cash holdings are substantially lower than they were in 1950 and are quite similar to cash holdings of Japanese firms in recent years, which face a similar interest rate environment. Our results indicate that changes in the opportunity costs of holding cash are likely to have been a major driver of the observed changes in the cash holdings of firms in the U.S. and abroad. Our paper does not show or argue, however, that firm-level factors that affect the benefits of holding cash and that have previously been shown to drive firms' cash holdings are unimportant in resolving the corporate cash puzzle. We merely show that changes in opportunity costs alone can also explain much of the observed variation. In auxiliary results we demonstrate, however, that our explanation is the only existing one that, to our knowledge, has the potential to predict historical patterns of cash holdings not only since 1980, but since 1950. Moreover, we are the first to explain international variation, which is also less straighforward with existing approaches.

The paper proceeds as follows. Section 2 relates the paper to the existing literature on corporate cash holdings. Section 3 lays out theoretical considerations investigating why firms demand liquid assets despite positive opportunity costs of doing so, and why these opportunity costs vary over time and in the cross-section. Section 4 details empirical methodology and data sources. Section 5 presents both the time-series and the cross-sectional results for

the U.S., and section 6 gives the international results. Section 7 concludes.

2 Related Literature

The present paper is closely related to three literatures. The first one is the large and growing literature on the dynamics of U.S. corporate cash holdings.The second is the macroeconomic literature on money demand and related unpublished studies in corporate finance. The third is a literature on international cash holdings.

The existing literature on the U.S. corporate cash-holdings puzzle has focused on two sets of determinants of firms' liquidity demand. The first strand builds on the idea that firms hoard cash due to precautionary motives. It explains the increase in cash over the last 30 years with changing firm characteristics and changes in the composition of firms. A prominent example is Bates, Kahle, and Stulz (2009), who approach the question "Why do US firms hold so much more cash than they used to?" by documenting that firm-level variables such as cash-flow volatility, R&D, market-to-book ratio, and leverage have statistically significant correlations with the cash-to-assets ratio. They also decompose changes over time in the characteristics of firms and changes in the composition of firms in the sample. Duchin (2010) shows that firms' increased focus can be a driver of the precautionary motive for holding cash. In a variation of the argument, Falato, Kadyrzhanova, and Sim (2013) focus on the increasingly important role of firms' intangible capital. Many more explanations have been proposed in the recent past, evidencing the strong interest by corporate researchers in resolving the puzzle.[4]

[4]Pinkowitz, Stulz, and Williamson (2013) focus on abnormal cash holdings of U.S. firms in the very recent past after the U.S. financial crisis. Gao (2013) proposes the widespread adoption of just-in-time inventory management as a key explanation for the increase in cash holdings for the subset of manufacturing firms. Less motivated by time-series than by cross-sectional variation, Dittmar and Mahrt-Smith, 2007 investigate

The second literature considers the impact of the macroeconomic environment on corporate cash holdings. As a frame, note the above-discussed corporate finance studies propose explanations for the increase of cash holdings in the last thirty years that are based on increased benefits of holding cash. None of them considers changes in the opportunity costs of holding cash as a potential siginificant driver of corporate cash holdings. Compared to the money demand literature in macroeconomics, e.g. Ball (2001), we contribute a measurement of the elasticity of corporate money demand with respect to changes in the interest rate environment that does not rely on the assumption that there is no trend in money demand resulting from technological change. We achieve this by controlling for a time trend. Compared to classic money demand estimations such as Lucas (1988) and Stock and Watson (1993), we make use of cross-sectional variation in the demand for money, similar to Meltzer (1963a); Vogel and Maddala (1967), and most recently Mulligan (1997). The difference to our approach is that we calculate how firm-level corporate cash holdings depend on the firm-level opportunity cost of holding cash, and not just on interest rates. In other words, our approach recognizes that firms hold part of their cash portfolio in interest-bearing assets. Taking the corporate perspective in this regard not only seems the economically right thing to do to us, but also allows us to make use of additional firm-level variation for cross-sectional tests, namely in the share of interest-bearing assets of the liquid asset portfolio. A more substantial methodological difference is that Mulligan (1997) identifies the effect of interest rates on cash holdings off long-run variation in cash holdings and interest rates. Given the question our paper tries to answer, identifying off long-run variation is something we would like to avoid. Our econometric approach therefore identifies only off short-run variation around

how the value of a marginal dollar of cash depends on the quality of governance. Della Seta (2011) and Morellec, Nikolov, and Zucchi (2009) show that competition increases cash holdings.

the trend, and in an alternative specification from cross-sectional variation alone.[5] Azar and Kagy (2011) are the first to apply the insights from the macroeconomic literature on money demand to the corporate cash puzzle. Using aggregate data on corporate cash holdings from Fed flow of funds (as opposed to Compustat firm-level cash-to-asset ratios as in this paper), they estimate the money demand of the nonfinancial corporate sector using a vector autoregression (VAR) analysis. They find that shocks to opportunity costs can explain around 80% of the long-run variations in aggregate corporate cash holdings and around 50% of the medium-run variations. Conversely, they find that corporate cash holdings do not have a significant effect on opportunity costs. Unlike Azar and Kagy (2011), the present paper also controls for firm characteristics. The use of Compustat data in the present paper also allows to provide cross-sectional analyses.

The third literature, on international evidence, has focused on agency problems, and how differences in governance affect the value of cash (Dittmar, Mahrt-Smith, and Servaes, 2003; Pinkowitz, Stulz, and Williamson, 2006; Kalcheva and Lins, 2007). The evidence is largely consistent with U.S. evidence such as that presented in Harford, Mansi, and Maxwell (2008). Somewhat differently from the previous papers, Lins, Servaes, and Tufano (2010) examine firms' choice between cash and lines of credit in an international context, and Agca (2012) investigates the effect of financial integration on corporate cash holdings in a cross-country study. One strand of the literature on international aspects of cash holdings focuses on the

[5] Another paper that focuses on a factor that affects opportunity costs is Stone, Gup, and Lee (2012), who explore whether interest rates have an effect on firm-level demand for cash. They find an unstable negative correlation between interest rates and cash holdings beginning in 1970 that disappears in the 1990s. In contrast to their paper, we do acknowledge the distinction between nominal rates and opportunity costs that arises because the return of the corporate cash portfolio is non-zero – physical cash earns zero return, but "cash" invested in assets such as the T-Bill earns the nominal T-Bill rate. Furthermore, we assess whether opportunity costs have the power to explain the secular trends in corporate cash holdings with a much longer sample. Lastly, our analyses include firm-fixed effects and year-fixed effects, which addresses a variety of endogenity concerns that might otherwise be present.

role of repatriation taxes. Foley, Hartzell, Titman, and Twite (2007) show that multinational firms hold more cash, which suggests repatriation taxes are an important motive for holding cash. Pinkowitz, Stulz, and Williamson (2012) show that firms do not increase their cash holdings after becoming multinational. We are not aware of previous papers linking monetary policy to cash holdings across countries.

3 Theory and Data on Firms' Demand for Liquid Assets

This section discusses reasons why firms hold liquid assets, and given that they hold liquid assets, why they invest these funds in different types of liquid assets. We then present Fed Flow of Funds data showing how much liquid assets U.S. firms hold, and how they invest these assets, over time. Lastly, based on these theoretical considerations, we construct the measure of opportunity costs that we use in the empirical analyses in this paper.

3.1 Reasons for Corporate Liquid Asset Holdings and Portfolio Choice

We follow the traditional economics literature by assuming that firms demand liquid assets to reduce transactions costs (see Baumol, 1952). Specifically, firms need liquid assets for operations, e.g., to transact with customers and to pay suppliers. Running out of liquid assets is costly, because profitable investments must be foregone, or operations come to a standstill, or because new cash must be raised, all of which is costly. In particular, as recognized by modern corporate finance theory (Riddick and Whited, 2009; Bolton, Chen,

and Wang, 2011; Nikolov and Whited, forthcoming), getting liquid assets into and out of the firm is costly. Loan negotiations with banks or securities issuances take time, require managerial resources, and may come at significant costs. In reverse, paying out dividends to shareholders quasi-continuously is impractical and undesirable for many shareholders. Smoothing out fluctuations in free cash flow by keeping residual cash inside the firm reduces these costs. The marginal benefit of holding an additional dollar of liquid assets is the reduction of the probability that the firm will be short of liquid assets.

On the other hand, there is a cost of keeping liquid assets inside the firm. Much of the literature assumes this to be agency costs (i.e. the manager wastes a fraction of liquid assets every period) or tax considerations; in contrast we will show that the return on corporate liquid asset portfolios are lower than their cost. This is especially true when regulation prevents interest payments on liquid assets holdings.[6] Optimal liquid assets holdings balance these costs and benefits as illustrated in Figure 1.

Given that firms hold liquid assets, how do firms decide in which types of liquid assets to invest? Once more, we invoke transactions costs. While less costly than raising new capital, it is nevertheless time-consuming and costly to liquidate less liquid forms of liquid assets such as government bonds to cash that can be used for transactions purposes. While this cost is much smaller in the age of online banking, SWEEP and NOW accounts, it was significant

[6]Regulation Q, which imposed maximum rates of interest on savings accounts and other bank deposits, made it much less attractive relative to firms until the end of 1980 to hold money in what we would now consider interest-bearing accounts, relative to holding cash in currency. The repeal of Regulation Q, driven by firms' demand for interest bearing assets in a highly inflationary enviroment, relieved such constraints and made it possible for firms to substitute non-interest bearing cash holdings with interest-bearing alternatives. The repeal, however, is not suitable as an instrument, because (i) its phase-out was gradual 1981-1986 and market participants had already found loopholes around interest rate restrictions before its official phasing out, and (ii) because the repeal itself ocurred in response to the existing loopholes, i.e. the causality goes two ways. Similarly, the introduction of SWEEP accounts in the mid-1990s comes contemporaneously with the widespread acceptance of money-market mutual funds and other interest-bearing liquid assets, as well as changes in the interest rate and is therefore not ideally suitable as an instrument for the question we investigate.

in earlier times (Teles and Zhou, 2005). Formally, we assume that firms anticipate two types of cash-flow shocks. Under the first type of shock, they need the cash immediately (e.g., the need to make everyday transactions). Under the second type of shock, firms need the cash in the near future, but not immediately (e.g., to invest in new projects). We assume that it is cheaper for firms to provide both for the short-term or intermediate-term shocks with internal cash rather than accessing the capital market. We divide the liquid assets that firms can hold into two broad asset categories. Type-1 liquid assets can address liquidity shocks of both types 1 and 2; that is, they can be used for everyday transactions. In contrast, Type-2 liquid assets can address liquidity shocks of type 2 only; that is, they cannot be used for everyday transactions. Whereas Type-1 assets provide a greater liquidity benefit, the return to holding them is lower (possibly a zero nominal return). We assume that currency and checking accounts are the only Type-1 assets. Savings and time deposits, mutual funds, and other liquid assets allow for less than instantaneous liquidity, and thus can be used to address only type 2 shocks. For longer-term or larger liquidity shocks, we assume firms access the capital markets; they do not provide internally for such funds.

In short, we assume that firms choose their level of liquid asset holdings optimally given the cost of accessing capital markets and the nature of cash flow shocks they expect, and we assume that they optimally choose the composition of their liquid asset portfolio, given the nature of the cash flow shocks they expect. Specifically, a transactions cost theory of liquid asset holdings predicts that because currency and checking accounts provide more liquidity than other assets, but at the cost of lower returns, firms will hold a mix of both categories of assets (of course, unless the firm is barred from holding interest-bearing assets by regulation in the first place, forcing a corner solution in the portfolio problem.) If unconstrained, however, firms' relative holding of each category depends on how long it takes to convert

holdings in mutual funds to checking accounts, and the cost of doing so. The time and cost of such conversion have gone down over time, due to improvements in electronic-payments technology. One should thus expect a downward-trend in firms' holdings of currency and checking accounts. While the cost of getting cash into and out of the firm has likely decreased over time as well. Note, however, that "everything else is not equal" – the cost of holding cash as measured by nominal interest rates, has decreased in the last thirty years. We would therefore not expect a decrease in the total amount of liquids held by U.S. firms.

3.2 Liquid Asset Holdings of U.S. Firms

While the "corporate cash puzzle" is widely discussed, it is a lesser known fact in the literature that the composition of the corporate liquid asset portfolio has changed dramatically over the last decades. Fed flow of funds data on the composition of corporate liquid asset holdings 1945-2011, presented in Figure 2(a), show that firms in the early half of the sample almost exclusively hold currency and checking accounts and government securities as liquid assets. Beginning just before the gradual repeal of Regulation Q around 1980, firms invest more and more in interest bearing forms of liquid assets. Nowadays, firms hold many types of liquid assets, ranging from currency (i.e. physical cash reserves) to money market mutual funds. These patterns are consistent with the hypotheses derived above that the decrease in transactions costs, combined with the relaxation of constraints on corporate liquid asset portfolios, has led to a decrease in firms' demand for non-interest bearing forms of cash relative to interest bearing forms of liquid assets.

Figure 2(b) aggregates all non-interest bearing liquid assets and all interest-bearing liquid assets in one group each and shows the declining time-trend of the fraction of non-interest

bearing liquid assets as a share of total liquid assets net of government securities over time.[7] The fraction of liquid assets held in currency and checking accounts decreased from close to 100% in the 1950s to about 20% in present times. The share was about 60% in 1980. The figure also plots a 10-year lagged average value of this share (not including the present year), which we will use in our empirical analyses, as explained in the next subsection.

3.3 A Measure of the Opportunity Costs of Holding Liquid Assets

As in Opler, Pinkowitz, Stulz, and Williamson (1999), we assume that the marginal benefit of an additional unit of liquid assets, a decrease in transactions costs, declines as holdings of liquid assets increase, creating a downward-sloping demand curve for liquid assets. In contrast, the marginal opportunity cost of holding an additional unit of liquid assets is equal to the spread between the return on an alternative investment with the same risk characteristics, minus the return on the firm's liquid assets portfolio. Cash is a risk-free investment. Thus, the gross cost of holding cash should correspond to the risk-free rate. Empirically, we approximate the risk-free rate with the three-month T-Bill rate.[8] The return

[7] As Greenwood (2005) point out, holdings of government securities play but a nominal role in corporate cash portfolios post-1965; before that, the holdings are driven by incentives to hold war bonds that are exogenous to risk management motives. Our study has no ambition to explain World War II-related holdings of government securities. Therefore, while we find it valuable to report the entire composition to start with, we exclude government securities from our further analyses to concentrate on the risk management motive that concerns the whole time series. This exclusion has but a nominal effect on our estimates.

[8] As Nagel (2014) points out, the T-Bill also contains a liquidity premium, which makes it an imperfect, but still very good proxy for the opportunity costs of holding cash. Note that the alternative investment of cash with the same risk characteristics is "not holding cash," i.e. disbursing cash to equity holders. The alternative project is not "investing in real assets," which has different risk characteristics and therefore a different cost of capital. We assume that the firm invests in all real NPV-positive projects, financed with an optimal capital structure. The decision we consider is what the firm does with any remaining cash after such investments, or whether it should raise additional cash. To make sure that differences in investment opportunities do not drive our results, we control for Tobin's Q in some robustness checks; in others we use the AA commercial paper rate instead of the T-Bill rate as the cost of holding cash, implicitly assuming that the alternative use of cash is paying down debt, rather than making payouts to shareholders. Firm-level costs of debt are not available for a long time series, unfortunately.

on the cash portfolio is typically lower than the T-Bill because a substantial fraction of cash is held in non-interest bearing currency and checking accounts. We will assume that such non-interest bearing assets earn a zero nominal return, while interest-bearing short-term investments earn the nominal T-Bill return. Denoting the share of non-interest bearing forms of cash investments of firm i at time t as $s_{i,t}$, and the 10-year lagged average $s_{i,t}$ (excluding the current year) as $\bar{s}_{i,t-\Delta}$, firm i's opportunity cost of holding one dollar of cash at time t is

$$OC_{i,t} = \text{T-Bill}_t - (1 - \bar{s}_{i,t-\Delta}) \cdot \text{T-Bill}_t = \bar{s}_{i,t-\Delta} \cdot \text{T-Bill}_t. \tag{1}$$

By using a ten-year moving average, we get less variation than we would by using the contemporaneous composition of cash holdings, but alleviate endogeneity concerns regarding the composition of the liquid assets portfolio. The aggregate version of the opportunity cost measure calculated from Compustat data omits the i subscript.

The measure derived above makes clear that there are two reasons why opportunity costs fluctuate over time. One is that the nominal T-Bill rate fluctuates. The other is that the ratio of non-interest bearing to interest bearing assets in the liquid asset portfolio changes over time.[9] We have provided evidence for the latter above. We now provide evidence for the formed, as well as the multiplicative effect.

