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? A large literature has evolved around this question, involving corporate finance researchers, policy makers, and investors. Policy makers wonder what they can do to make firms spend their cash instead of hoarding it and some investors believe they can increase firm value by making firms reduce their cash holdings. In response to this vivid debate, corporate finance researchers have investigated a wide range of explanations for why the benefits to firms of holding cash may have increased so much in recent decades.[1]

By contrast to these approaches, we investigate whether changes in the opportunity costs of holding liquid assets (as opposed to increases in the benefits of holding cash) can also explain most of the time-series changes in the level of liquid assets held by the nonfinancial corporate sector.[2] Figure 1 illustrates that difference in approaches in the context of the framework of Opler, Pinkowitz, Stulz, and Williamson (1999).[3] We provide three sets of analyses. First is a time-series estimation of firm-level cash holdings as a function of the opportunity costs of holding cash for U.S. firms. Second is a cross-sectional estimation ex-

[1] 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. Existing explanations for the increase in firms' demand for liquid assets, reviewed in section 2 below, include tax motives, increasing R&D and cash-flow volatility, increasing focus or decreasing diversification and operational hedging, and rising intangible capital.

[2] The cost of *holding* cash differs from the cost of *getting* cash into the firm. The latter is typically an important driver of cash holdings in structural models of cash such as Riddick and Whited (2009) or Nikolov and Whited (forthcoming), while the cost of *holding* cash is assumed to be constant over time in these models. We investigate the impact of changes in the cost of holding cash alone.

[3] The literature has correlated the increase in the corporate cash ratio since 1980 with variables that have been hypothesized to shift the liquid assets benefit curve (Figure 1(a)). By contrast, we argue that the increase in the cash ratio between 1980 and 2011 – as well as the decrease between 1951 and 1980 – can be explained by shifts in the opportunity costs of holding liquid assets over time (Figure 1(b)).

ploiting firm-level variation in the opportunity costs of holding cash that includes firm fixed effects and time fixed effects, as well as instrumental variable and difference-in-differences estimates. Third, we provide evidence that international variation in corporate cash holdings is well explained by variation in opportunity costs as well. All three sets of analyses consistently indicate that the reason firms hold so much cash is because the opportunity costs of doing so are currently close to zero. In the 1950s, opportunity costs were similarly low and firms' cash ratios were similarly high. In contrast, opportunity costs of holding cash were historically high in 1980, leading to a historical low in corporate cash holdings.

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 prooject "holding cash") and the return on the corporate sector's liquid asset portfolio. We find two main reasons for the existence and time variation of this spread. First, especially in the earlier parts of the sample, corporations hold a substantial fraction of their liquid assets portfolio in non-interest bearing currency (i.e., coins, or paper "cash") and checking accounts, mainly because of Regulation Q, but possibly also because converting interest-bearing assets into cash used for transactions was costly and time consuming at the time. As a result, the return on the firm's cash portfolio is lower than the cost of capital for the project "holding cash." Thus, holding cash is costly even without agency or tax costs. Because the cost of cash correlates with the 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. In particular, the opportunity costs were much higher in the inflationary period around 1980 than it is today. As a result, a corporate CFO had much stronger incentives to economize on cash held in non-interest bearing accounts in the period characterized by high inflation and nominal

interest rates around the year 1980 than either before or after.[4]

A graph of the opportunity cost and the U.S. corporate cash-to-assets ratio for the period 1945-2013, calculated using Fed flow of funds data and presented in Figure 4(a), suggests a strong negative correlation between the two time series. The opportunity costs of cash started at a low level in 1945, increased, and became particularly high in 1980, and then decreased again to reach near-zero levels by 2011. Corporate cash holdings followed the opposite pattern. (The "corporate cash puzzle" refers to the increase of cash in the final 30 years of that time series.) A scatterplot (Figure 4(b)) makes this negative correlation even more evident.

For the time-series results we formally estimate the effect of the opportunity-cost measure on firm-level cash holdings using Compustat data from 1980 to 2011. As the opportunity costs measure employed here is a macroeconomic variable, it is unlikely to be affected by individual firms' corporate financial policies. We control for firm-level characteristics, firm fixed effects, and a nonlinear time trend. 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 cash itself that we will later attempt to predict. In dynamic specifications, we also include lagged values of cash-to-assets ratios. In all specifications, we find that

[4]The wedge between corporate and personal income taxes on interest income, as discussed in Graham (2000) and Faulkender and Wang (2006), creates a second reason for a cost of holding cash. This disadvantage scales linearly with the level of nominal interest rates and therefore exhibits similar dynamics as the first reason detailed above. However, changes in the wedge will not explain the time series of cash holdings. 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. 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 by construction a second-order effect compared to the costs of cash arising from corporations investing in non-interest bearing assets.

the opportunity costs of holding cash have a negative and statistically significant effect on corporate cash holdings that is comparable with estimates from the existing macroeconomic literature on money demand. In particular, we estimate that a one percentage-point decline in opportunity costs increases cash to asset ratios by approximately 13%. As opportunity costs declined by approximately seven percentage points from 1980 to 2010, it is evident that the estimates are large enough to have the potential to explain why cash holdings increased by a factor of more than two between 1980 and 2010.