Figure 3 plots the T-Bill in solid blue and the return of the aggregate corporate cash

[9]In most existing papers we are aware of, this marginal cost is assumed to be roughly constant over time, whereas we allow it to vary.For example, in the risk management model of Bolton, Chen, and Wang (2011), the firm's rate of return on holding cash is $r - \lambda$, where λ is the carry cost of cash and is thought of as agency or tax costs. Our approach thinks of the cost of holding cash as the wedge between the cost of capital of holding cash and the return on cash. In the notation of Bolton, Chen, and Wang (2011), our model assumes that $\lambda = (1 - \bar{s}_{i,t-\Delta}) \cdot \text{T-Bill}_t$. While we think of the main effect as multiplicative according to equation (1), we recognize that interest rates and carry costs can play different roles in the firm's optimization problem. In particular, high interest rates may decrease the set of profitable investment opportunities, possibly reducing any precautionary demand for cash. We include standard proxies for investment opportunities in several empirical specifications to recognize this effect.

portfolio in dotted red over time. The spread between the two is the opportunity cost of holding cash. The opportunity cost has risen from 1950 to 1980 and fallen over the last three decades for two reasons. First, the nominal interest rate increased from close to zero in 1945 to about 15% in 1980, and decreased from that level to almost zero today. Note that nowadays, the zero nominal rate leaves little room to the zero lower bound on the nominal return to cash, and thus for a significant wedge or opportunity cost of holding cash. Second, firms now hold a much higher fraction of their liquid portfolios in interest-bearing assets, thus reducing the wedge between the nominal interest rate and the rate of return on their liquid assets portfolio.[10] Given the time-variation in the opportunity cost of cash, assuming a constant benefit of holding cash implies a decrease of corporate cash holdings between 1950 and 1980, and an in increase thereafter (Figure 1(b)), leading to a negative correlation between corporate cash holdings and the opportunity costs of holding cash.[11] Figure 4 gives a time-series and a scatterplot of corporate cash-to-asset ratios from Fed Flow of Funds data and opportunity costs as calculated above. These graphs strongly suggest a

[10] A second reason for a cost of holding cash could come from a difference between the corporate and personal income tax rates (Graham, 2000; Faulkender and Wang, 2006). If the corporate tax rate is 35% and personal income is taxed at 10%, the after-tax return on a cash portfolio invested at 18% (the Fed funds rate in 1980) is 11.7% if invested by the corporation and 16.2% if invested by the individual. If the cash is invested at a rate close to 0% (realistic in the current interest rate environment), the tax disadvantage is minimal. In principle, the tax motive would therefore also lead to the cost of holding cash being positive correlated with interest rates. However, the wedge between personal and corporate income taxes was much smaller in the 1980s than it is now, and therefore much smaller than the above example suggests. Now that the wedge is considerable, nominal rates are close to zero, so that the difference in tax payments is hardly relevant. Before 1980, personal marginal tax rates were higher than the corporate tax rate, rendering the tax motive unsuitable for explaining the cost of holding cash for the time before 1980. Even if the wedge had been the same since 1945, because the tax mechanism applies only to the 50% of cash holdings that were not invested in currency and checking accounts in 1980 and is less important in the current interest rate environment, differences in the return on the corporate cash portfolio are the first-order driver of changes in opportunity costs over the last decades. Therefore, when constructing our measure of opportunity costs, we rely only on the share of assets invested in the different asset classes and do not examine the tax explanation.

[11] Note that in any standard risk management model in the style of Bolton, Chen, and Wang (2011), optimal cash holdings correlate negatively with the cost of holding cash; see also Bolton, Schaller, and Wang (2013) and Tobin (1956).

negative correlation between the two time series, as hypothesized above. Whether changes in opportunity costs can quantiatively explain the increase in cash holdings since the 1980s as well as variation in corporate cash holdings pre-1980 and internationally is an empirical question. The answer depends on the magnitude of the decline in opportunity costs during that period, and the slope of the demand curve in Figure 1. In the next section, we show that the changes in opportunity costs and the slope of the demand curve with respect to opportunity costs are in fact large enough to resolve the cash puzzle.

4 Data and Empirical Method

4.1 Data

There are three main data sources we use. One is Compustat, one is the Fed Flow of Funds, and one is FRED. We use Compustat to calculate firm-level cash-to-asset ratios, the dependent variable of our study, as well as firm-level controls in accordance with the existing corporate finance literature (Bates, Kahle, and Stulz, 2009): firm size, industry cash-flow volatility, cash flow, net working capital, a dividend dummy, and R&D expenditures. Table 1 shows summary statistics for these control variables. Variable definitions are provided in the Appendix. We also use Compustat to calculate firm-level shares of liquid assets held in non-interest bearing accounts $s_{i,t-\Delta}$ used in our cross-sectional analyses. We use Fed Flow of Funds to calculate macro-level shares of liquid assets held in non-interest bearing accounts $s_{t-\Delta}$ used in our time-series analyses. Also, the time series of aggregate cash-to-asset ratios that we attempt to predict is calculated from Fed Flow of Funds.

Following the existing literature, we calculate firm-level cash-to-assets ratio of all CRSP/ Compustat firms in the years 1951-2011 as cash and short-term investments divided by

total assets. For greater accuracy, we also calculate the aggregate cash-to-assets ratio for the nonfinancial corporate sector using Fed flow of funds data from 1945 to 2013 as the sum of currency and checking deposits, time and savings deposits, money market mutual fund accounts, and mutual fund shares, divided by the book value of total assets.[12]

T-Bill rates and AA commercial paper rates (used in robustness checks) come from FRED. The T-Bill rate proxies both for the risk-free rate, and the return on interest-bearing risk-free investments in liquid assets.[13]

4.2 Static Regressions

We estimate the response of the firm-level cash ratios to changes in the opportunity costs of holding cash, while controlling for factors that change the marginal benefit of holding cash. We thus test the hypothesis that opportunity costs affect cash holdings against the null hypothesis that they don't. In particular, we run regressions of the log cash to net assets as a function of opportunity costs, a cubic time trend, firm fixed effects, as well as firm-level control variables. ("Cash" in this context are all liquid assets, including but not limited to non-interest bearing currency.)

$$\log\left(\frac{Cash_{i,t}}{NetAssets_{i,t}}\right) = \beta \cdot OC_t + \gamma \cdot X_{i,t} + f(t) + \nu_i + \varepsilon_{i,t}, \tag{2}$$

[12]Fed flow of funds data give an arguably cleaner picture of the dynamics of corporate cash holdings, for various reasons. (i) Fed flow of funds data are consolidated for the sector; (ii) the Compustat sample includes only firms with publicly traded securities, whereas the Fed flow of funds data include the cash holdings of all privately owned firms; (iii) the Compustat sample is missing many firms, especially in the pre-1980 period; (iv) and Compustat data start in 1951, whereas we can calculate the cash-to-assets ratio from flow of funds data starting in 1945. The two measures of the cash ratio show a qualitatively similar pattern over time: both decrease between 1945/1951 and around 1980, and then increase between 1980 and 2011.

[13]Because historical data on rates for money market accounts, certificates of deposit, and other forms of interest-bearing assets do not go back far enough in time, we assume that interest-bearing liquid assets returned the T-Bill rate.

where OC_t is the opportunity costs of holding cash at time t (note that a lagged version of s_t is used to construct OC_t), and X_{it} is a vector of firm-level controls. Because we control for a time trend $f(t)$, we are identifying the effect of opportunity costs on the cash ratio from variation of cash ratios and opportunity costs around their trend. In the reported results, we use a cubic time trend. The results, however, are robust to other non-linear forms; we tried up to order 5. Following Petersen (2009), we two-way cluster standard errors by both firm and year unless otherwise noted.

We alternative the above specification with a second one that is similar to the first, except that it uses the raw cash-to-assets ratio instead of the logarithm of the net cash ratio as a dependent variable:[14]

$$\frac{Cash_{i,t}}{Assets_{i,t}} = \beta \cdot OC_t + \gamma \cdot X_{i,t} + f(t) + \nu_i + \varepsilon_{i,t}. \tag{3}$$

This alternative specification ensures robustness with respect to the specific functional form.

The first four specifications replace OC_t with the T-Bill. This is an important first step to alleviate concerns that the corporate sector's choice of $s_{t-\Delta}$ drives the results. The first two specifications don't include controls, the next two do. Based on the theoretical considerations laid out and data presented in Section 3, we should use s in the construction of opportunity costs – omitting it would implictly make the counterfactual assumption that corporations hold all of their cash in non-interest bearing assets. We also calculate Bayesian information criteria and Akaike information criteria for specifications using the T-Bill and specifications using opportunity costs. The latter are strongly preferred.[15] We thus repeat the analysis using

[14]Following Bates, Kahle, and Stulz (2009) logs are chosen in the first specification to reduce the incidence of extreme outliers.

[15]This is a direct consequence of a positive correlation between s and the T-Bill (not reported). That is, firms invest a higher fraction of their liquid assets in interest-bearing assets when the nominal rate is higher. Note that this positive correlation works against the hypothesis that our results are driven by firms'

OC_t in specifications (5) through (8). Recall that while we now use s in the construction of opportunity costs, we alleviate the endogeneity concern by lagging and averaging s over 10 peridos.

Specifications (9) and (10) use multiple imputation to ensure that results are unbiased because of missing values in the controls.[16] In all specifications, we weight firms by their average assets over time, multiplied by the number of time periods in which the firm is in the sample. The motivation for this weighting scheme is that the aggregate cash ratio in the Fed flow of funds data can be thought of as an asset-weighted average of firm-level cash ratios. The results do not substantially change if we estimate the specifications using simple OLS instead of WLS. Using a balanced panel of firms between 1980 and 2011 also leads to a similar estimated effect of opportunity costs on cash-to-assets ratios. Other robustness tests are discussed in Section 5.

endogenous choice of s. Specifically, we follow the Bayesian Information Criteria (BIC) explained in Schwarz (1978) that are widely used for model selection for several alternative econometric models. We start with the model of (Bates, Kahle, and Stulz, 2009), and then add, alternatively, the T-bill rate, and the fraction of currency and checking as a share of liquid assets. The improvements in BIC are large in both cases, and of comparable magnitude. Then, we replace the T-Bill or share of currency and checking with our measure of opportunity costs. We find that the BIC improves even more, and that the increase relative to T-Bills is large. We thus determine that the model with opportunity cost as the dependent variable is strongly preferred over the two alternatives.

[16] One problem with the Compustat panel–especially in the early years of the sample–is that some control variables are missing for many of the firms. To avoid losing these observations, the ability to impute (or "fill in") the missing data with plausible values would be desirable. A naive imputation method, however, may create more problems than it would solve. Simple imputation methods, for example, overstate the precision of estimates because they do not account for the uncertainty regarding the imputed values. Rubin (1987) developed the multiple imputation procedure that allows statistically valid imputation of missing values. Multiple imputation of missing values allows us to incorporate observations that are missing some controls in our analysis of the effect of opportunity costs on the cash ratio, while modeling the uncertainty associated with the missing observations. Following Schafer (1999), we impute missing values for net working capital, cash flow, industry sigma, leverage, acquisitions, capital expenditures, and the market-to-book ratio, based on all the other variables in each regression specification. Fields other than corporate finance are already applying the multiple-imputation procedure on a large scale: labor economics (Brownstone and Valletta, 1996), health economics (Shore-Sheppard, Buchmueller, and Jensen, 2000), political science (King, Honaker, Joseph, and Scheve, 2001), transportation economics (Steimetz and Brownstone, 2005), and medical research (see Mackinnon, 2010 for a review). We cluster by firm in the specifications that use multiple imputation.

4.3 Dynamic Regressions

Following (Opler, Pinkowitz, Stulz, and Williamson, 1999), we also run dynamic regressions with the lagged cash ratio as a regressor:[17]

$$\log\left(\frac{Cash_{it}}{NetAssets_{i,t}}\right) = \alpha \log\left(\frac{Cash_{i,t-1}}{NetAssets_{i,t-1}}\right) + \beta \cdot OC_t + \gamma \cdot X_{i,t} + f(t) + \nu_i + \varepsilon_{i,t}. \quad (4)$$

Similar to the levels regressions, an alternative specification ues the raw cash-to-assets ratio as a dependent variable instead of the logarithm of the cash ratio:

$$\frac{Cash_{i,t}}{Assets_{i,t}} = \alpha \frac{Cash_{i,t-1}}{Assets_{i,t-1}} + \beta \cdot OC_t + \gamma \cdot X_{i,t} + f(t) + \nu_i + \varepsilon_{i,t}. \quad (5)$$

The specifications are ordered as in the static regressions. Alternative versions of dynamic regressions with lagged opportunity costs instead of lagged cash ratios as controls do not substantially affect the results. Again, many robustness checks are discussed in the results section.

4.4 Cross-sectional Identification

In our main results, we identify the effect of opportunity costs on corporate cash holdings from the variation of opportunity costs over time around a cubic time trend, using aggregate Fed Flow of Funds data to construct the opportunity costs of holding cash. The specifications discussed here, we show that the effect can also be identified in the cross section, using firm-

[17] Note that running a regression in levels controlling for lagged values of the dependent variable is arithmetically equivalent to running a regression in differences controlling for lagged values of the dependent variable. Note also that "nickel bias" that results from lagging dependent variables in panel regressions with short panels is not a significant concern in our sample of 32 years.

level variation in the share of interest bearing versus not interest bearing cash investments, and controlling for year fixed effects. We construct a firm-level measure of opportunity costs using Compustat data on the fraction of cash that is held in immediately negotiable media of exchange (variable CH) compared to the fraction held in interest bearing assets (variable CHE) instead of using the Fed Flow of Funds-implied s_t, multiplied with the T-Bill rate. Most of the components included in immediately negotiable media of exchange (see appendix) pay zero or low interest, and thus we use this as a proxy for the fraction of liquid assets that is non-interest-bearing. Most of the assets in CHE pay a rate of return close to the T-Bill rate. (More detailed data on firm-level variation in the composition of cash become available only after 2009 (Duchin, Gilbert, Harford, and Hrdlicka, 2013).) Importantly, to alleviate endogeneity concerns, we only use (strongly) lagged values of $s_{i,t-\Delta}$ to construct $OC_{i,t}$. We discuss variations of the method below. Because this measure of opportunity cost varies in the cross section in addition to over time, we can include both firm and year fixed effects. The idea of our cross-sectional specifications is captured in the following regression equation:

$$\log\left(\frac{Cash_{i,t}}{NetAssets_{i,t}}\right) = \beta \cdot OC_{i,t} + \gamma \cdot X_{i,t} + \gamma_t + \nu_i + \varepsilon_{i,t}. \tag{6}$$

A potential concern is that the fraction of cash held in interest-bearing assets by the firm is endogenous due to division bias, and potentially for other reasons due to the fact that the composition of liquid assets is a choice variable for the firm. We address this endogeneity concern by running only instrumental variable and difference-in-difference regressions that only use firms' choice of s_i in the 1970's. We never use contemporaneous $s_{i,t}$ or s_t in any specification in the paper.

In the first four specifications, we create an instrumental variable $OC^{IV}_{i,t} = \overline{\left(\frac{CH}{CHE}\right)}_{i,t-\Delta} \cdot$ T-Bill$_t$, that replaces OC_{it} in equation (6). In all cases, the instrument is the firms' average

s_i in the years 1970-1979. Hence, we identify off differences in firms' propensity to hold liquid assets in more or less interest-bearing assets before out estimation sample starts. In the first specification $OC_{i,t}^{IV}$ is constructed with one year lagged s_t, i.e., $t - \Delta$ is $t - 1$. In the second specification, $t - \Delta$ is the average of the last ten years, not including the current year. Specifications (3) and (4) add the controls to these two specifications.

Specifications (5) to (8) use a difference-in-differences approach. We sort firms by their average s_i 1970 to 1979 and split the sample at the median (specifications (5) and (7)) or extract the upper and lower quintile (specifications (6) and (8)). The treatment is the passage of time between 1980 and 2011, including (but of course not limited to) the decrease in nominal interest rates by about 15%. Thus, the coefficient on "treated" times "post" measures how strongly firms that held most liquid assets in currency and relatively few liquid assets in interest bearing accounts in the 1970s responded to the decrease in interest rates, compared to firms that held most of their liquid assets in interest bearing assets. Following the previous logic, specifications (7) and (8) include firm-level controls, compared to specifications (5) and (6).

5 Results on the U.S. Cash Puzzle

5.1 Effect of Opportunity Costs on Corporate Cash Holdings

Table 2 shows the results from the static regressions of firm-level money demand. The first four specifications with the T-Bill rate as the main explanatory variable and log cash to net asset ratios as the dependent variable yield coefficients of -6.161 and -4.178 in the specifications without and with a full set of controls. The specifications with raw cash to asset ratios yield coefficients of -0.326 and -0.262 respectively, indicating robustness to a

different functional form. All coefficients are highly statistically significant. The magnitudes are roughly comparable to the magnitudes estimated by the traditional macroeconomics literature on money demand. Qualitatively, these results go in the hypothesized direction. To gauge the quantitative importance of our theory, we move on to specifications (5) through (10). The regressions with the logarithm of the net cash ratio as the dependent variable yield a range of estimated effects of opportunity costs on corporate money demand between -11.77 and -16.12. In the specifications with the cash ratio in levels, we find estimated effects between -.603 and -0.952. In particular, a coefficient of -12 means that if opportunity costs decrease by 1 percentage point, cash holdings increase by approximately 13%. As explained in the next subsection, these coefficients are not only highly statistically significant, but also large enough to explain the more-than-doubling of corporate cash holdings in the last 30 years.[18]

The coefficients on the control variables are largely consistent with what the existing literature reports. In particular, the negative coefficient on total assets indicates economies of scale in holding cash, which is consistent both with results reported in the previous literature (Mulligan, 1997) and with our theoretical considerations about the firms' transactions demand for cash.[19] The regression results for the dynamic specifications are shown in Table

[18]Note that the magnitude of the non-logged coefficients is more difficult to relate to the secular increase in corporate cash holdings as measured with Fed Flow of Funds. These coefficients, predict by how many percentage points cash holdings increase in response to a percentage point decrease of opportunity costs. They can only reasonably be applied to Compustat data, whose levels and changes in cash-to-asset ratios are not quantiatively comparable to Fed Flow of Funds. By contrast, the coefficients from log specifications predict percentage changes in cash-to-asset ratios in response to percentage point changes in opportunity costs, and can therefore be applied to both Compustat and Fed Flow of Funds data. For reasons outlined in section 4, the Fed Flow of Funds data give a cleaner picture of the dynamics of cash ratios and should be used for gauging magnitudes.

[19]We find no significant effect of industry sigma on firms' cash ratios, which is consistent with the relation between cash ratios and industry sigma in an international comparison, but at odds with some results reported in the literature. This difference is driven by the fact that we are weighting by firm size and number of periods with observations, and is not driven by the fact that we are including opportunity costs. If we use OLS instead of WLS, we find that industry sigma has a significant effect on firms' cash ratios. As mentioned previously, changing the weights does not substantially change our main results, i.e., the coefficient on opportunity costs.