To investigate the power of these estimates to explain the dynamics of U.S. corporate cash holdings also at intermediate points as well as before 1980, we apply our estimates for the effect of the opportunity costs on cash holdings to the observed changes in opportunity costs for 1945-2013 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 for the period 1945-2013 (Figures 5 and 6). The most notable exception is the period immediately following World War II and lasting until the late 1950s, during which firms held a large amount of government securities in relation to the war mobilization for reasons that were extraneous to the firms' usual economic motives for holding liquid assets.[5] For example, U.S. firms received tax refunds in the form of war bonds (see Greenwood 2005). As a result, opportunity costs alone underpredict cash holdings at the very beginning of this period. We discuss the effect of the repeal of Regulation Q and financial innovation on other time periods during which the model's predictions slightly differ from observed cash holdings

[5]Based on the cash-to-asset series going back to 1920 reported in Graham, Leary, and Roberts (2013), we know that the abnormally high levels of the cash ratio indeed started during World War II. We also created a predicted series for the corporate cash ratio going back to 1920, and it closely matches the actual changes except for the world war period and its immediate aftermath. (Cash holdings increases from 1920 to 1950 while opportunity costs decreased from 1920 to 1950.) However, the data has not been made public yet.

in the results section.

Next, to address endogenity concerns that may arise in the context of the time-series identification strategy, we identify the effect of opportunity costs on cash holdings in the cross-section. We use firm-level variation in the ratio of non-interest bearing to total cash holdings (Compustat *CH* over *CHE*) multiplied with the T-Bill rate as a measure of firm-level opportunity costs. The intuition is that the opportunity cost of firms that for operational reasons hold most of their cash in currency and checking accounts is more sensitive to changes in interest rates. Making use of this firm-level variation in opportunity costs, we are able to replace the non-linear time trend of the time-series identification strategy with year-fixed effects. The cross-sectional coefficients are similar to those estimated in the time series. We then instrument for the firm-level opportunity costs with the product of the average ratio of non-interest bearing to total cash from 1970 to 1979 and the T-Bill rate and continue to get similar results. This strategy is illustrated in Figure 7. Firms that on average in the 1970s held more liquid assets in non-interest bearing forms of "cash," and whose opportunity costs of holding cash are thus more senstive to changes in nominal interest rates, increased their cash-to-asset ratios much more than firms that held most of their liquid assets in interest bearing forms of "cash," therefore faced low opportunity costs of holding cash and afforded higher cash-to-asset ratios already in 1980. In fact, firms with above-median holdings of cash in interest bearing accounts did not increase their cash holdings at all from 1980-2011. The highest quintile of firms by interest bearing liquid assets as a share of total liquid assets 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.

As robustness checks, we investigate the time stability of the estimated effect of oppor-

tunity costs on the cash ratio and find a statistically significant and largely stable effect of opportunity costs on cash holdings for all periods; we examine the cross-sectional stabililty of the estimates across firm characteristics and industries and find similar results; we ensure that similar results obtain for a balanced panel; we confirm that adding macro-variable such as GDP or investment opportunities (Tobin's Q) as controls does not substantially change the results; and estimate Bayesian information criteria of alternative models and find that the model with our measure of opportunity costs is strongly preferred to alternative econometric models, e.g., some that use the T-Bill rate instead of opportunity costs as the key explanatory variable.

We then provide a third set of results that 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. We show that differences in average opportunity costs explain differences in average cash ratios across countries very well, and it is also true that changes in opportunity costs over time can explain changes in the cash ratio over time within these countries. Notably, the regression coefficients in the cross-country study and for the within-country estimates match those obtained in the U.S.-only part of the paper. Moreover, we find that the results from a regression using year fixed effects and those using a cubic time trend used in the U.S. specifications are similar, providing robustness to the time-series estimates of part one.

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 are not abnormal

in the context of either a long-term or international perspective, or both. In particular, current U.S. cash holdings are quite similar to Japanese firm's cash holdings of recent years (Figure 8), and they are substantially lower than they were in 1950. These 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 even 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. We note, however, that our explanation is the only one thus far that predicts historical pattern of cash holdings not only since 1980, but since 1950, and we provide suggestive evidence that existing explanations have more difficulty with predictions including years before 1980. Moreover, we are the first to explain international variation, which we show to also prove more difficult with existing approaches.

The paper proceeds as follows. Section 2 relates the paper to the existing corporate finance 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 the data sources and empirical specifications. Section 5 presents the 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 one is a

smaller literature on international differences in cash holdings and their determinants. The third one is the small but growing literature linking macroeconomics to corporate finance.

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 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 over time. A variation of the argument, by Falato, Kadyrzhanova, and Sim (2013), focuses on the increasingly important role of firms' intangible capital, which can explain the increased benefits of holding cash. Many more explanations have been proposed in the recent past, evidencing the strong interest by researchers in resolving the puzzle.[6]

The second strand focuses on the 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.

The third literature considers the impact of the macroeconomic environment on corporate

[6] 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 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.

cash holdings. All of the above papers 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. The only paper that focuses on a factor that affects opportunity costs is Stone, Gup, and Lee (2013), 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 to the corporate cash portfolio is non-zero – physical cash earns zero return, but "cash" invested in the T-Bill earns the nominal rate. Furthermore, we assess whether opportunity costs have the power to explain the secular trends in corporate cash holdings. The sample we consider is much longer, and we speak to cross-country differences in cash holdings, as well as the time-series variation in cash holdings in these countries. Lastly, our regressions have firm-fixed effects and year-fixed effects, which addresses a variety of endogenity concerns that might otherwise be present. 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 (1963); Vogel and Maddala (1967), and most recently Mulligan (1997). The difference to our approach is, we do calculate how firm-level corporate cash holdings depend on the firm-level opportunity cost of holding cash, and not just on interest rates and several firm-level controls. 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, 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 the trend, and in an alternative specification from cross-sectional variation alone.