3. The coefficients are also highly statistically significant throughout. Their magnitude is likewise large enough to explain the time-variation in corporate cash holdings (although we omit reporting these results for space reasons).

5.2 Implications of Estimated Effects for the Corporate Cash Puzzle

To see if the observed changes in opportunity costs can resolve the corporate cash puzzle in the sense of predicting a substantial share of the time-series variation, we calculate the predicted response of corporate cash holdings to variations in opportunity costs, holding all factors other than opportunity costs constant. The static calculations use the estimated effect from specification (9) in Table 2.

Figure 5(a) compares the predicted values of the cash ratio with the actual cash ratio between 1945 and 2013 from Fed flow of funds. We normalize the predicted series so that its average value in logs is equal to the average value for the actual series. We can see from the graph that changes in opportunity costs over the period can explain most of the long-run changes in the corporate cash-to-assets ratio. The only significant exception is that from the end of World War II until the end of the 1950s, actual corporate cash holdings were higher than the predicted values. A possible reason is that our econometric model does not account for the fact that personal income taxes relative to corporate income taxes were much higher then than they are today, giving firms an additional incentive to hold on to more cash and not pay it out.[20] The slight overprediction of the increase of cash holdings between 1980 and 2010 could be due to the increasing availability of credit lines (see Disatnik, Duchin, and

[20] As the dynamics of tax rates does not seem to have the potential to explain the secular trends over long horizons, we do not include this variation in our econometric approach. We want to make clear that the sole driver of the results presented in this paper are opportunity costs.

Schmidt, forthcoming).[21]

Figure 5(b) shows the results of a static prediction exercise identical to that in Figure 5(a), but using quarterly instead of annual data, and focusing on the period 1980-2013. We can see from the graph that changes in opportunity costs over the period can explain some of the short-run changes in the corporate cash-to-assets ratio, whereby our predictions anticipate the actual changes slightly. (We use annual data in the other specifications to be consistent with the bulk of the existing literature.) The slight overprediction in the early 1990s and to a lesser extent the early 2000s may be due to the introduction of SWEEP accounts in the mid-1990s, which made it cheaper for firms to hold a given amount of cash, as they can hold a higher fraction of it in interest-bearing accounst while allowing similar benefits in terms of liquidity management. As our opportunity cost measure is based on a 10-year lagged ratio of cash held in non-interest bearing and interest bearing accounts, our econometric model would then assume too high a fraction in interest-bearing accounts before the introduction of SWEEP accounts, and thus overpredict the amount of cash firms "should" have held, given interest rates.

5.3 Identification Using Cross-sectional Variation in the Opportunity Costs of Holding Cash

The following results for the cross-sectional identification approach rely on the idea that firms whose cash holdings, for operational reasons, include high fractions of liquid assets that do not earn interest, such as currency and checking accounts, should respond more to changes in the T-Bill rate. Figure 6 provides an illustration. It plots the time series of

[21] Unfortunately, aggregate credit lines for the corporate sector from call reports are only available post-2009.

weighted average cash-to-asset ratios for two subsets of Compustat firms. In blue are firms that on average from 1970 to 1979 held more of their liquid asset portfolio in interest-bearing accounts, compared to the median firm. In red are firms that held more of their assets in non-interest bearing accounts, compared to the median. We note that *all* of the secular increase of cash holdings after 1980 is driven by firms with above-median cash holdings in non-interest bearing assets – in fact, firms that held relatively more of their cash in interest-bearing accounts decreased their cash holdings weakly. To the extent that the composition of the corporate cash portfolio in the 1970s of these firms is exogenous to how their cash portfolio after 1980 depends on interest rates, this figure can be viewed as a difference-in-differences test of our hypothesis. We split firms at the median only for clarity. Ranking firms by quintiles leads to similar results. The fourth and fifth quintiles of firms by average $CH/CHE_{1970-1979}$ ratio in fact *decreased* their cash-to-asset ratios from 1980 to 2010. Only the bottom three quintiles increased their cash ratios over the last thirty years. The ranking of quintiles in terms of average $CH/CHE_{1970-1979}$ ratio also perfectly predicts the ranking of increases in cash holdings 1980-2010.

Table 4 presents formal results of this idea. First of all, note that exploiting cross-sectional variation in the fraction of non-interst bearing assets allows us to include not only year-fixed effects, but also firm-fixed effects in all regressions. This is the major advantage compared to the time-series identification presented before. The first four columns present results from an instrumental variable approach as explained in section 4, the fifth to eighth column present results from a double-difference approach as illustrated above. Across all IV specifications, the results that use 10-year lagged averages of s_i have slightly lower coefficients, which is expected because of attenuation bias. Specifically, the coefficients range from -9.741 to -17.18 (one-year lagged opportunity costs; no controls). Remarkably, the coefficient using the first

lag of opportunity costs and controls (specification (3)) is quantitatively almost identical to the coefficient estimated in the time-series regressions with controls.

The positive coefficient of the difference-in-difference specifications indicates that firms that on average in the 1970s held a higher fraction of cash in assets that do not earn interest increased their cash holdings significantly more over time, compared to firms that held a lower fraction in assets that do not earn interest, as predicted by our hypothesis. Quantitatively, the coefficient in specification (7) of 1.170 means that firms above the median in terms of $CH/CHE_{1970-1979}$ have increased their cash holdings by approximately 192% from 1980-2011 relative to firms below the median. (This estimate matches the results illustrated in figure 6 by construction.) The coefficient in specification (8) of 2.264 means that firms in the highest quintile in terms of $CH/CHE_{1970-1979}$ have increased their cash holdings by approximately 404% from 1980-2011 compared to firms in the lowest quintile. Note that firms in the highest quintile in fact reduced their cash holdings during that period, while firms in the lowest quintile increased liquid assets holdings the most.

5.4 Robustness Tests

We test our results for robustness in several dimensions: time stability, inclusion of investment opportunities and other macroeconomic variables as controls, accounting for changes in risk premia by replacing the T-Bill with the AA commercial paper rate in the calculation of opportunity costs, stability of estimates across firms with different characteristics, and stability of estimates across industries. We present those test in the same order below. We also discuss further robustness checks that we don't report.

To examine the robustness of the estimated effect of opportunity costs on corporate cash demand over time, we first perform rolling regressions of the static specification using the

log of cash over net assets as the dependent variable, and opportunity costs, firm size, firm fixed effects, and a cubic time trend as controls. For each year in the rolling regression, the estimation window includes the 21-year period centered around the given year. Because we are using data going back to 1951 in the estimation of the rolling regressions, which is missing many of the control variables, we do not include the full set of firm-level controls in the rolling regressions. In Appendix Figure B.1, we present the time-series and confidence intervals of our estimates of the effect of opportunity costs on cash holdings. The effect is statistically significant for all time periods. The point estimates vary between approximately -4 and -13, nesting the estimated effects in the main results section of about -12. (The average effect in the rolling regressions is lower because of the missing controls.) The stability of the estimates is a distinguishing feature from earlier papers (Stone, Gup, and Lee, 2012).

We examine whether adding macro variables such as GDP substantially change the results and find that they don't. Tables B.1 and B.2 present the results from static and dynamic regression specifications similar to the basic results presented in tables 2 and 3, but with GDP as an additional control. Replacing GDP with Tobin's Q does not substantially alter the results either.[22]

To alleviate concerns that time-changing risk premia drive our results, we run regressions of the cash-to-asset ratio on AA commercial paper as well as the opportunity cost measure constructed with AA commercial paper rather than the T-Bill rate. (These regressions can also be viewed as appropriate when the alternative use of cash is not to pay it out to shareholders, but to pay down debt.) The results are presented in tables B.3 (static) and B.4

[22]We find that the log of real GDP has a significant effect on firms' cash ratios in static specifications, but the effect of GDP on cash ratios is not significant when controlling for lagged values of the cash ratio. In either case, the coefficient β on the opportunity costs is not strongly affected. Following Duchin (2010), we calculate Tobin's Q as market value of assets (book assets (at) + market value of common equity (csho*prcc) – common equity (ceq) – deferred Taxes (txdb)) / (0.9*book value of assets (at) + 0.1*market value of assets).

(dynamic). As expected (the AA commercial paper rate positively covaries with T-Bill rates and therefore decreased more from 1980 to 2011 than the T-Bill rate), the point estimates are slightly smaller than in the main specifications we present, but not distinguishably so. We furthermore refer the reader to Nagel (2014), who shows that the liquidity premium in T-Bills dwarfs in comparison to the time-series variation if the T-Bill rate's level.

To examine cross-sectional robustness of the effect of opportunity costs on the cash ratio, we re-estimate our baseline specification (specification 7 in Table 2) for various firm types. In particular, for each firm-level control, we calculate the average across firms. We then divide firms into two groups according to whether their time averages of the control variable are above or below the median time average.[23] The results are shown in table B.5. We find that the estimated effect is generally similar across groups. Point estimates indicate that small firms' demand for cash is less elastic than that of large firms and that the effect for firms with high levels of acquisition activity is lower than for firms with low levels of acquisition activity. The differences, however, are not statistically significant, and all groups have a significant estimated effect of opportunity costs on the cash ratio. Thus, the results largely confirm the validity of the hypothesis advanced in this paper for different subsets of firms. Similarly, we run separate regressions for Manufacturing, Services, Retail Trade, and for "other" SIC industry divisions as a group. The results are shown in Table B.6. The effect of opportunity costs is negative and statistically significant for all four groups of firms. The point estimate of the effect of opportunity cost on the cash ratio is highest for Retail Trade, but also not statistically different from the other groups. These regressions show that the results are not driven by a particular industry or set of firms.

[23] We are not aware of theories predicting a different sensitivity of cash holdings to opportunity costs for different firm characteristics. However, it is possible that firms differ with respect to the slopes of their marginal benefit curve of holding cash. In sum, we do not have a strong prior in which direction, if any, differences between subgroups should go.

A potential concern is that Compustat data before 1970 suffers from a severe survivorship bias. To test whether this bias drives our results, we run our regressions with a balanced panel of firms. Combined with the result that the multiple imputation approach already indicated robustness to missing values, we are less concerned that survivorship bias drives our results. We omit reporting these results to conserve space.

Lastly, we provide suggestive evidence as to the power of existing explanations of the corporate cash puzzle to explain not only the 1980-2010 subperiod, but also the 1950-1980 subperiod. Figure B.2 provides time-series plots of the key variables hypothesized by Bates, Kahle, and Stulz (2009) (BKS) to be the key drivers of corporate cash holdings. They are cash flow volatility, R&D expenditures, cash flow divided by assets, and a dummy for dividend-paying firms. Using post-1980 data, BKS find that increased cash flow volatility, R&D expenditures, lower cash flows are drivers of higher cash holdings, while a dividend-payer dummy negatively is negatively related to cash holdings. Figure B.2 shows that cash flow volatility and R&D expenditures indeed increased and the fraction of dividend payers in Compustat indeed decreased from 1980 to 2010. However, these trends began long before 1980, while cash ratios were falling, so they are unlikely to explain the time-series evidence before 1980. Moreover, cash flow divided by assets does not seem to have a robust time trend at all. While these observations do not prove the validity of the opportunity cost hypothesis in comparison with the arrived explanations, it illustrates one reason why we believe the empirical relationship between cash and opportunity costs to be a more robust explanation. (For space constraints we do not include market-to-book ratios. They fluctuate at much higher frequencies than cash-to-asset ratios and do not exhibit pronounced secular trends.)

6 International Evidence

In this section, we use Compustat Global data to estimate the relationship between opportunity costs and firm-level cash ratios for the largest five European economies and Japan. For this purpose, we proxy for opportunity costs by using short-term nominal interest rates for each country, multiplied by the average by country and year of the fraction of cash that is held in immediately negotiable media of exchange.[24] Because data are available for a small number of firms for earlier years, we use data for the period 1996-2011.[25]

Figure 7 shows a scatter plot of the time average of the cash ratio (defined as total cash divided by total assets) and the average opportunity costs for the period 1996-2011 for the United States, Japan, Germany, France, the United Kingdom, Italy, and Spain. We also show the cash ratio for the United States in 1980, 1990, 2000, and 2010 of reference. The regression line in the graph is estimated using the country averages, and not the points for the United States in 1980, 1990, 2000, and 2010. A negative relationship exists between average opportunity costs and the average cash ratio across countries. Japan's average cash ratio is high relative to other countries in the sample during the period 1996-2011. These high cash levels are explained by low opportunity costs during that period. The level of the cash ratio for the United States in 2010 is close to the value for Japan over the period 1996-

[24] We use three-month treasury bill rates from the International Data section of Fred for Japan, France, the United Kingdom, Italy, Spain, and the United States. We use 90-day interbank rates for Germany because they are available for a longer time period. For the period during which three-month treasury bill rates are available for Germany, they are close to the 90-day interbank rates.

[25] Also, because of the shorter time period and the small number of firms for some countries, we cluster standard errors by firm only, as opposed to two-way clustering by firm and year as in the rest of the paper. This is following Petersen (2009): "When both a firm and a time effect are present in the data, researchers can address one parametrically (e.g., by including time dummies) and then estimate standard errors clustered on the other dimension. Alternatively, researchers can cluster on multiple dimensions. *When there are a sufficient number of clusters in each dimension*, standard errors clustered on multiple dimensions are unbiased and produce correctly sized confidence intervals whether the firm effect is permanent or temporary." (emphasis is ours)

2011, and the level of opportunity costs is also similar. The regression line has a slope of -1.14 – strikingly similar to the non-logged estimates obtained for the within-U.S.-analyses presented above. In sum, cash levels in U.S. firms have not been abnormal in any way in any period during the last 30 years, as judged by an international comparison using data from 15 years overlapping with, but not covering the time period of the "corporate cash puzzle."

Figure 8 plots the level of opportunity costs and the cash ratio by country over time for the period 1996-2011. The graphs suggest a negative correlation between cash-to-assets ratios and opportunity costs, similar to the U.S. evidence in Figure 4. Given a smaller amount of variation of opportunity costs over these short time periods, the relationships may not appear to be as stark, however.

Table 5 shows results of firm-level money demand regressions by country and of regressions including firms from all seven countries. Note that they do not include a full set of controls to conserve data. The first seven specifications are estimated for each country separately and similar to specification (5) in Table 2. The last two specifications show results pooling firms from all countries. Specification (8) uses a cubic time trend, and specification (9) controls for year fixed effects. We find a statistically significant negative effect of opportunity costs on the cash ratio for Germany, France, Spain, Japan, and the United States.[26] For the UK and Italy, the estimated coefficient is negative but not significant; in the case of Italy, this lack of significance may be attributable to the small number of observations, or due the political drive towards reducing cash payments in the shadow economy related to the inclusion in the European Monetary Union, leading to an exogenous downward-trend in cash holdings. We find a statistically significant negative coefficient in both pooled specifications. Moreover, the coefficients for the specification including a cubic time trend are

[26]The U.S. coefficient is slightly lower than estimated in the U.S.-only part of the paper mainly because of the different sample periods.

similar to those in the specification including year fixed effects. The coefficient in the most similar specification to specification (5) in Table 2, column (8), is indeed almost identical to the U.S.-only estimate.

Figure 9 shows the results of a prediction exercise for each country similar to that described previously for the United States in Figure 5. We use the estimated coefficient from the pooled specification with year fixed effects (Table 5, column 9). Even in these short samples with litte variation in opportunity costs and no full set of controls, changes in opportunity costs over time can explain some of the variation in cash ratios, especially for France, Germany, Italy, and Spain. The variation in cash ratios over time for the United Kingdom, and Japan seems harder to rationalize as resulting from changes in opportunity costs. Note that the estimated effect of opportunity costs on cash ratios for Japanese firms is relatively large, but the changes in opportunity costs over time were small.

Finally, note that cross-sectional variation in cash-to-asset ratios across countries are difficult to reconcile with the arrived explanations for the time-series increase in U.S. cash holdings. Figure B.3 presents scatter plots of average cash-to-asset ratios 1996-2011 in the top 5 European economies and Japan over the average from 1996-2011 of the same arrived explanatory variables: cash flow volatility, R&D expenditures, cash flow to assets, and dividend payer dummy. The direction of the relationship found by Bates, Kahle, and Stulz (2009) is positive for cash flow volatility, R&D, and dividend payer dummy, and negative for cash flow/assets. In contrast, in the international cross-section we see a negative relationship of cash-to-asset ratios with cash flow volatility and R&D, and a positive relationship to dividend payments. Cash-flow to assets is the only explanation that goes in the same direction as the evidence in BKS suggests. However, it is clear from these scatterplots that the relationships we measure are quite weak to start with. That is, rather than suggestion

oppositive directions than what the existing literature has found, the take-away is that the existing explanations do not have much power in explaining the international cross-section.

7 Conclusion

We provide evidence that changes in opportunity costs of holding cash can explain long-run changes in corporate cash holdings. We thus complement the large literature on the dynamics of corporate cash holdings that has thus far focused on changes in the benefits of holding cash. Our approach starts with the calculation of a measure of the opportunity costs of holding liquid assets as the difference between the cost of holding cash and the return on the corporate liquid asset portfolio. We proxy for the cost of holding cash with the T-Bill rate as a measure of the risk-free rate. More suprisingly, we find that the return on liquid assets is substantially lower than the T-Bill rate because firms hold much of their liquid assets in non-interest bearing assets. Using this opportunity cost measure, we identify a large negative effect of opportunity costs on the cash-to-assets ratio of nonfinancial Compustat firms, using variation around the time trend of cash holdings from 1980 to 2011. We use that estimate to predict changes in aggregate cash holdings for 1945-2013 and find that they closely match actual changes in cash holdings over that period. Several robustness tests indicate that our results are applicable to a wide universe of firms and do not depend on the precise econometric specification or proxy for the cost and return of cash. Next, we offer a cross-sectional identification from instrumental variable and difference-in-difference strategies that make use of firm-level variation in the fraction of liquid assets held in non-interest bearing accounts. Lastly, we show that differences in opportunity costs also explain cross-country differences of cash-to-assets ratios in the five largest European economies and Japan very

well, as well as within-country time variation in these countries, similar to the U.S. The coefficients from all three sets of analyses match remarably well. We cannot entirely rule out that one omitted variable drives both cash holdings, firms' portfolio choice and interest rates (and thus opportunity costs) in the time series analysis, and that another similarly drives the cross-sectional results. However, the opportunity costs hypothesis is the only existing theory that has been shown to explain not only the time series of U.S. corporate cash holdings from 1980 to 2011, but also the time series reaching back to 1945, as well as the only one that has been shown to explain international variation in corporate cash holdings.

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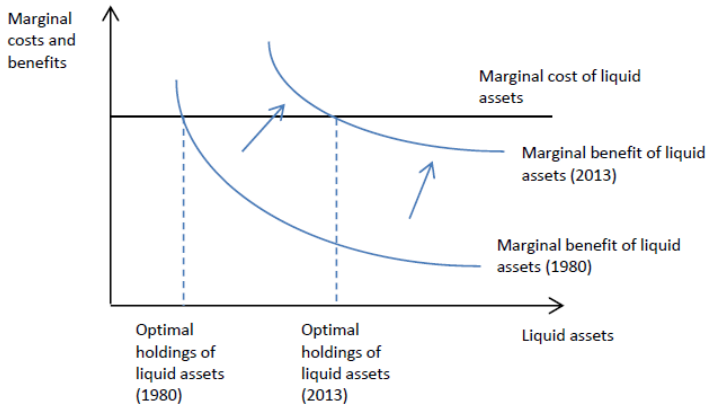
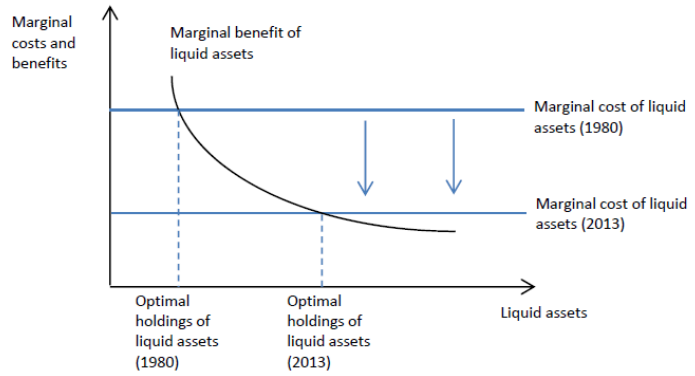
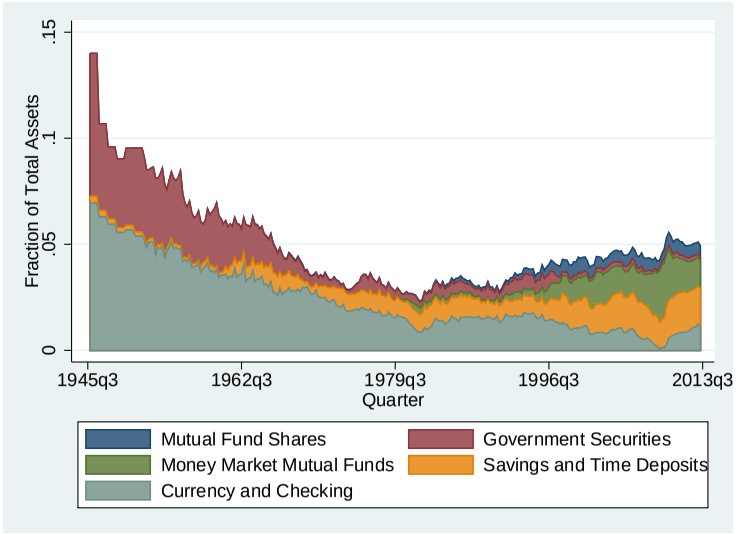


(a) Shift in the marginal benefits of holding cash

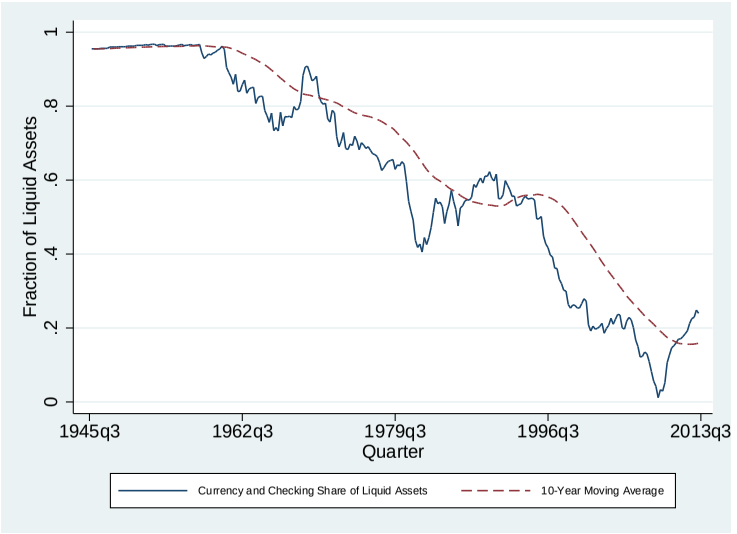


(b) Shift in the marginal cost of holding cash

Figure 1: Two possible explanations for changes in optimal holdings of liquid assets.
The left graph illustrates explanations arguing that an increase in the marginal benefits of holding cash have driven the increase in corporate cash holdings over the last three decades. The right graph illustrates the alternative explanation advanced in the present paper, which argues that a reduction in the marginal costs of holding cash drove the increase in corporate cash holdings.



(a) Components of the corporate sector liquid asset portfolio



(b) Currency and checking as share of the liquid asset portfolio

Figure 2: Components of the aggregate corporate liquid asset portfolio.

Data on the components of the nonfinancial corporate sector's liquid assets portfolio depicted in the left panel is from the Fed Flow of Funds. The right panel plots the share of currency and checking accounts as a share of total liquid assets excluding government securities, as well as the 10-year lagged moving average of that quantity (not including the current year). The lagged fraction of liquid assets held in currency and checking accounts is used in the econometric time-series analyses.

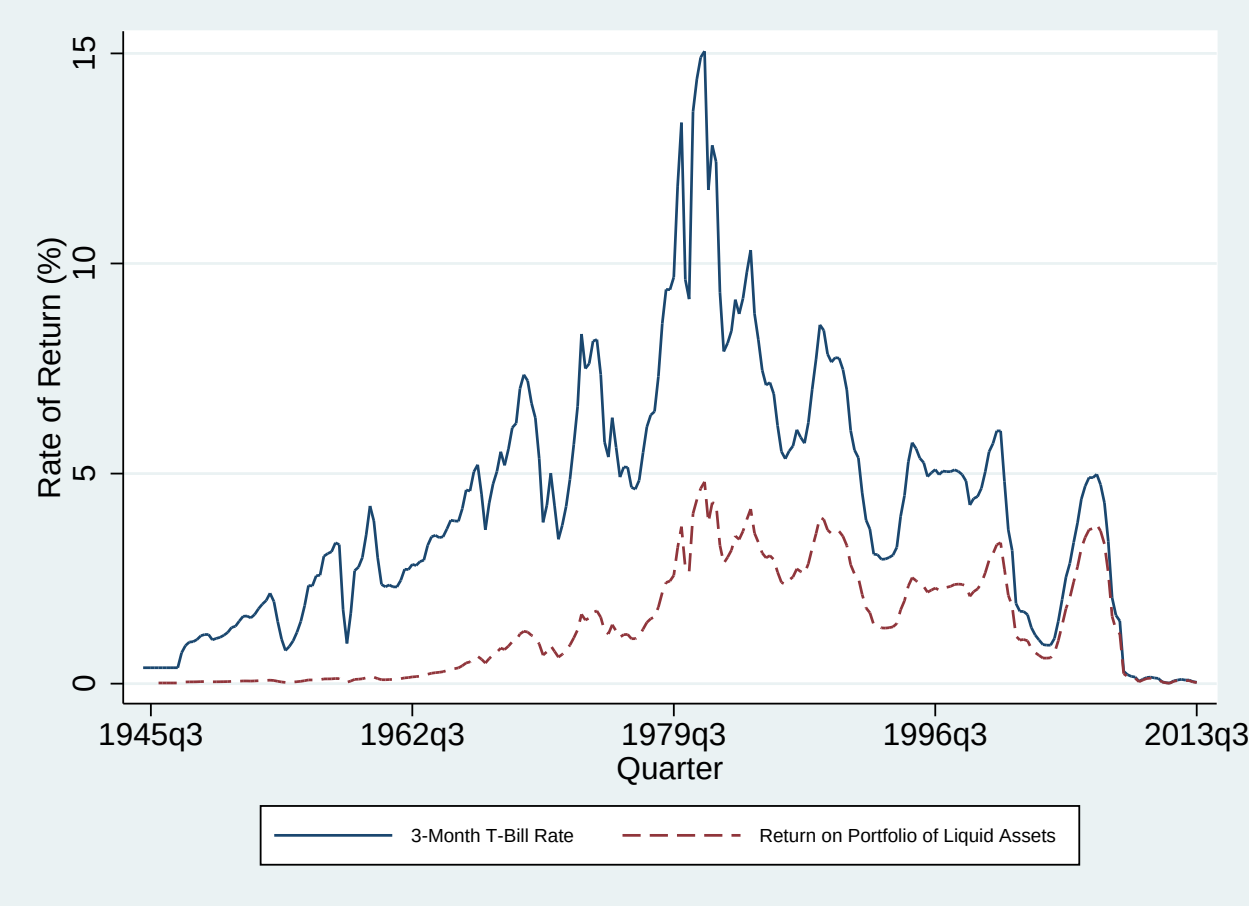
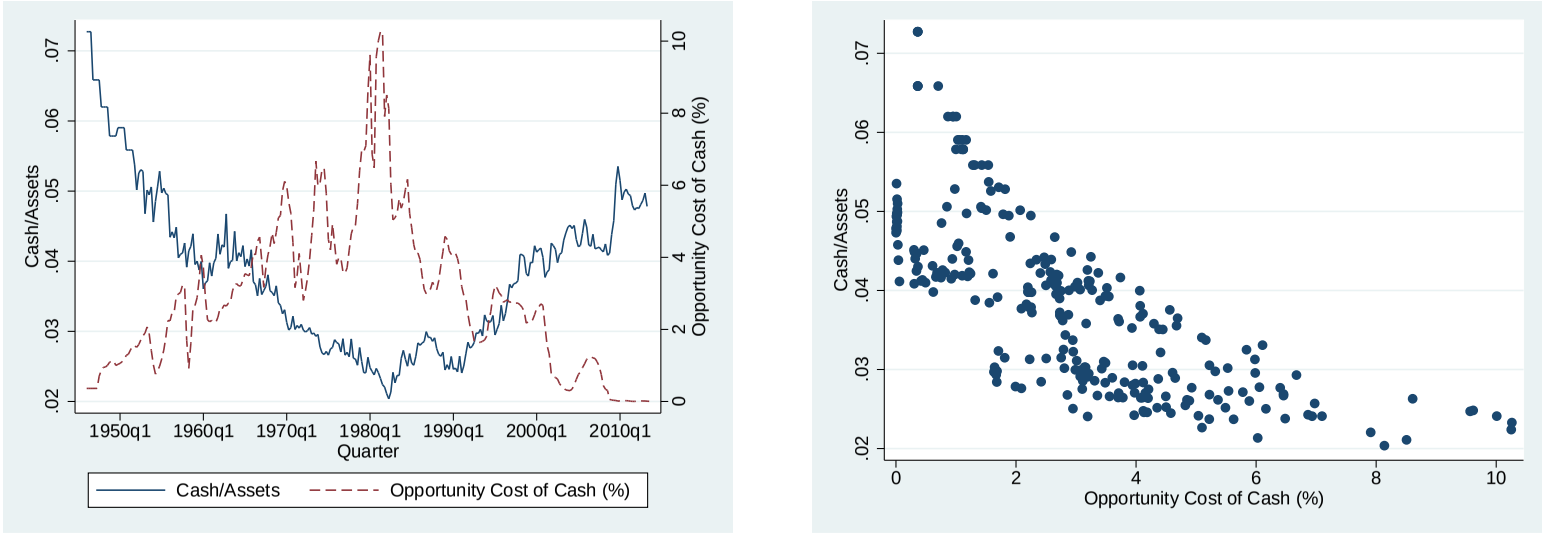


Figure 3: T-Bill return and return of the aggregate corporate liquid asset portfolio.

Data on the components of the nonfinancial corporate sector's liquid assets portfolio is from the Fed Flow of Funds. The T-Bill (from FRED) approximates the cost of capital of the corporate cash portfolio. To approximate the return on the liquid assets portfolio of the nonfinancial corporate sector, we use Fed flow of funds data on the composition of liquid assets to calculate a lagged 10-year average of the share of liquid assets held in currency and checking accounts, assume the currency and checking component of the liquid assets portfolio has a zero nominal return, and proxy for the return on all other components using the nominal three-month T-Bill rate. The wedge between cost and return of the cash portfolio (the difference between the blue and red line in the graph) is the opportunity cost of holding cash.

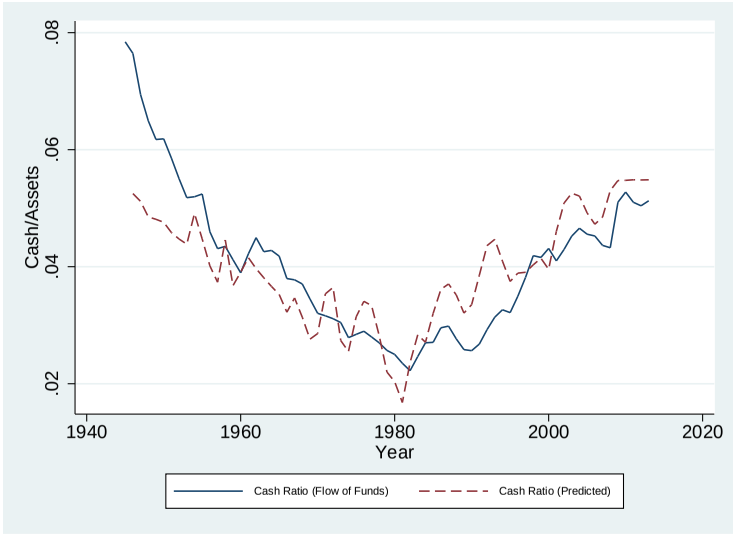


(a) Time series

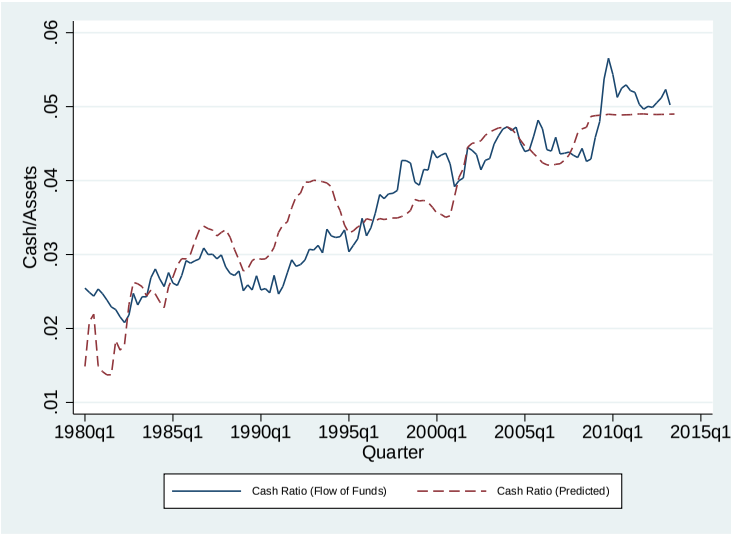
(b) Scatterplot

Figure 4: Cash-to-asset ratio and opportunity costs of cash.

The aggregate cash-to-assets ratio is calculated for the nonfinancial corporate sector using Fed flow of funds data from 1945 to 2013 as the sum of currency and checking deposits, time and savings deposits, money market mutual fund accounts, and mutual fund shares, divided by total assets. The opportunity cost of holding liquid assets is calculated as the spread between the three-month T-Bill rate and the rate of return on the portfolio of liquid assets held by the corporate sector, as explained in the caption of figure 3. Each dot in the scatterplot is the combination of cash-to-asset ratios and average opportunity cost across for a given year using the same data as in the time-series graph.



(a) Predicted versus actual cash holdings 1945-2011



(b) Predicted versus actual cash holdings 1980-2013

Figure 5: Predicted versus actual values of the corporate cash-to-asset ratio.

We calculate the predicted response of corporate cash holdings to variations in opportunity costs using the estimated effect from specification (9) in Table 2, holding all other factors constant. We normalize the predicted series so that its average value in logs is equal to the average value for the actual series, i.e., we predict changes, not the level, of cash holdings. The left panel (1945-2011) uses annual data. The right panel (1980-2013) uses quarterly data.