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, 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. Their findings show that in the context of a VAR model of aggregated data for the corporate sector, shocks to opportunity costs can explain most of the increase in corporate cash holdings between 1980 and 2010, whereas corporate cash holdings do not have a significant effect on opportunity costs. Unlike Azar and Kagy (2011), the present paper uses Compustat data and estimates the sensitivity of firm-level cash holdings to opportunity costs and controls for firm characteristics. The latter allows us to control for potential changes in the marginal benefit of holding cash over time. In addition, we show that the relationship between cash holdings and opportunity costs holds across industries and for various types of firms, which is only possible using firm-level data.

The fourth 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 (2012). 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. We are not aware of previous papers linking monetary policy to cash holdings across countries.

3 Theory: Demand for Liquid Assets

The section following this constructs a measure of opportunity costs that takes the composition of firms' liquid asset portfolio as given. In this section, we provide theoretical considerations to make sense of the observed variation in that composition. These considerations also help understand why these opportunity costs change over time. Before arriving there, we discuss why firms demand liquid assets, and how this is related to the present research in relation to existing approaches.

We assume that firms' choice of liquid assets, and the composition thereof, is governed largely by transactions costs. It is costly to issue securities and thus increase cash balances, and it is also costly (albeit less) to liquidate less liquid forms of liquid assets such as government bonds to cash. The simple model in Figure 1, based on Opler, Pinkowitz, Stulz, and Williamson (1999) illustrates the consequences. Being short of liquid assets is costly for a firm, because it either has to raise additional funds at a cost or forego proftiable projects.

Holding liquid assets decreases the probability that a firm will be short of cash. The marginal benefit of holding an additional dollar of cash is the reduction of the probability that the firm will be short of cash. As in Opler, Pinkowitz, Stulz, and Williamson (1999), we assume that the marginal benefit of an additional unit of liquid assets declines as holdings of liquid assets increase, creating a downward-sloping demand curve for liquid assets. In contrast, the marginal 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.[7] 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. The return 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 $s_{i,t}$, the opportunity cost of holding one dollar of cash of firm i at time t is

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

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.[8] The measure outlined above makes clear that there

[7] Note that the alternative investment of cash with the same risk characteristics is "not holding cash," i.e. paying down debt or 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. The decision we consider is what the firm does with any remaining cash after such investments. We do run tests controlling for investment opportunities (Tobin's Q), however, to make sure.

[8] 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 assumes that $\lambda = (1 - s_{i,t}) \cdot \text{T-Bill}_t$.

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 fluctuates. We provide evidence for both below. 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 our empirical approach to recognize this effect.

While the time-variation of nominal rates is commonly known, it is less known 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, presented in Figure 2(a), show that firms hold many types of liquid assets, ranging from currency (i.e. physical cash reserves) to money market mutual funds. In the early half of the sample, firms almost exclusively hold currency and checking accounts and government securities as liquid assets. 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.) After the gradual repeal of Regulation Q, firms invest more and more in interest bearing forms of liquid assets. We discuss this evidence in more detail below. Different kinds of liquid assets provide varying degrees of liquidity benefits and pay different rates of return.

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 assets over time. We propose a simple theory in which firms balance the different liquidity benefits and the different returns of various liquid assets, and thus choose to hold more than one type of liquid asset. The theory also rationalizes the secular decline in the ratio of immediately negotiable media of exchange to short-term investments over time.

We assume that firms' demand for liquid assets is a transactions demand. Firms have 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. Firms then hold assets with varying degrees of liquidity because of frictions in the capital market that lead to a delay or a cost in converting some of the assets to cash. 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.

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. Their 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. As a result, today firms hold a relatively small fraction (around 20%) of their liquid assets in currency and checking accounts. The fraction of liquid assets held in currency and checking accounts was much higher in the 1970s, at around 60% of the corporate portfolio of liquid assets. Moreover, there is substantial cross-sectional variation in the composition of liquid assets composition across firms. For example, retail firms hold a higher portion of their liquid assets portfolio in immediately negotiable media of exchange (Compustat CH) than in interest-bearing types of liquid assets (Compustat $CHE - CH$). Given the nature of how retail firms transact with their customers, we find this fact to be consistent with our theoretical considerations. Also, technological innovations in payment technology, as previously discussed, are consistent with the decrease of currency and checking accounts as a share of total liquid assets over time. We discuss the evolution of the components of the corporate portfolio of liquid assets in detail in the next section.

The fact that a portion of the liquid assets portfolio is held in assets that pay a lower nominal rate than the nominal interest rate creates a spread between the nominal interest rate and the rate of return on the portfolio of liquid assets held by the corporate sector

(Figure 3). The spread has fallen over the last three decades for two reasons. First, the nominal interest rate decreased from around 15% in 1980 to almost zero today, leaving little room between the nominal interest rate and the zero lower bound on the nominal return to cash. Second, improvements in electronic-payments technology led firms to 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.[9]

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

[9] 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). Modern papers on the subject are typically agnostic about the source of this cost of cash, however.

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.

Whether changes in opportunity costs can quantiatively explain the increase in cash holdings since the 1980s 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

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. 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, government securities, and mutual fund shares, divided by the book value of total assets.