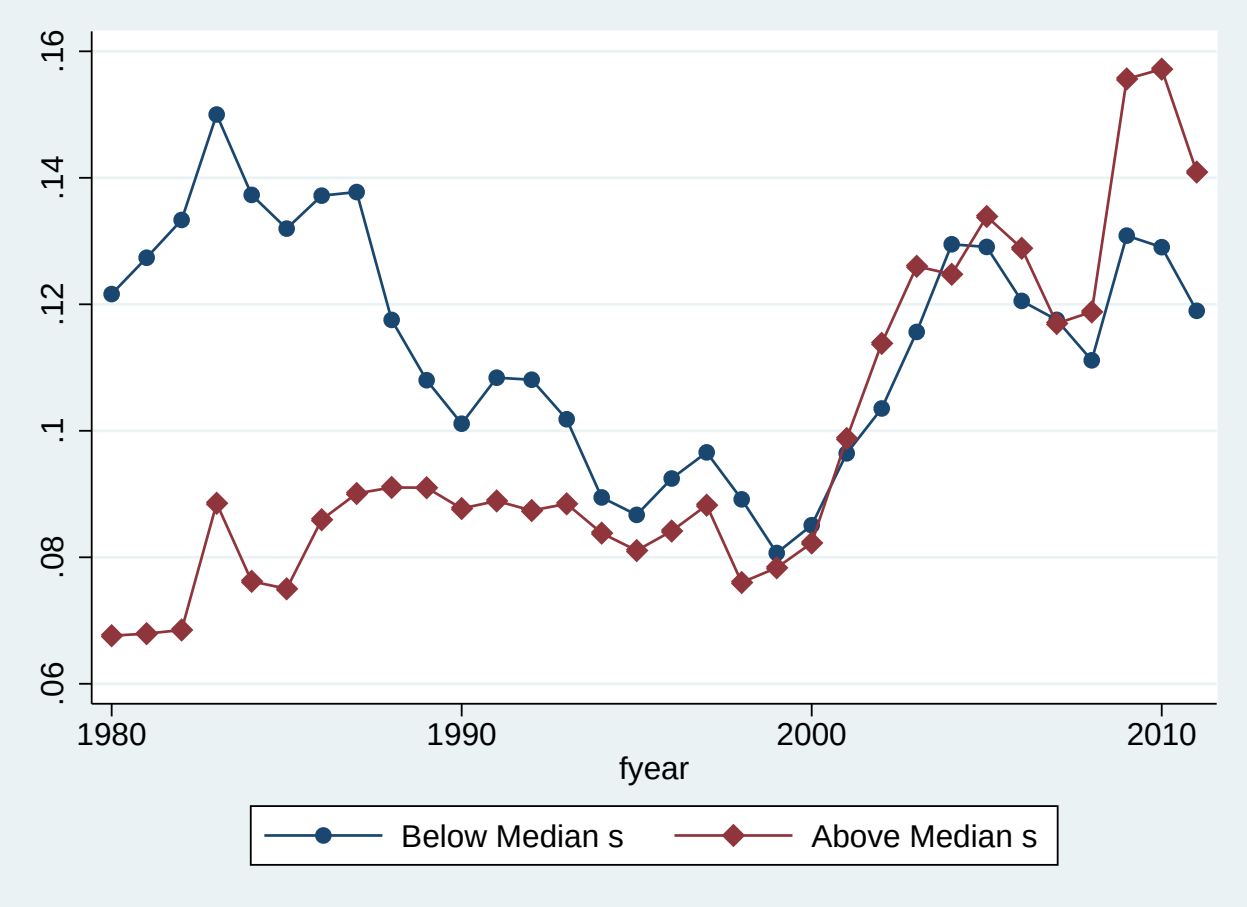


Figure 6: Time-series of actual cash-to-asset ratios of Compustat firms by share of non-interest bearing assets of the cash portfolio in the 1970s ("s").

The red line depicts the average cash-to-asset ratio of firms that on average between 1970 and 1979 held above-median levels of non-interest bearing assets as a fraction of the total liquid asset holdings (Compustat CH/CHE), i.e. most of their liquid assets were invested in currency and checking accounts, but not in savings accounts or other interest-bearing assets. These firms' opportunity cost of holding cash depends strongly on interest rates according to the theory guiding our analysis. The blue line depicts the average cash-to-asset ratio of firms that on average between 1970 and 1979 held below-median levels of non-interest bearing assets as a fraction of the total cash holdings, i.e. they held more of their cash in interest-bearing liquid assets. These firms' opportunity cost of holding cash depends less on interest rates according to our hypothesis. Interest rates decreased by approximately 15% between 1980 and 2011.

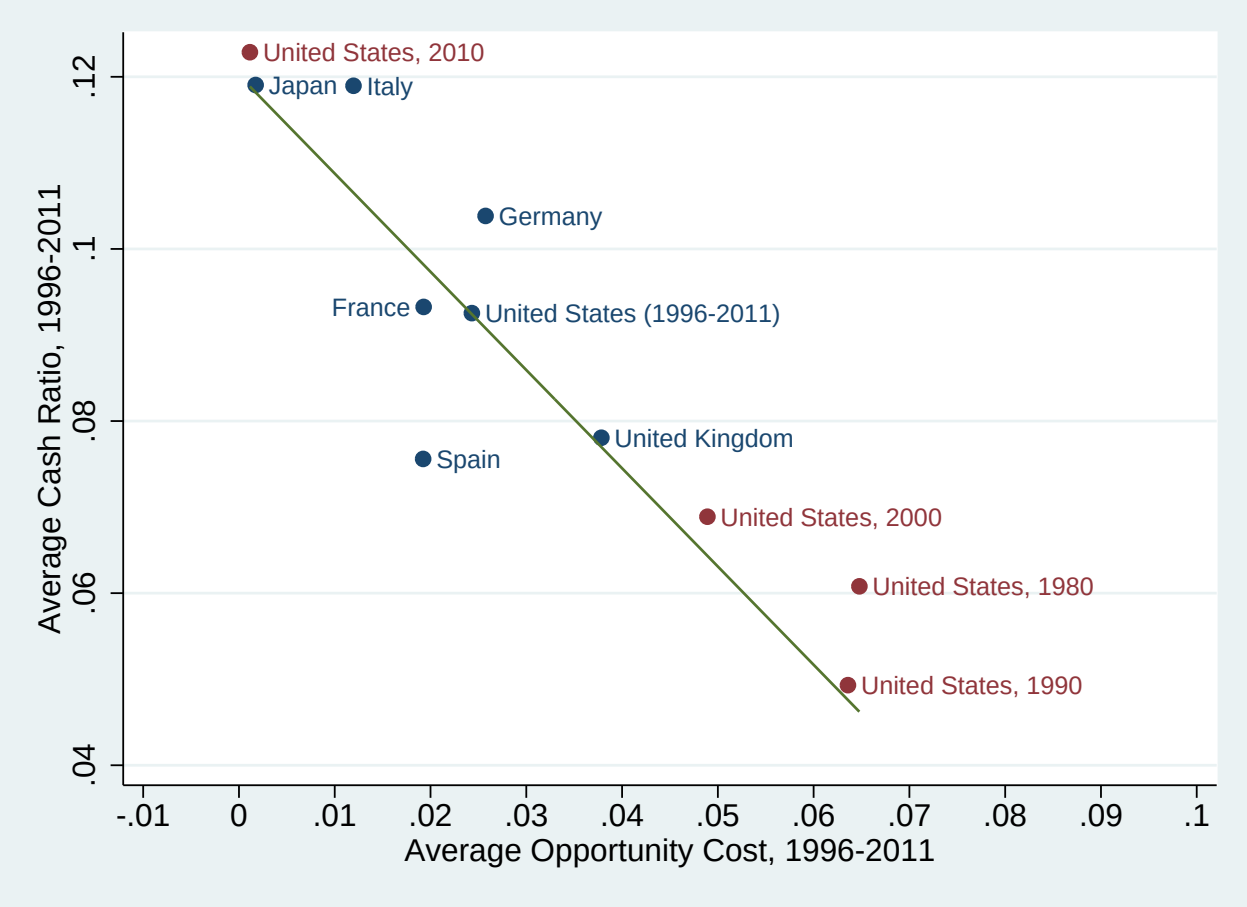


Figure 7: Average cash-to-asset ratio versus average opportunity cost, by country.
The sample includes all Compustat North America and Compustat Global firm-year observations between 1996 and 2011. We exclude from the sample: (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), and (ii) firms with non-positive values for book value of total assets or sales revenue. Firms with less than 10 years of observations are excluded from the sample. We first calculate an asset-weighted average of the cash to assets ratio and of opportunity cost for each country-year. Then we average across years. Opportunity cost is calculated as the country's interest rate times the average fraction of cash that is held in immediately negotiable media of exchange. Interest rate data on three-month interest rates is from FRED. We use treasury bill rates for all countries except Germany, for which we use the 90-day interbank lending rate, because it is available for a longer timer period. The regression line is estimated using only country averages for the period 1996-2011. The U.S. averages for specific years (in red) are given as a reference.

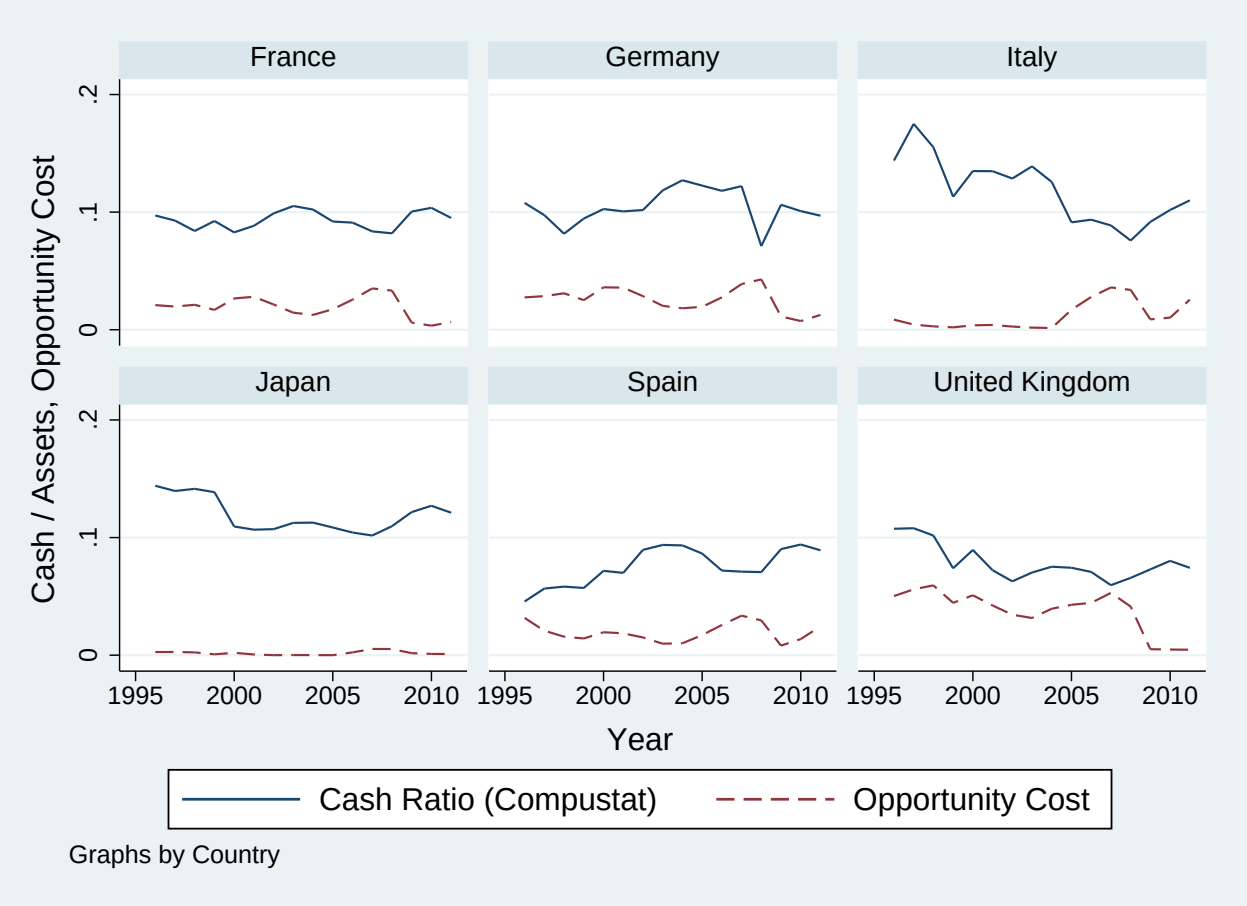


Figure 8: Cash-to-asset ratio and opportunity cost over time, by country.

The sample includes all Compustat North America and Compustat Global firm-year observations between 1996 and 2011. We exclude from the sample: (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), and (ii) firms with non-positive values for book value of total assets or sales revenue. Firms with less than 10 years of observations are excluded from the sample. The cash ratio is calculated as an asset-weighted average of the cash to assets ratio for each country-year. Opportunity cost is calculated as the country's interest rate times the average fraction of cash that is held in immediately negotiable media of exchange. Interest rate data on three-month interest rates is from FRED. We use treasury bill rates for all countries except Germany, for which we use the 90-day interbank lending rate, because it is available for a longer timer period.

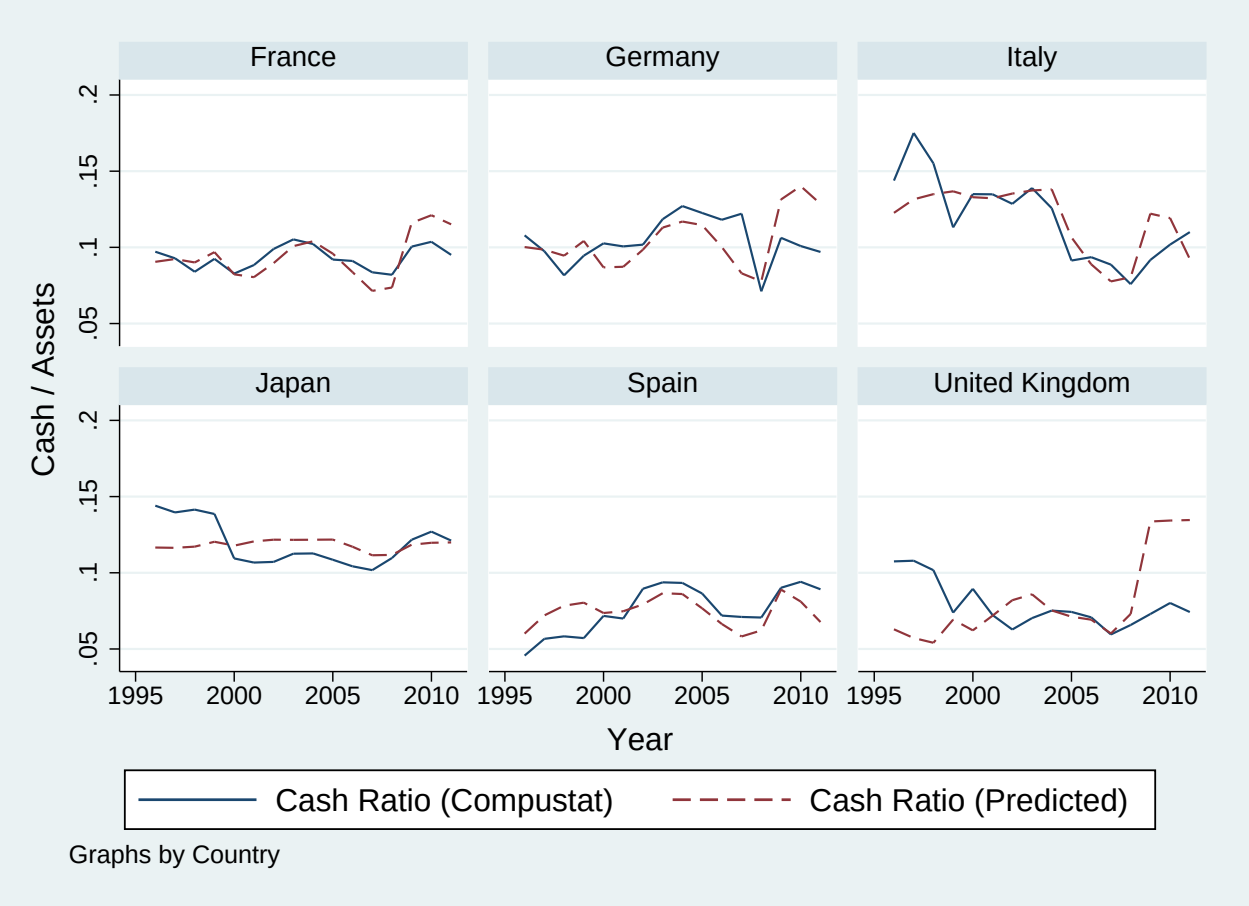


Figure 9: Predicted versus actual cash-to-asset ratio, 1996-2011, by country.

We calculate the predicted response of corporate cash holdings to variations in opportunity costs, holding all other factors constant. The static calculations use the estimated effect from specification (9) in table 5. For each country, we normalize the predicted series so that its average value in logs is equal to the average value for the actual series. That is, we predict changes of cash-to-asset ratios in response to changes in opportunity costs, but not levels of cash-to-asset ratios.

Table 1: Summary statistics for firm-level variables.

The sample includes all Compustat firm-year observations between 1980 and 2011, except (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, and (iii) firms with non-positive values for book value of total assets or sales revenue. Variable definitions are provided in the appendix.

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Cash / Assets	0.178	0.214	0	1	131694
Total Assets (in millions of 2005 USD)	1655	11573	0.004	775485	131694
Industry Sigma	0.083	0.04	0.013	0.207	131651
Cash Flow / Assets	0.003	0.213	-1.021	5.271	123749
NWC / Assets	0.1	0.209	-0.547	0.923	127818
R&D / Sales	0.172	0.723	0	5.350	131694
Dividend Dummy	0.305	0.461	0	1	131694
Market to Book	2.02	1.731	0.122	10.839	130957
Capex	0.069	0.075	0	0.408	130146
Leverage	0.234	0.219	0	1	131239
Acquisition Activity	0.021	0.057	-0.002	0.328	126119

Table 2: Static regressions of firm-level money demand.