While Compustat data are needed for firm-level regressions, Fed flow of funds data give an arguably cleaner picture of the dynamics of corporate cash holdings, for several 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; and (iv) Compustat data start in 1951, whereas we can calculate the cash-to-assets ratio from flow of funds data starting in 1945. Because of the arguably greater accuracy, we build our first set of results on Fed Flow of Funds data alone, and afterwards show that very similar results obtain using Compustat data. The two measures of the cash ratio show a similar pattern over time: both decrease between 1945/1951 and around 1980, and then increase between 1980 and 2011. To be more precise, the Fed flow of funds cash ratio reaches its minimum in 1982, shortly after interest rates peak. The Compustat cash ratio starts its secular increase a few years later. (The literature on the "corporate cash puzzle" is largely based on the final 30 years of that time series.) Our econometric approach works well for both measures. Figure 4 shows the cash ratio calculated using the Fed flow of funds data between 1945 and 2013. The figure also shows the opportunity costs measure, whose construction we now describe.

We calculate the opportunity costs of holding liquid assets 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. To estimate the cost of holding cash inside the firm, we need to find the cost of the "project" of holding cash. Given that cash, whether held as currency or in an interest-bearing risk-free asset, is a risk-free project, its cost of capital is equal to the risk-free rate. As a proxy, we use the T-Bill from FRED. 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. The secular fluctuations in the T-Bill rate eclipse the liquidity premium. Moreover, the liquidity premium positively comoves with the nominal rate. As a result the cost of cash was lower then the T-Bill rate in 1980 when the liquidity premium was high, making cash holdings relatively less expensive than what the T-Bill rate indicates. Thus, our results are biased against the hypothesis we advance, and

risk considerations are unlikely to be a contributor to our findings. In later robustness tests, we also include Tobin's Q as a measure of investment opportunities as a control and find that our results are practically unchanged.

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 for the sector to calculate a rolling lagged-ten-year average of the share of liquid assets held in currency and checking accounts. 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. Figure 2(a) shows the components of the cash portfolio for the nonfinancial corporate sector between 1945 and 2013.[10] The composition of the liquid assets portfolio changed dramatically throughout the period. In 1945, the nonfinancial corporate sector held essentially only two categories of liquid assets: currency and checking deposits, and government securities. Between 1945 and around 1980, we see a large reduction in the fraction of government securities, and an increase in time and

[10]We think of the long-run changes in the portfolio of liquid assets as an endogenous decision made by firms that is driven by changes in financial regulation and technology. Such changes in financial regulation and technology are not driven by the firms' short-term liquid portfolio choice. These changes gave rise, for example, to the emergence of money market mutual funds (see Teles and Zhou, 2005). Due in part to the rapid development of electronic payments in the 1990s, nowadays firms can easily hold mutual fund shares and other interest-bearing liquid assets, thus decreasing the opportunity costs of holding cash. The liquidity provided by interest-bearing assets was lower in 1980 than it is today, thus justifying the decrease in currency and checking accounts as a share of total liquid assets. Also, Regulation Q, which imposed maximum rates of interest on savings accounts and other bank deposits, made it much less attractive relative to firms until 1986 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.

savings deposits. Between 1980 and the present, the corporate sector reduced the fraction of the liquid assets portfolio held in currency and checking accounts, and added mutual funds to its portfolio (both money market and other types of mutual funds). Figure 2(b) shows the fraction of the liquid assets portfolio held in currency and checking accounts between 1945 and 2013, together with its 20-year moving average. The nonfinancial corporate sector's share of liquid assets held in currency and checking accounts was relatively stable around 60% until the 1970s, when the share began to fall steadily until the present, to around 20% of the liquid assets portfolio.

For the construction of the return on cash measure, we assume the currency and checking component of the liquid assets portfolio has a zero nominal return. We proxy for the return on all other components using the nominal three-month T-Bill rate (historical data on rates for money market accounts only go back to 2000 in FRED; historical data on certificates of deposit go back to 1964). Figure 3 shows the three-month T-Bill rate together with the return on the nonfinancial corporate sector's portfolio of liquid assets. Note that substantial comovement occurs between the the level of interest rates and the cost of holding cash (the difference between the blue and red lines in Figure 3 – this difference is depicted as the opportunity costs of cash (red dotted line) in Figure 4.) Note also that in recent years, the return on the liquid assets portfolio has been much closer to the T-Bill rate than in the past, due to the higher share of the portfolio held in interest-bearing assets.

From the Compustat database, we calculate a set of firm-level control variables according to 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.

4.2 Static Regressions

Figure 4 suggests a strong negative correlation between the cash ratio and the opportunity costs of holding cash between 1945 and 2013. We now adopt a quantitative approach to make the claim that the latter has the power to explain the former. We estimate the response of the corporate cash ratio 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 ratio as a function of opportunity costs, a cubic time trend, firm fixed effects, as well as firm-level control variables.[11] These specifications are analogous to the basic models of money demand analyzed in the macro literature; however, they are estimated at the firm level and introduce controls for firm-level characteristics:

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

where OC_t is the opportunity costs of holding cash at time 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. The changes in opportunity costs are driven by macroeconomic factors, and are therefore likely to be exogenous at the level of the individual firm. We run additional regressions including real GDP to control for the potential effect of the business cycle on cash holdings, and find similar results (reported in appendix tables B.1 and B.2). We also run tests that control for Tobin's Q to alleviate

[11] Following Petersen (2009), we two-way cluster standard errors by both firm and year unless otherwise noted.

concerns about time-changing investment opportunities.[12]

The first specification includes only firm size as a firm-level control. Following Bates, Kahle, and Stulz (2009), the second specification is similar to the first, except that it uses the raw cash-to-assets ratio instead of the logarithm of the cash ratio as a dependent variable:

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

Specifications 3 and 4 are similar to specifications 1 and 2, except that they include the full set of firm-level controls.

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. Multiple imputation is a statistically valid method of imputing data.[13] Specifications 5 and 6 are similar to specifications 3 and 4, except that their estimation uses multiple imputation to avoid dropping observations

[12] 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).

[13] Rubin (1987) developed a 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).

with some missing controls.[14]

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 main results do not 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.

4.3 Dynamic Regressions

Following (Opler, Pinkowitz, Stulz, and Williamson, 1999), we also run dynamic regressors with the lagged cash ratio as a regressor[15]:

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

Similar to the levels regressions, the first dynamic specification includes only firm size as a firm-level control. As before, the second dynamic specification is similar to the first, except that it uses the raw cash-to-assets ratio as a dependent variable instead of the logarithm of the cash ratio:

[14] We cluster by firm in the specifications that use multiple imputation.

[15] We 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. "Nickel bias" that results from lagging dependent variables in panel regressions with short panels is not a concern in our sample of 32 years.

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

The dynamic specifications 3 and 4 are similar to specifications 1 and 2, except that they include the full set of firm-level controls. The dynamic specifications 5 and 6 are similar to specifications 3 and 4, except that their estimation uses multiple imputation to avoid dropping observations with missing controls. Alternative versions of dynamic regressions with lagged opportunity costs as a control do not substantially affect the results.

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 effect can also be identified in the cross section, using firm-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). Most of the components included in immediately negotiable media of exchange 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. (The composition of both is listed in the appendix. More detailed data on firm-level variation in the composition of cash become available only after 2009 (Duchin, Gilbert, Harford, and Hrdlicka, 2013).) We then construct a measure of firm-level opportunity costs by multiplying the fraction of cash

held in immediately negotiable media of exchange by the three-month T-Bill rate. This is equivalent to subtracting the return on the cash portfolio from the cost of holding cash, which we assume to approximate the T-Bill rate as before. 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. Our main specification is the following:

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

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 two additional specifications. In the first additional specification, we average the fraction of cash held in interest-bearing assets by industry, creating an industry-level measure of opportunity costs. In the second additional specification, we instrument firm-level opportunity costs using the T-Bill rate times the firm's average level of the fraction of cash that is held in immediately negotiable media of exchange in the years 1970-1979. That is, we create an instrumental variable $OC^{IV}_{i,t} = \overline{\left(\frac{CH}{CHE}\right)}_i \cdot R_t$, that replaces OC_{it} in equation (6) in some specifications, where R_t is the T-Bill rate. We are identifying the effect out of the difference in the response to interest rates of firms that hold most of their cash in interest bearing assets and firms that hold most of their cash in non-interest bearing assets on average for operating reasons. For example, retail shops need more cash, especially in the early years of the sample, because of the way customer sales are settled. (This is the "transactions" motive for holding cash.) This cross-sectional identification strategy greatly attenuates the problem of division bias, since any measurement error in CH/CHE will be averaged over time. The identification assumption is that the error does not contain an

unobserved factor that affects the sensitivity of a firm's cash holdings to interest rates, and that is also correlated with the share of cash that is held in interest-bearing assets.

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 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 -12 and -16. In the specifications with the cash ratio in levels, we find estimated effects between -.6 and -0.9, indicating robustness to a different functional form. 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. In particular, a coefficient of -12 means that if opportunity costs decrease by 1 percentage point, cash holdings increase by approximately 13%. 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.[16] The regression results for the dynamic specifications are shown in Table 3. The coefficients are comparable in magnitude and also highly statistically significant

[16]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.

throughout. The next set of results provides more analyses to gauge the economic magnitude of the results.

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 5 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 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 likely 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.[17]

For Figure 5(b), we calculate predicted values starting with the cash ratio in 1945 and applying the estimated dynamic model. We calibrate the constant so that the mean log cash

[17] 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.

ratio implied by the dynamic model (given the average level of opportunity costs) is equal to the mean log cash ratio in the data. The results from this prediction exercise, consistent with the approach used in the static predictions, use the estimates from specification 5 in Table 3. The predicted level of cash quite closely matches the observed levels, however, the model slightly overpredicts the increase in corporate cash holdings from 1980-2013. The increasing availability of credit lines, which can serve as a substitute of internal cash holdings, may explain that firms increased their observable liquidity reserves less than changes in the opportunity costs of cash would predict (Disatnik, Duchin, and Schmidt, 2013).

Figure 6 shows the results of a static prediction exercise identical to that in Figure 5(a), but using quarterly data instead of yearly, 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.)[18]

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 don't earn interest, such as currency and checking accounts, should respond more to

[18]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 20-year moving average ratio of cash held in interest-bearing and non-interest bearing accounts, our econometric model would then assume too high a fraction in interest-bearing accounts before and after the introduction of SWEEP accounts, and thus overpredict the amount of cash firms "should" have held, given interest rates.