The sample includes all Compustat firm-year observations between 1980 and 2011, except (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, (iii) firms with non-positive values for book value of total assets or sales revenue, and (iv) firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Standard errors are two-way clustered by firm and year in specifications (1) to (8). Standard errors are clustered by firm in specifications (9) and (10). Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$
T-Bill	-6.161***	-0.326***	-4.178***	-0.262***						
	(1.807)	(0.0917)	(1.606)	(0.0749)						
Opportunity Cost					-16.12***	-0.952***	-11.77***	-0.661***	-12.41***	-0.603***
					(2.206)	(0.0969)	(2.362)	(0.102)	(1.559)	(0.113)
Log of Real Assets	-0.390***	-0.0377***	-0.281***	-0.0177***	-0.393***	-0.0378***	-0.282***	-0.0177***	-0.358***	-0.0350***
	(0.0663)	(0.0117)	(0.0414)	(0.00317)	(0.0660)	(0.0117)	(0.0415)	(0.00317)	(0.0641)	(0.0128)
Industry Sigma			0.703	0.0266			0.543	0.0172	0.726	0.228
			(0.737)	(0.0530)			(0.723)	(0.0526)	(1.897)	(0.278)
Cash Flow / Assets			0.196	-0.00752			0.190	-0.00787	-0.0814	-0.0448*
			(0.374)	(0.0225)			(0.369)	(0.0222)	(0.301)	(0.0238)
NWC / Assets			-3.197***	-0.260***			-3.156***	-0.258***	-1.586***	-0.130***
			(0.411)	(0.0190)			(0.413)	(0.0191)	(0.384)	(0.0396)
R&D / Sales			0.212***	0.0509***			0.210***	0.0508***	0.229***	0.0445***
			(0.0655)	(0.0101)			(0.0646)	(0.0100)	(0.0642)	(0.0101)
Dividend Dummy			-0.106	-0.00345			-0.104	-0.00335	-0.00349	0.000898
			(0.0805)	(0.00598)			(0.0804)	(0.00600)	(0.0774)	(0.00869)
Market to Book			0.0720***	0.00800***			0.0755***	0.00817***	0.0901***	0.00825***
			(0.0212)	(0.00239)			(0.0210)	(0.00237)	(0.0214)	(0.00268)
Capex			-4.225***	-0.286***			-4.029***	-0.277***	-3.543***	-0.343***
			(0.408)	(0.0275)			(0.389)	(0.0270)	(0.566)	(0.0992)
Leverage			-2.055***	-0.149***			-2.015***	-0.147***	-1.457***	-0.0947***
			(0.246)	(0.0134)			(0.246)	(0.0133)	(0.222)	(0.0225)
Acquisition Activity			-1.012***	-0.106***			-1.017***	-0.107***	-1.112***	-0.113***
			(0.256)	(0.0176)			(0.251)	(0.0173)	(0.235)	(0.0241)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Multiple Imputation									✓	✓
Observations	88,071	88,071	76,062	76,062	88,071	88,071	76,062	76,062	88,071	88,071
R-squared	0.475	0.595	0.464	0.499	0.477	0.596	0.465	0.499		
Number of Firms	5,058	5,058	4,938	4,938	5,058	5,058	4,938	4,938	5,058	5,058

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Dynamic regressions of firm-level money demand.

The sample includes all Compustat firm-year observations between 1980 and 2011, except (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, (iii) firms with non-positive values for book value of total assets or sales revenue, and (iv) firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Standard errors are two-way clustered by firm and year in specifications (1) to (8). Standard errors are clustered by firm in specifications (9) and (10). Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$
T-Bill	-5.340***	-0.266***	-3.970***	-0.213***						
	(1.036)	(0.0729)	(0.884)	(0.0419)						
Opportunity Cost					-11.12***	-0.553***	-8.501***	-0.426***	-8.395***	-0.332***
					(1.545)	(0.119)	(1.313)	(0.0660)	(1.082)	(0.102)
Lagged ln(Cash/Net Assets)	0.600***		0.558***		0.595***		0.554***		0.580***	
	(0.0186)		(0.0115)		(0.0184)		(0.0112)		(0.0186)	
Lagged (Cash/Assets)		0.717***		0.573***		0.715***		0.571***		0.703***
		(0.0624)		(0.0155)		(0.0627)		(0.0154)		(0.0611)
Log of Real Assets	-0.174***	-0.0116***	-0.138***	-0.00795***	-0.178***	-0.0118***	-0.140***	-0.00803***	-0.174***	-0.0120***
	(0.0234)	(0.00164)	(0.0179)	(0.00150)	(0.0237)	(0.00166)	(0.0181)	(0.00151)	(0.0263)	(0.00249)
Industry Sigma			-0.220	-0.0141			-0.337	-0.0203	-0.322	0.0318
			(0.406)	(0.0291)			(0.399)	(0.0291)	(0.811)	(0.0592)
Cash Flow / Assets			0.330	0.0228			0.322	0.0223	0.0962	0.00601
			(0.259)	(0.0163)			(0.255)	(0.0159)	(0.196)	(0.0140)
NWC / Assets			-1.950***	-0.158***			-1.935***	-0.158***	-0.951***	-0.0703***
			(0.235)	(0.0138)			(0.237)	(0.0139)	(0.248)	(0.0215)
R&D / Sales			0.0236	0.00985**			0.0245	0.00996**	0.0279	0.000590
			(0.0433)	(0.00489)			(0.0434)	(0.00492)	(0.0404)	(0.00709)
Dividend Dummy			-0.0237	0.000280			-0.0231	0.000316	0.0295	0.00322
			(0.0491)	(0.00338)			(0.0494)	(0.00340)	(0.0490)	(0.00361)
Market to Book			0.0425***	0.00413***			0.0445***	0.00421***	0.0490***	0.00310*
			(0.0135)	(0.00150)			(0.0134)	(0.00149)	(0.0139)	(0.00176)
Capex			-4.299***	-0.313***			-4.205***	-0.309***	-3.428***	-0.280***
			(0.278)	(0.0210)			(0.267)	(0.0206)	(0.336)	(0.0322)
Leverage			-0.922***	-0.0639***			-0.902***	-0.0629***	-0.631***	-0.0276**
			(0.147)	(0.00720)			(0.146)	(0.00720)	(0.121)	(0.0130)
Acquisition Activity			-2.608***	-0.215***			-2.615***	-0.216***	-2.410***	-0.205***
			(0.211)	(0.0201)			(0.206)	(0.0200)	(0.178)	(0.0156)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Multiple Imputation									✓	✓
Observations	88,071	88,071	76,062	76,062	88,071	88,071	76,062	76,062	88,071	88,071
R-squared	0.475	0.595	0.464	0.499	0.477	0.596	0.465	0.499		
Number of Firms	5,058	5,058	4,938	4,938	5,058	5,058	4,938	4,938	5,058	5,058

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Cross-sectional identification of firm-level money demand.

The sample is constructed as in all previous tables. Specifications (1) through (4) use firms' average fraction of non-interest bearing assets as a share of total liquid assets, s_i, in the 1970s as an instrument. In the difference-in-differences specifications (5) through (8), firms above the median or in the highest quintile by 1970-1979-average s are "treated"; the control groups are assigned symmetrically. "Post" means the year 2011 as compared to the year 1980, i.e. the treatment is the interest rate decrease from 1980-2011. Standard errors are two-way clustered by firm and year. Variable definitions are provided in the appendix.

	Dependent Variable: ln(Cash/Net Assets)							
	(1) IV (1st lag of OC)	(2) IV (10y-avg-lag of OC)	(3) IV (1st lag of OC)	(4) IV (10y-avg-lag of OC)	(5) Diff-in-diff (median)	(6) Diff-in-diff (quintiles)	(7) Diff-in-diff (median)	(8) Diff-in-diff (quintiles)
Firm-Level OC	-17.18***	-14.03***	-12.15***	-9.741***				
	(5.569)		(3.589)					
Above-median $\bar{s}_{1970s}$ × post					0.869***		1.170***	
					(0.206)		(0.192)	
Highest-quintile $\bar{s}_{1970s}$ × post						1.688***		2.264***
						(0.267)		(0.215)
Log of Real Assets	-0.455***	-0.427***	-0.256***	-0.269***	-0.422***	-0.573***	-0.350***	-0.505***
	(0.0999)	(0.0981)	(0.0428)	(0.0433)	(0.0898)	(0.0990)	(0.0614)	(0.0731)
Industry Sigma			0.747	0.701			-0.235	-0.210
			(0.933)	(0.871)			(1.985)	(2.294)
Cash Flow / Assets			0.203	0.0490			2.457*	7.236***
			(0.550)	(0.544)			(1.360)	(1.470)
NWC / Assets			-3.297***	-3.270***			-3.607***	-4.357***
			(0.618)	(0.615)			(0.612)	(0.687)
R&D / Sales			1.202*	1.144*			10.56***	8.326***
			(0.630)	(0.616)			(2.539)	(1.883)
Dividend Dummy			-0.171**	-0.170*			-0.362*	-0.279
			(0.0813)	(0.0872)			(0.189)	(0.194)
Market to Book			0.113**	0.116**			-0.0819	-0.531***
			(0.0480)	(0.0476)			(0.103)	(0.131)
Capex			-5.242***	-5.306***			-5.854***	-6.016***
			(0.551)	(0.528)			(1.248)	(0.966)
Leverage			-2.198***	-2.265***			-1.147**	-0.909*
			(0.232)	(0.227)			(0.459)	(0.474)
Acquisition Activity			-1.715***	-1.627***			0.576	-0.273
			(0.270)	(0.254)			(1.392)	(1.348)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓
Observations	31,315	32,358	27,688	28,603	850	374	686	308
R-squared	0.226	0.214	0.304	0.285	0.255	0.490	0.378	0.591
Number of Firms	1,608	1,609	1,570	1,571	425	187	343	154

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Firm-level money demand estimation for the Top 5 European economies and Japan.

The sample includes all Compustat firm-year observations between 1980 and 2011, except (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, and (iii) firms with non-positive values for book value of total assets or sales revenue. We exclude firms with less than ten periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Standard errors are clustered by firm. Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Dependent Variable: ln(Cash/Net Assets)								
	US	Germany	France	UK	Italy	Spain	Japan	All Countries (Time Trend)	All Countries (Year FE)
Opportunity Cost	-7.685***	-15.95**	-8.707***	-2.300	-5.126	-7.714**	-12.94**	-13.61***	-16.68***
	(1.303)	(6.658)	(2.863)	(2.863)	(6.079)	(3.274)	(5.390)	(1.300)	(1.944)
Log of Real Assets	-0.569***	0.256	-0.260	0.135	0.0650	-0.163	-0.0704	-0.178**	-0.189***
	(0.0565)	(0.167)	(0.252)	(0.0974)	(0.193)	(0.184)	(0.0695)	(0.0714)	(0.0704)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	
Year FE									✓
Observations	40,153	6,635	6,832	12,089	2,151	1,347	36,144	105,351	105,351
R-squared	0.230	0.066	0.058	0.028	0.066	0.155	0.132	0.078	0.086
Number of Firms	2,858	478	496	893	157	93	2,488	7,463	7,463

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

A Apendix: Variable Definitions

A.1 Control variable definitions

Numbers in brackets correspond to the variable numbers in the Compustat database.

- Acquisition Activity: ratio of acquisitions [#129] to total book assets [#6].
- Capex: ratio of capital expenditures [#128] to total book assets [#6].
- Cash/Assets: ratio of cash and short-term investments [#1] to total book assets [#6].
- Cash/Net Assets: ratio of cash and short-term investments [#1] to net assets, where net assets equal total book assets [#6] minus cash holdings [#1].
- Cash Flow/Assets: ratio of operating income before depreciation [#13], after interest [#15], dividends [#21] and taxes [#16] to total book assets [#6].
- Dividend Dummy: indicator variable equal to 1 if a firm paid a common dividend in a given year (i.e., #21 is positive).
- Industry Sigma: volatility of cash flow to assets within the two-digit SIC group of a firm. As in Bates, Kahle, and Stulz (2009), for a given year and two-digit SIC group, we calculate the standard deviation of Cash Flow / Assets over the previous 10 years for each firm within that group. A firm must have at least three observed Cash Flow/Assets over the previous 10 years in order to be counted. Industry Sigma for a two-digit SIC group is the average of the standard deviations of Cash Flow/Assets across all firms in the group.
- Leverage: ratio of the sum of long-term debt [#9] and debt in current liabilities [#34] to total book assets [#6].

- Market to Book: ratio of the market value of the firm to total book asset value [#6]. Market value is proxied as book value of assets [#6] plus market value of equity (equal to the stock price at fiscal year close [#199] times the number of common shares outstanding [#25]) less book value of common equity [#60].

- NWC/Assets: ratio of net working capital, net of cash and short-term investments [#179-#1], to total book assets [#6].

- Opportunity Cost: spread between the T-Bill rate and the return on the nonfinancial corporate sector's liquid assets portfolio. The return on the nonfinancial corporate sector's liquid assets portfolio equals the nominal three-month T-Bill rate times 1 minus the share of liquid assets net of government securities held in currency and checking accounts by the corporate sector. For the time-series identification, in any given year, the share of liquid assets held in currency and checking accounts is calculated as a lagged 10-year average (excluding the current year) of annual ratios of the sector's holding of currency and checking accounts to total liquid assets holdings. Data on the corporate sector's cash holdings are from the Fed Flow of Funds. For the cross-sectional identification, the return on the firm's liquid asset portfolio is the sum of non-interest bearing cash (CH) multiplied with zero return and interest-bearing cash (CHE-CHE) multiplied with the T-Bill rate. In sum, the opportunity cost is the cash held in non-interest bearing cash multiplied with the T-Bill rate.

- R&D / Sales: ratio of R&D expenditures [#46] to sales [#12]. When missing from Compustat, R&D is set equal to 0.

- Real Assets: ratio of total book assets [#6] to the US GDP deflator in the corresponding year (equal to 100 in 2005) divided by 100. The US GDP deflator is obtained from

FRED.

- Total Assets: book value of total assets [#6].

A.2 Compustat definition of the CH and CHE variables

- CH includes
  - 1. Bank drafts
  - 2. Banker's acceptances
  - 3. Cash
  - 4. Certificates of deposit included in cash by the company
  - 5. Checks (cashiers or certified)
  - 6. Demand certificates of deposit
  - 7. Demand deposits
  - 8. Letters of credit
  - 9. Money orders
- CHE includes all items included in CH, plus
  - 1. Accrued interest combined with short-term investments
  - 2. Brokerage firms' good faith and clearing-house deposits
  - 3. Cash in escrow
  - 4. Cash segregated under federal and other regulations
  - 5. Certificates of deposit included in short-term investments by the company

- 6. Certificates of deposit reported as a separate item in current assets
- 7. Commercial paper
- 8. Gas transmission companies' special deposits
- 9. Government and other marketable securities (including stocks and bonds listed as shortterm)
- 10. Margin deposits on commodity futures contracts
- 11. Marketable securities
- 12. Money-market fund
- 13. Repurchase agreements shown as a current asset
- 14. Real estate investment trusts shares of beneficial interest
- 15. Restricted cash shown as a current asset
- 16. Term deposits
- 17. Time deposits and time certificates of deposit (savings accounts shown in current assets)
- 18. Treasury bills listed as short-term