changes in the T-Bill rate. Figure 7 provides an illustration. It plots the time series of 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 corpoate cash portfolio in the 1970s of these firms is exogenous to how the 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 *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 call, 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 of the time-series identification presented before. The first specification shows results using the industry-level measure of opportunity costs, which is the T-Bill rate multiplied with the 2-digit SIC-code level industry-average of the fraction of cash held in immediately negotiable media of exchange (i.e., currency and checking accounts), Compustat CH/CHE. The highly significant coefficient of -21.55 even higher than the coefficients estimated in previous

specifications from the time series. Thus, if the time-series approach is biased relative to the standard cross-sectional approach used in corporate finance and presented in this section, the bias attenuates the results towards zero. The second specification uses the firm-level measure of opportunity costs that is calculated equally, but using CH/CHE at the firm-year level. The highly significant coefficient of -15.21 is still slightly higher than the coefficients estimated from the time series. Similar results obtain when we run OLS instead of WLS; as explained before, we report WLS because we think it is the right thing to do given the structure of the Compustat data. The third specification instruments the firm-level measure of opportunity costs, using the IV strategy described in the methodology section. In short, we calculate the average CH/CHE from 1970-1979 for the firm and multiply it with the T-Bill rate. The coefficient hardly changes, despite the substantially smaller sample. (Note that to qualify for the IV sample, the firm has to exist all through the 1970s in compustat.) The qualitative insight from these specifications is that firms that were less exposed to changes in nominal rates because their cash was held in interest-bearing accounts, did indeed not respond much to changes in interest rates. In contrast, firms holding lots of liquid assets in non-interest bearing accounts for which the opportunity cost is high when interest rates are high, responded strongly to changes in interest rates. Specifications (4) and (5) provide difference-in-difference results. In specification (4) a firm is "treated" when it falls above the sample median in terms of average CH/CHE during the period 1970-1979, and in the control group when its CH/CHE is below the median. In specification (5) the firm is "treated" when it is in the highest quintile in terms of average CH/CHE in the 1970s. In both specification, "pre" treatment is the year 1980 and "post" treatment is the year 2011. The result is that firms that on average in the 1970s held a higher fraction of cash in assets that don't earn interest increased their cash holdings significantly more over time, compared

to firms that held a lower fraction in assets that don't earn interest. Quantitatively, the coefficient in specification (4) of 1.076 means that firms above the median in terms of CH/CHE have increased their cash holdings by approximately 190% from 1980-2011 relative to firms below the median. The coefficient in specification (5) of 1.951 means that firms in the highest quintile in terms of CH/CHE have increased their cash holdings by approximately 500% 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.)

5.4 Robustness Tests

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 -11.

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 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.

To examine cross-sectional robustness of the effect of opportunity costs on the cash ratio, we re-estimate our baseline specification (specification 5 in Table 2) for various firm types. In particular, for each firm-level control, we calculate the average for each firm. 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.[19] The results are shown in Table B.3. 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, the effect for firms with high levels of R&D is lower than for firms with low levels of R&D, and that the effect for firms with high levels of acquisition activity is lower than for firms with low levels of acquisition activity. None of these differences, however, is statistically significant. 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.4. 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.

A frequent question is whether instead of the opportunity cost measure we use, the T-Bill rate alone or the share of liquid assets in interest-bearing assets alone would also have a significant effect on cash holdings. The answer is yes in both cases. However, we prefer the model we run not only because it is the economically sensible thing to do, but also on

[19] 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.

more pragmatic grounds: the model with opportunity costs performs better. For example, we calculate Bayesian Information Criteria (BIC) (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.

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 cannot 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 more robust. (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.) 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 as well. 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 BKS 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. That is, more than the direction of the evidence, the take-away is that the existing explanations do not have much power in explaining the international cross-section.

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.[20] Because data are available for a small number of firms for earlier years, we use data for the period 1996-2011.[21]

Figure 8 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. 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 1996-2011, and the

[20] 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.

[21] 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).

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.

Figure 9 shows the level of opportunity costs and the cash ratio by country over time for the period 1996-2011. The graphs indicate 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. The first seven specifications are estimated for each country separately and similar to specification 1 in Table 2. The last two specifications show results pooling firms from all countries. Specification 7 uses a cubic time trend, and specification 8 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. 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. We find a statistically significant negative coefficient in both pooled specifications, and the coefficients for the specification including a cubic time trend are similar to those in the specification including year fixed effects.[22]

Figure 10 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

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

samples with litte variation in opportunity costs, changes in opportunity costs over time can explain some of the variation in cash ratios for France, Germany, and Spain. The variation in cash ratios over time for Italy, 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.

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. We then 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. As a second set of results, we offer a cross-sectional identification using firm-level variation in the fraction of liquid assets held in non-interest bearing accounts. The panel estimation with year fixed effects and firm fixed effects yields similar estimates to the time-series estimation. 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. We cannot entirely rule out that an omitted variable drives both cash holdings and interest rates, and thus opportunity costs both in the U.S. and in developed economies elsewhere. 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.

References

Agca, S. (2012): "Financial Integration and Corporate Cash Holdings," *Available at SSRN 2024097*. 2

Azar, J., and J.-F. Kagy (2011): "Changes in the Opportunity Cost of Cash: A Solution to the Corporate Cash Hoarding Puzzle," Ph.D. thesis, Princeton University. 2

Ball, L. (2001): "Another look at long-run money demand," *Journal of Monetary Economics*, 47(1), 31–44. 2

Bates, T. W., K. M. Kahle, and R. M. Stulz (2009): "Why do US firms hold so much more cash than they used to?," *The Journal of Finance*, 64(5), 1985–2021. 2, 4.1, 4.2, 5.4, A.1, B.2, B.3

Bolton, P., H. Chen, and N. Wang (2011): "A Unified theory of Tobin's q, Corporate Investment, Financing, and Risk Management," *The Journal of Finance*, 66(5), 1545–1578. 8, 9

Bolton, P., H. Schaller, and N. Wang (2013): "The Marginal Value of Cash and Corporate Savings," Discussion paper, Columbia University Working Paper. 9

Brownstone, D., and R. G. Valletta (1996): "Modeling earnings measurement error: a multiple imputation approach," *The Review of Economics and Statistics*, pp. 705–717. 13

Della Seta, M. (2011): "Cash and competition," *Available at SSRN 1808979*. 6

Disatnik, D., R. Duchin, and B. Schmidt (2013): "Cash Flow Hedging and Liquidity Choices*," *Review of Finance*, p. rft006. 5.2

Dittmar, A., and J. Mahrt-Smith (2007): "Corporate governance and the value of cash holdings," *Journal of Financial Economics*, 83(3), 599–634. 6

Dittmar, A., J. Mahrt-Smith, and H. Servaes (2003): "International corporate governance and corporate cash holdings," *Journal of Financial and Quantitative analysis*, 38(1), 111–134. 2

Duchin, R. (2010): "Cash holdings and corporate diversification," *The Journal of Finance*, 65(3), 955–992. 2, 12

Duchin, R., T. Gilbert, J. Harford, and C. M. Hrdlicka (2013): "Precautionary Savings with Risky Assets: When Cash Is Not Cash," Discussion paper, Available at SSRN: http://ssrn.com/abstract=2348415 or http://dx.doi.org/10.2139/ssrn.2348415. 4.4

Falato, A., D. Kadyrzhanova, and J. W. Sim (2013): "Rising Intangible Capital, Shrinking Debt Capacity, and the US Corporate Savings Glut," Discussion paper, Federal Reserve Board. 2

Faulkender, M., and R. Wang (2006): "Corporate financial policy and the value of cash," *The Journal of Finance*, 61(4), 1957–1990. 4, 3

Foley, C. F., J. C. Hartzell, S. Titman, and G. Twite (2007): "Why do firms hold so much cash? A tax-based explanation," *Journal of Financial Economics*, 86(3), 579–607. 2

Gao, X. (2013): "Corporate Cash Hoarding: The Role of Just-in-Time Adoption," *University of British Columbia*. 6

Graham, J. R. (2000): "How big are the tax benefits of debt?," *The Journal of Finance*, 55(5), 1901–1941. 4, 3

Graham, J. R., M. T. Leary, and M. R. Roberts (2013): "A Century of Capital Structure: The Leveraging of Corporate America," Discussion paper, Working Paper. 5

Greenwood, R. M. (2005): *Aggregate corporate liquidity and stock returns*. Division of Research, Harvard Business School. 1, 3

Harford, J., S. A. Mansi, and W. F. Maxwell (2012): "Corporate governance and firm cash holdings in the US," in *Corporate Governance*, pp. 107–138. Springer. 2

Kalcheva, I., and K. V. Lins (2007): "International evidence on cash holdings and expected managerial agency problems," *Review of Financial Studies*, 20(4), 1087–1112. 2

King, G., J. Honaker, A. Joseph, and K. Scheve (2001): "Analyzing incomplete political science data: An alternative algorithm for multiple imputation," *American Political Science Review*, 95(1), 49–70. 13

Lins, K. V., H. Servaes, and P. Tufano (2010): "What drives corporate liquidity? An international survey of cash holdings and lines of credit," *journal of financial economics*, 98(1), 160–176. 2

Lucas, R. E. (1988): "Money demand in the United States: A quantitative review," in *Carnegie-Rochester Conference Series on Public Policy*, vol. 29, pp. 137–167. North-Holland. 2

Mackinnon, A. (2010): "The use and reporting of multiple imputation in medical research–a review," *Journal of Internal Medicine*, 268(6), 586–593. 13

Meltzer, A. H. (1963): "The demand for money: A cross-section study of business firms," *The Quarterly Journal of Economics*, 77(3), 405–422. 2

Morellec, E., B. Nikolov, and F. Zucchi (2009): "Competition, Cash Holdings, and Financing Decisions," *Available at SSRN 1364009*. 6

Mulligan, C. B. (1997): "Scale economies, the value of time, and the demand for money: Longitudinal evidence from firms," *Journal of Political Economy*, 105(5), 1061–1079. 2, 5.1

Nagel, S. (2014): "The Liquidity Premium for Near-Money Assets," Discussion paper, University of Michigan Working Paper. 4.1

Nikolov, B., and T. M. Whited (forthcoming): "Agency Conflicts and Cash: Estimates from a Structural Model," *The Journal of Finance*. 2

Opler, T., L. Pinkowitz, R. Stulz, and R. Williamson (1999): "The determinants and implications of corporate cash holdings," *Journal of Financial Economics*, 52(1), 3–46. 1, 3, 4.3

Petersen, M. A. (2009): "Estimating standard errors in finance panel data sets: Comparing approaches," *Review of financial studies*, 22(1), 435–480. 11, 21

Pinkowitz, L., R. Stulz, and R. Williamson (2006): "Does the contribution of corporate cash holdings and dividends to firm value depend on governance? A cross-country analysis," *The Journal of Finance*, 61(6), 2725–2751. 2

Pinkowitz, L., R. M. Stulz, and R. Williamson (2012): "Multinationals and the high cash holdings puzzle," Discussion paper, National Bureau of Economic Research. 2

Pinkowitz, L., R. M. Stulz, and R. Williamson (2013): "Is there a U.S. High Cash Holdings Puzzle after the Financial Crisis?," Discussion paper, Fisher College of Business Working Paper No. 2013-03-07. Available at SSRN: http://ssrn.com/abstract=2253943. 1, 6