B Appendix: Figures and Tables

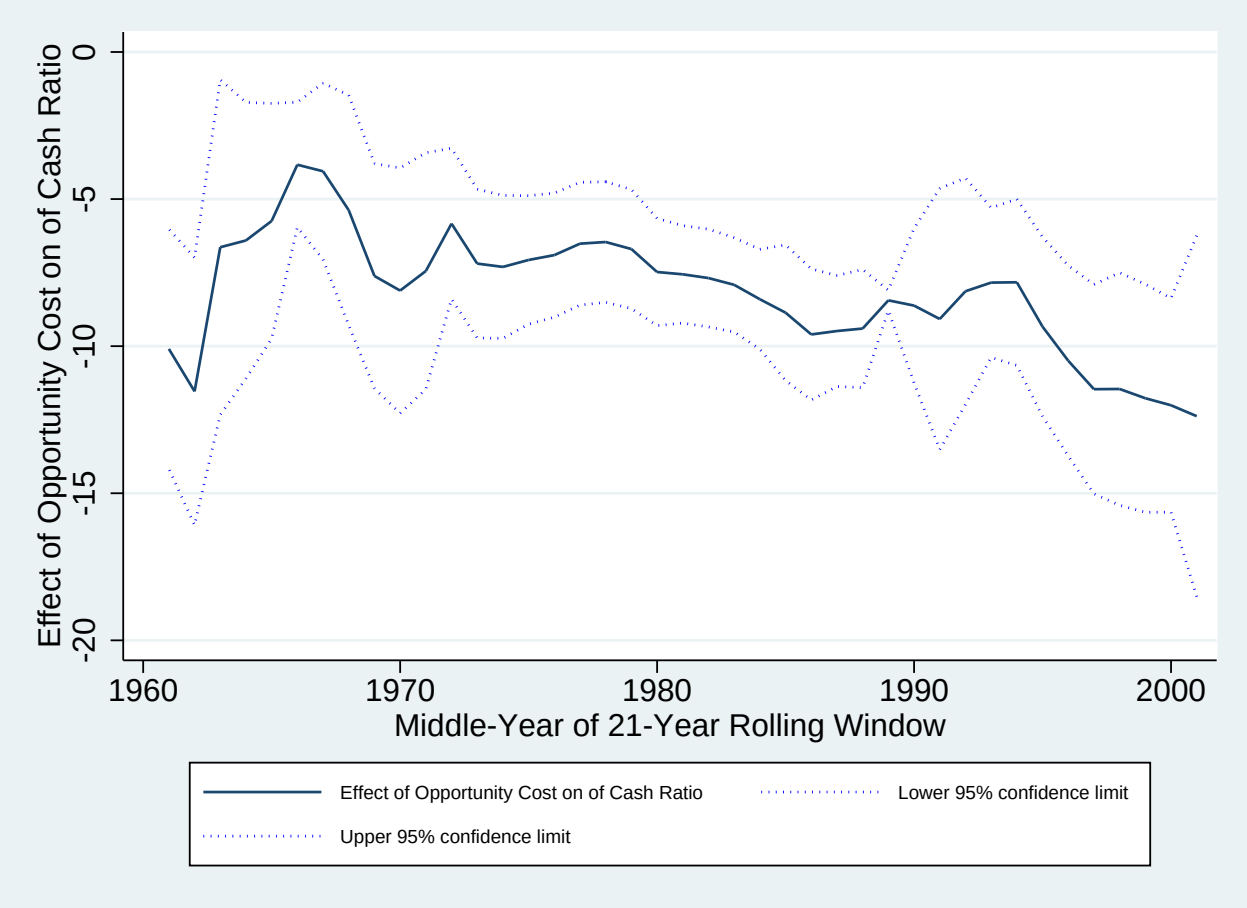
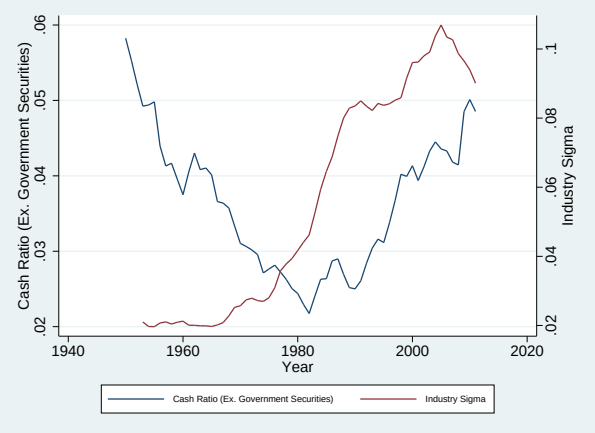
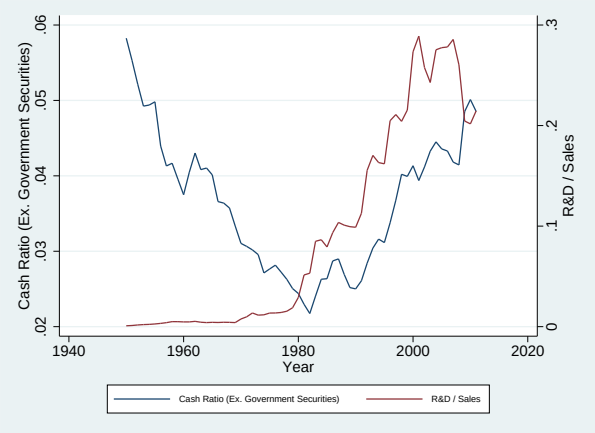


Figure B.1: Rolling Regressions of Firm-Level Money Demand.

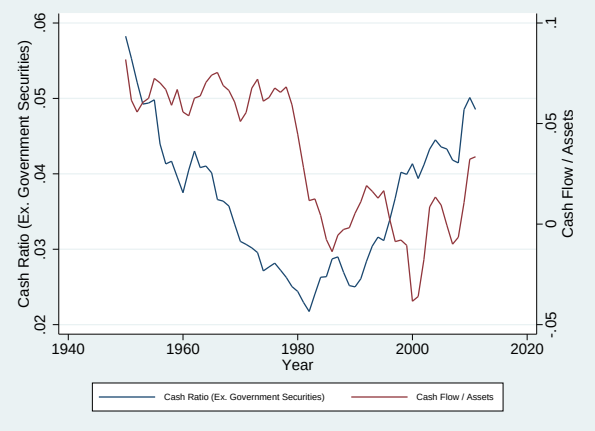
The estimated effects of the opportunity cost on the cash ratio are based on rolling regressions of the log cash ratio as a function of opportunity cost, log of assets, a cubic time trend, and firm fixed effects. The window includes ten years before and ten years after the year indicated in the horizontal axis. Firms with less than 10 observations over the window are excluded. Regressions are estimated by WLS, with firms weighted by average assets multiplied by number of periods with observations. Standard errors are two-way clustered by firm and year.



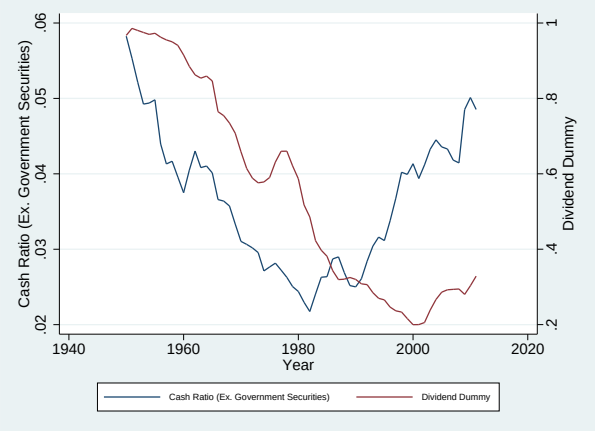
(a) Cash flow volatility



(b) R&D



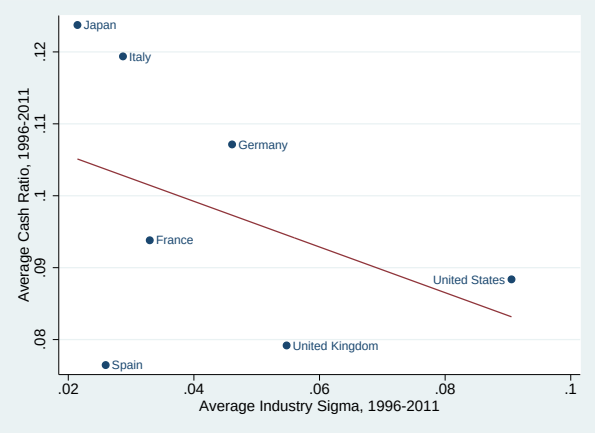
(c) Cash flow / assets



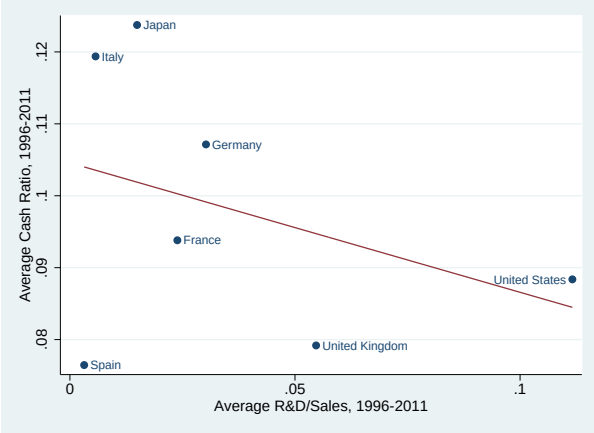
(d) Dividend dummy

Figure B.2: Time-series plots of cash holdings and explanatory papers from the literature, 1950-2013.

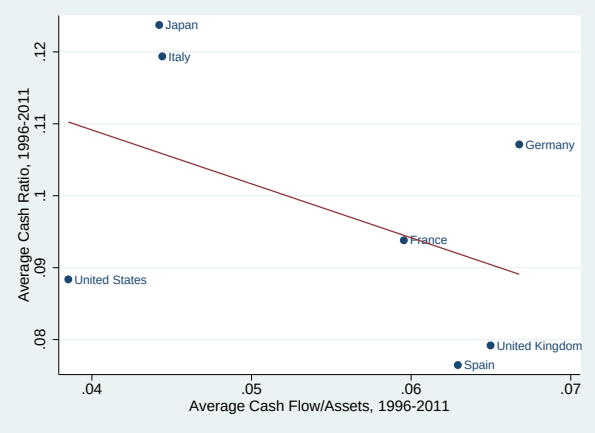
Data comprises all Compustat firms except financials and utilities. All variables are calculated as in Bates, Kahle, and Stulz (2009).



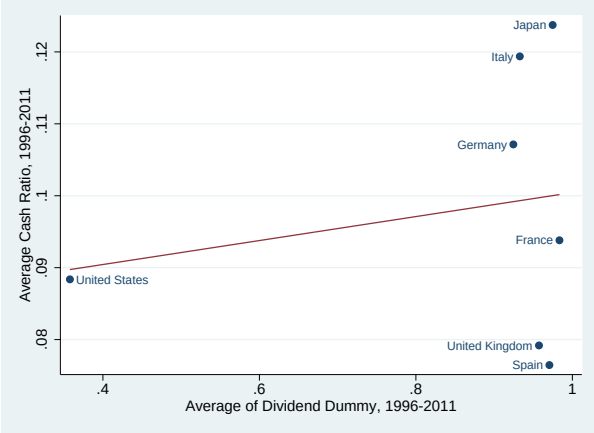
(a) Cash flow volatility



(b) R&D



(c) Cash flow / assets



(d) Dividend dummy

Figure B.3: Scatter plots of cash holdings versus explanatory papers from the literature, average values 1996-2011, by country.

Data comprises all Compustat firms except financials and utilities. All variables are calculated as in Bates, Kahle, and Stulz (2009).

Table B.1: Static Regressions of Firm-Level Money Demand with GDP.

The sample includes all Compustat firm-year observations between 1980 and 2011. We exclude from the sample: (i) financial firms (SIC code 6000- 6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, and (iii) firms with non-positive values for book value of total assets or sales revenue. We exclude firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Standard errors are two-way clustered by firm and year in specifications (1) to (8). Standard errors are clustered by firm in specifications (9) and (10). Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$
T-Bill	-8.354***	-0.480***	-6.095***	-0.364***						
	(1.335)	(0.0396)	(1.278)	(0.0603)						
Opportunity Cost					-16.43***	-0.976***	-11.97***	-0.671***	-12.76***	-0.627***
					(1.895)	(0.0674)	(2.065)	(0.0899)	(1.581)	(0.114)
Log of Real GDP	4.003***	0.281**	3.724***	0.198***	2.415***	0.190*	2.614***	0.131***	2.368***	0.160**
	(1.020)	(0.113)	(0.901)	(0.0497)	(0.881)	(0.103)	(0.813)	(0.0478)	(0.646)	(0.0735)
Log of Real Assets	-0.398***	-0.0382***	-0.287***	-0.0180***	-0.398***	-0.0382***	-0.287***	-0.0179***	-0.363***	-0.0353***
	(0.0668)	(0.0119)	(0.0418)	(0.00320)	(0.0666)	(0.0119)	(0.0419)	(0.00320)	(0.0649)	(0.0129)
Industry Sigma			0.317	0.00609			0.251	0.00256	0.432	0.208
			(0.715)	(0.0539)			(0.711)	(0.0534)	(1.878)	(0.272)
Cash Flow / Assets			0.163	-0.00923			0.165	-0.00913	-0.0778	-0.0446*
			(0.364)	(0.0219)			(0.363)	(0.0217)	(0.295)	(0.0235)
NWC / Assets			-3.179***	-0.259***			-3.152***	-0.257***	-1.586***	-0.130***
			(0.409)	(0.0190)			(0.410)	(0.0191)	(0.383)	(0.0398)
R&D / Sales			0.211***	0.0508***			0.209***	0.0507***	0.231***	0.0446***
			(0.0651)	(0.0102)			(0.0646)	(0.0101)	(0.0649)	(0.0101)
Dividend Dummy			-0.106	-0.00346			-0.104	-0.00337	-0.00601	0.000727
			(0.0796)	(0.00589)			(0.0800)	(0.00595)	(0.0768)	(0.00869)
Market to Book			0.0750***	0.00816***			0.0766***	0.00823***	0.0902***	0.00826***
			(0.0208)	(0.00239)			(0.0206)	(0.00236)	(0.0212)	(0.00266)
Capex			-4.120***	-0.281***			-4.016***	-0.276***	-3.534***	-0.342***
			(0.405)	(0.0277)			(0.390)	(0.0274)	(0.562)	(0.0991)
Leverage			-2.047***	-0.149***			-2.013***	-0.147***	-1.458***	-0.0947***
			(0.249)	(0.0135)			(0.247)	(0.0133)	(0.224)	(0.0226)
Acquisition Activity			-1.097***	-0.111***			-1.093***	-0.111***	-1.182***	-0.118***
			(0.254)	(0.0173)			(0.253)	(0.0173)	(0.238)	(0.0248)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Multiple Imputation									✓	✓
Observations	92,206	92,206	79,624	79,624	92,206	92,206	79,624	79,624	92,206	92,206
R-squared	0.174	0.139	0.208	0.209	0.178	0.141	0.210	0.210		
Number of Firms	5,058	5,058	4,949	4,949	5,058	5,058	4,949	4,949	5,058	5,058

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table B.2: Dynamic Regressions of Firm-Level Money Demand with GDP.

The sample includes all Compustat firm-year observations between 1980 and 2011. We exclude from the sample: (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900- 4999), (ii) firms not incorporated in the United States, and (iii) firms with non-positive values for book value of total assets or sales revenue. We exclude firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Standard errors are two-way clustered by firm and year in specifications (1) to (8). Standard errors are clustered by firm in specifications (9) and (10). Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$
T-Bill	-5.681***	-0.271***	-4.407***	-0.225***						
	(0.912)	(0.0642)	(0.831)	(0.0393)						
Opportunity Cost					-11.04***	-0.546***	-8.505***	-0.424***	-8.373***	-0.328***
					(1.540)	(0.118)	(1.304)	(0.0660)	(1.073)	(0.1000)
Lagged ln(Cash/Net Assets)	0.598***		0.555***		0.596***		0.554***		0.581***	
	(0.0190)		(0.0117)		(0.0187)		(0.0116)		(0.0182)	
Lagged (Cash/Assets)		0.717***		0.572***		0.716***		0.572***		0.703***
		(0.0621)		(0.0155)		(0.0621)		(0.0154)		(0.0606)
Log of Real GDP	0.615	0.00804	0.843	0.0216	-0.458	-0.0429	0.0421	-0.0195	-0.125	-0.0250
	(0.768)	(0.0557)	(0.676)	(0.0343)	(0.707)	(0.0551)	(0.613)	(0.0334)	(0.423)	(0.0312)
Log of Real Assets	-0.176***	-0.0116***	-0.140***	-0.00800***	-0.177***	-0.0116***	-0.140***	-0.00799***	-0.173***	-0.0119***
	(0.0242)	(0.00172)	(0.0182)	(0.00151)	(0.0242)	(0.00173)	(0.0183)	(0.00152)	(0.0266)	(0.00253)
Industry Sigma			-0.300	-0.0162			-0.342	-0.0183	-0.308	0.0347
			(0.387)	(0.0292)			(0.389)	(0.0294)	(0.793)	(0.0568)
Cash Flow / Assets			0.322	0.0226			0.322	0.0226	0.0962	0.00602
			(0.258)	(0.0161)			(0.255)	(0.0159)	(0.196)	(0.0141)
NWC / Assets			-1.951***	-0.158***			-1.936***	-0.158***	-0.951***	-0.0702***
			(0.236)	(0.0138)			(0.237)	(0.0139)	(0.248)	(0.0215)
R&D / Sales			0.0237	0.00989**			0.0245	0.00993**	0.0278	0.000543
			(0.0435)	(0.00491)			(0.0435)	(0.00491)	(0.0404)	(0.00704)
Dividend Dummy			-0.0242	0.000270			-0.0231	0.000329	0.0296	0.00324
			(0.0490)	(0.00337)			(0.0496)	(0.00341)	(0.0490)	(0.00360)
Market to Book			0.0433***	0.00415***			0.0445***	0.00420***	0.0490***	0.00310*
			(0.0136)	(0.00151)			(0.0134)	(0.00149)	(0.0139)	(0.00176)
Capex			-4.276***	-0.312***			-4.204***	-0.309***	-3.429***	-0.280***
			(0.285)	(0.0213)			(0.267)	(0.0206)	(0.336)	(0.0321)
Leverage			-0.925***	-0.0639***			-0.902***	-0.0628***	-0.630***	-0.0276**
			(0.148)	(0.00725)			(0.147)	(0.00719)	(0.121)	(0.0129)
Acquisition Activity			-2.620***	-0.215***			-2.615***	-0.215***	-2.407***	-0.204***
			(0.206)	(0.0200)			(0.205)	(0.0200)	(0.181)	(0.0159)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Multiple Imputation									✓	✓
Observations	88,071	88,071	76,062	76,062	88,071	88,071	76,062	76,062	88,071	88,071
R-squared	0.475	0.595	0.464	0.499	0.477	0.596	0.465	0.499		
Number of Firms	5,058	5,058	4,938	4,938	5,058	5,058	4,938	4,938	5,058	5,058

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table B.3: Static Regressions with AA Commercial Paper Replacing T-Bill as Capital Cost of Cash.

These regressions correspond to Table 2, except that AA commercial paper for nonfinancial corporations from FRED between 1997 and 2013, the AA commercial paper rate from FRED between 1971 and 1997, and the commercial paper rate for the U.S. from the NBER Macrohistory database (XIII: Interest Rates) for all years before 1971 is used as a proxy for the cost of capital of cash. The sample includes all Compustat firm-year observations between 1980 and 2011. We exclude from the sample: (i) financial firms (SIC code 6000- 6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, and (iii) firms with non-positive values for book value of total assets or sales revenue. We exclude firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Standard errors are two-way clustered by firm and year in specifications (1) to (8). Standard errors are clustered by firm in specifications (9) and (10). Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$
AA Commercial Paper Rate	-5.822***	-0.316***	-3.880***	-0.246***						
	(1.596)	(0.0800)	(1.457)	(0.0674)						
Opportunity Cost					-13.54***	-0.810***	-9.557***	-0.553***	-10.14***	-0.505***
					(1.927)	(0.0714)	(2.111)	(0.0921)	(1.342)	(0.0942)
Log of Real Assets	-0.390***	-0.0377***	-0.281***	-0.0177***	-0.392***	-0.0378***	-0.282***	-0.0177***	-0.358***	-0.0350***
	(0.0663)	(0.0117)	(0.0415)	(0.00318)	(0.0661)	(0.0117)	(0.0417)	(0.00318)	(0.0641)	(0.0128)
Industry Sigma			0.709	0.0270			0.586	0.0196	0.777	0.231
			(0.738)	(0.0530)			(0.726)	(0.0526)	(1.898)	(0.278)
Cash Flow / Assets			0.196	-0.00748			0.193	-0.00773	-0.0890	-0.0452*
			(0.374)	(0.0224)			(0.370)	(0.0220)	(0.303)	(0.0239)
NWC / Assets			-3.193***	-0.259***			-3.154***	-0.257***	-1.584***	-0.130***
			(0.411)	(0.0190)			(0.413)	(0.0191)	(0.383)	(0.0396)
R&D / Sales			0.212***	0.0509***			0.208***	0.0507***	0.226***	0.0444***
			(0.0653)	(0.0101)			(0.0646)	(0.00996)	(0.0642)	(0.0101)
Dividend Dummy			-0.105	-0.00343			-0.103	-0.00333	-0.00392	0.000879
			(0.0803)	(0.00596)			(0.0799)	(0.00596)	(0.0768)	(0.00867)
Market to Book			0.0718***	0.00799***			0.0744***	0.00812***	0.0896***	0.00824***
			(0.0211)	(0.00239)			(0.0209)	(0.00236)	(0.0214)	(0.00269)
Capex			-4.209***	-0.285***			-4.032***	-0.276***	-3.547***	-0.342***
			(0.407)	(0.0275)			(0.391)	(0.0270)	(0.567)	(0.0995)
Leverage			-2.049***	-0.149***			-2.007***	-0.147***	-1.448***	-0.0942***
			(0.246)	(0.0133)			(0.245)	(0.0132)	(0.222)	(0.0224)
Acquisition Activity			-1.014***	-0.106***			-1.022***	-0.107***	-1.113***	-0.114***
			(0.255)	(0.0175)			(0.251)	(0.0172)	(0.236)	(0.0241)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Multiple Imputation									✓	✓
Observations	92,206	92,206	79,624	79,624	92,206	92,206	79,624	79,624	92,206	92,206
R-squared	0.168	0.134	0.202	0.206	0.175	0.139	0.206	0.208		
Number of Firms	5,058	5,058	4,949	4,949	5,058	5,058	4,949	4,949	5,058	5,058

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table B.4: Dynamic Regressions with AA Commercial Paper Replacing T-Bill as Capital Cost of Cash.

These regressions correspond to Table 3, except that AA commercial paper for nonfinancial corporations from FRED between 1997 and 2013, the AA commercial paper rate from FRED between 1971 and 1997, and the commercial paper rate for the U.S. from the NBER Macrohistory database (XIII: Interest Rates) for all years before 1971 is used as a proxy for the cost of capital of cash. The sample includes all Compustat firm-year observations between 1980 and 2011. We exclude from the sample: (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900- 4999), (ii) firms not incorporated in the United States, and (iii) firms with non-positive values for book value of total assets or sales revenue. We exclude firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Standard errors are two-way clustered by firm and year in specifications (1) to (8). Standard errors are clustered by firm in specifications (9) and (10). Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$	$\ln(\frac{Cash}{NetAssets})$	$\frac{Cash}{Assets}$
AA Commercial Paper Rate	-5.027***	-0.260***	-3.722***	-0.206***						
	(0.954)	(0.0707)	(0.823)	(0.0404)						
Opportunity Cost					-9.660***	-0.506***	-7.282***	-0.386***	-7.226***	-0.316***
					(1.395)	(0.116)	(1.154)	(0.0593)	(0.989)	(0.0941)
Lagged ln(Cash/Net Assets)	0.600***		0.558***		0.595***		0.555***		0.581***	
	(0.0186)		(0.0115)		(0.0184)		(0.0114)		(0.0186)	
Lagged (Cash/Assets)		0.717***		0.573***		0.715***		0.571***		0.703***
		(0.0624)		(0.0154)		(0.0627)		(0.0154)		(0.0610)
Log of Real Assets	-0.174***	-0.0116***	-0.138***	-0.00794***	-0.178***	-0.0117***	-0.140***	-0.00802***	-0.173***	-0.0120***
	(0.0234)	(0.00164)	(0.0180)	(0.00151)	(0.0237)	(0.00166)	(0.0183)	(0.00152)	(0.0263)	(0.00249)
Industry Sigma			-0.214	-0.0137			-0.310	-0.0190	-0.293	0.0327
			(0.407)	(0.0290)			(0.402)	(0.0290)	(0.811)	(0.0591)
Cash Flow / Assets			0.331	0.0229			0.325	0.0225	0.0915	0.00580
			(0.258)	(0.0161)			(0.254)	(0.0157)	(0.196)	(0.0141)
NWC / Assets			-1.945***	-0.158***			-1.929***	-0.157***	-0.947***	-0.0700***
			(0.235)	(0.0138)			(0.237)	(0.0139)	(0.247)	(0.0215)
R&D / Sales			0.0234	0.00983**			0.0239	0.00992**	0.0268	0.000543
			(0.0435)	(0.00489)			(0.0437)	(0.00493)	(0.0405)	(0.00709)
Dividend Dummy			-0.0234	0.000297			-0.0227	0.000342	0.0290	0.00321
			(0.0489)	(0.00337)			(0.0490)	(0.00338)	(0.0483)	(0.00359)
Market to Book			0.0424***	0.00413***			0.0439***	0.00420***	0.0490***	0.00313*
			(0.0135)	(0.00150)			(0.0133)	(0.00148)	(0.0138)	(0.00175)
Capex			-4.282***	-0.311***			-4.189***	-0.307***	-3.418***	-0.278***
			(0.275)	(0.0208)			(0.266)	(0.0203)	(0.336)	(0.0323)
Leverage			-0.915***	-0.0635***			-0.893***	-0.0623***	-0.622***	-0.0271**
			(0.147)	(0.00716)			(0.146)	(0.00714)	(0.121)	(0.0129)
Acquisition Activity			-2.610***	-0.215***			-2.618***	-0.216***	-2.411***	-0.205***
			(0.210)	(0.0200)			(0.204)	(0.0199)	(0.177)	(0.0156)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Multiple Imputation									✓	✓
Observations	88,071	88,071	76,062	76,062	88,071	88,071	76,062	76,062	88,071	88,071
R-squared	0.476	0.596	0.464	0.499	0.477	0.596	0.465	0.499		
Number of Firms	5,058	5,058	4,938	4,938	5,058	5,058	4,938	4,938	5,058	5,058

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table B.5: Firm-level money demand for different groups of firms defined by the level of control variables.

The sample includes all Compustat firm-year observations between 1980 and 2011, except (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, (iii) firms with non-positive values for book value of total assets or sales revenue, and (iv) firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Specifications labeled below median include only firms whose average value between 1980 and 2011 for the variable specified above is below the median of the average value across the firms in the sample. Above median indicates the average value for the variable is above the median. Standard errors are two-way clustered by firm and year. Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Dependent Variable: ln(Cash/Net Assets)									
	Log Real Assets		Industry Sigma		Cash Flow / Assets		NWC / Assets		R&D / Sales	
	Below Median	Above Median	Below Median	Above Median	Below Median	Above Median	Below Median	Above Median	Below Median	Above Median
Opportunity Cost	-6.094***	-11.81***	-11.90***	-10.85***	-12.68***	-10.89***	-11.32***	-13.36***	-12.45***	-10.01***
	(1.665)	(2.384)	(2.970)	(1.941)	(2.251)	(2.584)	(2.362)	(3.210)	(3.004)	(2.398)
Log of Real Assets	0.0524	-0.287***	-0.313***	-0.224***	-0.285***	-0.281***	-0.293***	-0.249***	-0.253***	-0.297***
	(0.0321)	(0.0423)	(0.0628)	(0.0417)	(0.0835)	(0.0388)	(0.0490)	(0.0552)	(0.0579)	(0.0476)
Industry Sigma	3.119***	0.504	0.711	0.471	-0.350	0.603	0.794	-0.427	1.327	0.464
	(1.004)	(0.728)	(3.025)	(0.868)	(1.277)	(0.934)	(0.844)	(1.610)	(0.810)	(1.083)
Cash Flow / Assets	0.238	0.114	0.608	-0.187	0.147	0.315	0.255	0.0510	-0.438	0.634
	(0.147)	(0.403)	(0.705)	(0.295)	(0.267)	(0.680)	(0.438)	(0.359)	(0.436)	(0.479)
NWC / Assets	-2.305***	-3.220***	-3.539***	-2.559***	-2.887***	-3.314***	-3.251***	-2.874***	-3.508***	-2.981***
	(0.153)	(0.431)	(0.655)	(0.303)	(0.348)	(0.557)	(0.642)	(0.280)	(0.696)	(0.487)
R&D / Sales	0.199***	0.212***	0.551	0.187***	0.174***	0.382	0.201***	0.475**	-58.25***	0.254***
	(0.0294)	(0.0786)	(0.361)	(0.0566)	(0.0603)	(0.255)	(0.0723)	(0.194)	(17.17)	(0.0692)
Dividend Dummy	0.144*	-0.106	-0.128	-0.101	-0.0439	-0.154	-0.0949	-0.123	-0.150	-0.0779
	(0.0771)	(0.0817)	(0.112)	(0.0937)	(0.122)	(0.0971)	(0.101)	(0.0961)	(0.103)	(0.119)
Market to Book	0.0912***	0.0767***	0.0982*	0.0638***	0.144***	0.0674***	0.0734***	0.0798***	0.120***	0.0601***
	(0.0122)	(0.0218)	(0.0538)	(0.0193)	(0.0359)	(0.0226)	(0.0269)	(0.0261)	(0.0417)	(0.0222)
Capex	-2.217***	-4.080***	-4.732***	-3.293***	-3.149***	-4.389***	-4.148***	-4.032***	-2.975***	-5.862***
	(0.239)	(0.402)	(0.643)	(0.384)	(0.709)	(0.501)	(0.468)	(0.802)	(0.478)	(0.747)
Leverage	-3.218***	-1.996***	-1.998***	-2.072***	-1.855***	-2.139***	-1.933***	-2.277***	-1.673***	-2.497***
	(0.158)	(0.251)	(0.342)	(0.215)	(0.384)	(0.266)	(0.297)	(0.220)	(0.310)	(0.318)
Acquisition Activity	-1.524***	-1.023***	-0.694**	-1.547***	-0.198	-1.383***	-0.834***	-1.676***	-0.529	-1.432***
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	36,931	42,693	40,514	39,110	35,435	44,189	36,514	43,110	39,754	39,870
R-squared	0.202	0.209	0.214	0.205	0.208	0.213	0.200	0.235	0.191	0.247
Number of Firms	2,492	2,457	2,464	2,485	2,456	2,493	2,471	2,478	2,442	2,507

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table B.5: Firm-level money demand for different groups of firms defined by the level of control variables (continued).

The sample includes all Compustat firm-year observations between 1980 and 2011, except (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, (iii) firms with non-positive values for book value of total assets or sales revenue, and (iv) firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Specifications labeled below median include only firms whose average value between 1980 and 2011 for the variable specified above is below the median of the average value across the firms in the sample. Above median indicates the average value for the variable is above the median. Standard errors are two-way clustered by firm and year. Variable definitions are provided in the appendix.

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
	Dependent Variable: ln(Cash/Net Assets)									
	Dividends		Market to Book		Capex		Leverage		Acquisition Activity	
	Below Median	Above Median	Below Median	Above Median	Below Median	Above Median	Below Median	Above Median	Below Median	Above Median
Opportunity Cost	-9.939***	-11.59***	-12.94***	-9.773***	-10.65***	-12.16***	-9.902***	-12.39***	-14.77***	-8.755***
	(3.029)	(2.416)	(3.004)	(1.791)	(2.452)	(2.923)	(1.261)	(2.989)	(2.876)	(2.492)
Log of Real Assets	-0.206***	-0.315***	-0.303***	-0.268***	-0.416***	-0.204***	-0.208***	-0.322***	-0.191***	-0.336***
	(0.0320)	(0.0471)	(0.0675)	(0.0461)	(0.0636)	(0.0419)	(0.0506)	(0.0579)	(0.0504)	(0.0592)
Industry Sigma	0.634	0.433	1.028	-0.680	-0.933	1.067	1.432	0.00132	0.581	0.804
	(1.136)	(0.810)	(0.942)	(1.150)	(1.076)	(0.967)	(0.972)	(0.899)	(1.059)	(0.988)
Cash Flow / Assets	0.265	0.127	0.299	-0.0143	-0.178	0.553	0.814	-0.0902	1.309*	-0.681*
	(0.219)	(0.468)	(0.541)	(0.442)	(0.342)	(0.594)	(0.579)	(0.447)	(0.699)	(0.403)
NWC / Assets	-2.395***	-3.358***	-2.848***	-3.323***	-3.128***	-3.059***	-2.872***	-3.301***	-3.592***	-2.712***
	(0.228)	(0.485)	(0.338)	(0.653)	(0.337)	(0.667)	(0.371)	(0.633)	(0.674)	(0.421)
R&D / Sales	0.228***	0.879*	0.564	0.165**	0.0702	0.451***	0.292***	0.218**	0.317***	0.152
	(0.0468)	(0.504)	(1.094)	(0.0733)	(0.0660)	(0.144)	(0.0934)	(0.0917)	(0.0818)	(0.118)
Dividend Dummy	0.825**	-0.109	-0.211**	0.0328	0.0647	-0.246**	-0.0355	-0.149	-0.171	-0.0903
	(0.403)	(0.0826)	(0.0983)	(0.0962)	(0.107)	(0.0970)	(0.0956)	(0.0981)	(0.124)	(0.0908)
Market to Book	0.0463	0.0838***	0.245***	0.0520***	0.0610**	0.0797***	0.0624***	0.0578	0.0519*	0.0954***
	(0.0318)	(0.0277)	(0.0813)	(0.0193)	(0.0309)	(0.0275)	(0.0187)	(0.0507)	(0.0299)	(0.0269)
Capex	-1.185***	-4.705***	-4.291***	-3.517***	-4.293***	-4.054***	-4.426***	-3.661***	-4.193***	-3.766***
	(0.361)	(0.459)	(0.514)	(0.494)	(1.266)	(0.441)	(0.721)	(0.456)	(0.565)	(0.624)
Leverage	-1.616***	-2.085***	-1.822***	-2.269***	-2.126***	-1.944***	-3.059***	-1.731***	-1.916***	-2.020***
	(0.213)	(0.271)	(0.350)	(0.276)	(0.373)	(0.266)	(0.332)	(0.289)	(0.354)	(0.305)
Acquisition Activity	-1.192***	-1.021***	-1.041***	-1.083***	-0.772***	-1.323***	-1.866***	-0.630**	-1.625**	-0.918***
	(0.287)	(0.264)	(0.301)	(0.375)	(0.281)	(0.273)	(0.369)	(0.266)	(0.787)	(0.222)
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	34,706	44,918	41,945	37,679	38,146	41,478	38,811	40,813	38,687	40,937
R-squared	0.169	0.218	0.208	0.223	0.253	0.196	0.274	0.193	0.227	0.203
Number of Firms	2,477	2,472	2,454	2,495	2,460	2,489	2,492	2,457	2,457	2,492

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table B.6: Firm-level money demand by SIC industry definition.

The sample includes all Compustat firm-year observations between 1980 and 2011, except (i) financial firms (SIC code 6000-6999) and utilities (SIC codes 4900-4999), (ii) firms not incorporated in the United States, (iii) firms with non-positive values for book value of total assets or sales revenue, and (iv) firms with less than 10 periods of observations. Observations are weighted by average real assets over time multiplied by the number of periods with observations. Standard errors are two-way clustered by firm and year. Variable definitions are provided in the appendix.

	(1)	(2)	(3)	(4)
	Dependent Variable: ln(Cash/Net Assets)			
	Manufacturing	Services	Retail Trade	All Others
Opportunity Cost	-9.746***	-10.63***	-19.48***	-13.48***
	(2.290)	(1.644)	(4.258)	(5.107)
Log of Real Assets	-0.269***	-0.176***	-0.409***	-0.296***
	(0.0539)	(0.0550)	(0.0720)	(0.0820)
Industry Sigma	-0.0730	3.042*	-2.480	1.475
	(1.143)	(1.764)	(5.452)	(1.059)
Cash Flow / Assets	0.353	-0.288	-2.124***	0.552
	(0.459)	(0.374)	(0.651)	(0.887)
NWC / Assets	-2.816***	-3.623***	-4.777***	-2.358***
	(0.456)	(0.434)	(1.216)	(0.367)
R&D / Sales	0.230***	0.222*	0.534*	0.565
	(0.0659)	(0.117)	(0.308)	(0.441)
Dividend Dummy	0.000472	-0.126	0.0969	-0.305*
	(0.118)	(0.121)	(0.168)	(0.157)
Market to Book	0.0860***	0.0694***	0.00352	0.223***
	(0.0256)	(0.0209)	(0.0155)	(0.0860)
Capex	-5.351***	-2.453***	-4.733***	-3.494***
	(0.617)	(0.677)	(1.472)	(0.674)
Leverage	-2.619***	-1.633***	-1.214***	-1.311***
	(0.320)	(0.274)	(0.348)	(0.498)
Acquisition Activity	-1.083***	-1.793***	-2.541**	-0.503
	(0.250)	(0.291)	(1.163)	(0.477)
Firm FE	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓
Observations	45,009	13,197	7,051	14,367
R-squared	0.234	0.272	0.353	0.155
Number of Firms	2,646	972	427	904

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.