Riddick, L. A., and T. M. Whited (2009): "The corporate propensity to save," *The Journal of Finance*, 64(4), 1729–1766. 2

Rubin, D. B. (1987): *Multiple imputation for nonresponse in surveys*. Wiley (New York). 13

Russolillo, S. (October 24, 2013): "Carl Icahn's Letter to Apple CEO Tim Cook," *Wall Street Journal*. 1

Sanchez, J. M., and E. Yurdagul (2013): "Why are corporations holding so much cash?," *Federal Reserve Bank of St. Louis' The Regional Economist*, 21(1), 5–8. 1

Schafer, J. L. (1999): "Multiple imputation: a primer," *Statistical methods in medical research*, 8(1), 3–15. 13

Schwarz, G. (1978): "Estimating the dimension of a model," *The Annals of Statistics*, 6(2), 461–464. 5.4

Shore-Sheppard, L., T. C. Buchmueller, and G. A. Jensen (2000): "Medicaid and crowding out of private insurance: a re-examination using firm level data," *Journal of Health Economics*, 19(1), 61–91. 13

Steimetz, S. S., and D. Brownstone (2005): "Estimating commuters'"value of time"

with noisy data: a multiple imputation approach," *Transportation Research Part B: Methodological*, 39(10), 865–889. 13

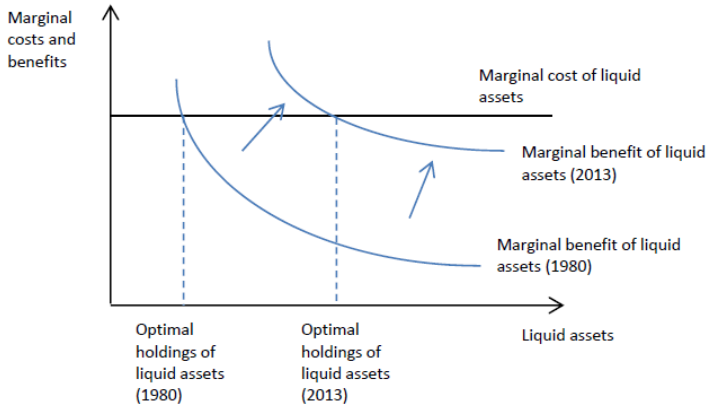
Stock, J. H., and M. W. Watson (1993): "A simple estimator of cointegrating vectors in higher order integrated systems," *Econometrica: Journal of the Econometric Society*, pp. 783–820. 2

Stone, A.-L., B. E. Gup, and J. Lee (2013): "Corporate Cash Holdings and Interest Rates: 1970-2011," Discussion paper, Working Paper. 2

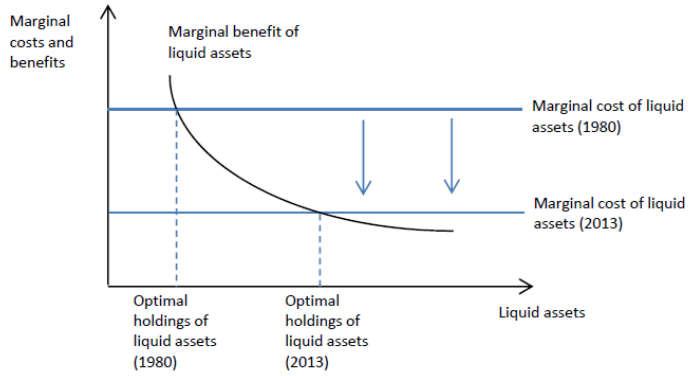
Teles, P., and R. Zhou (2005): "A stable money demand: Looking for the right monetary aggregate," *Economic Perspectives - Federal Reserve Bank of Chicago*, 29(1), 50. 10

Tobin, J. (1956): "The interest-elasticity of transactions demand for cash," *The Review of Economics and Statistics*, 38(3), 241–247. 9

Vogel, R. C., and G. Maddala (1967): "Cross-Section Estimates Of Liquid Asset Demand By Manufacturing Corporations," *The journal of Finance*, 22(4), 557–575. 2



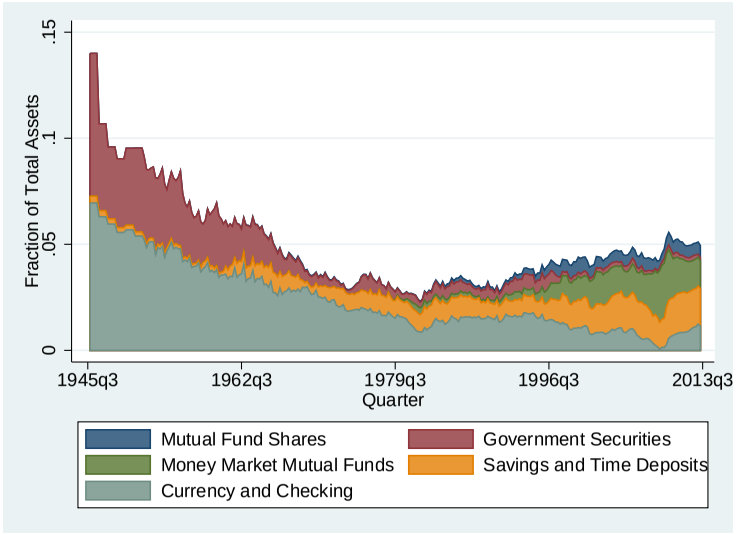
(a) Shift in the marginal benefits of holding cash



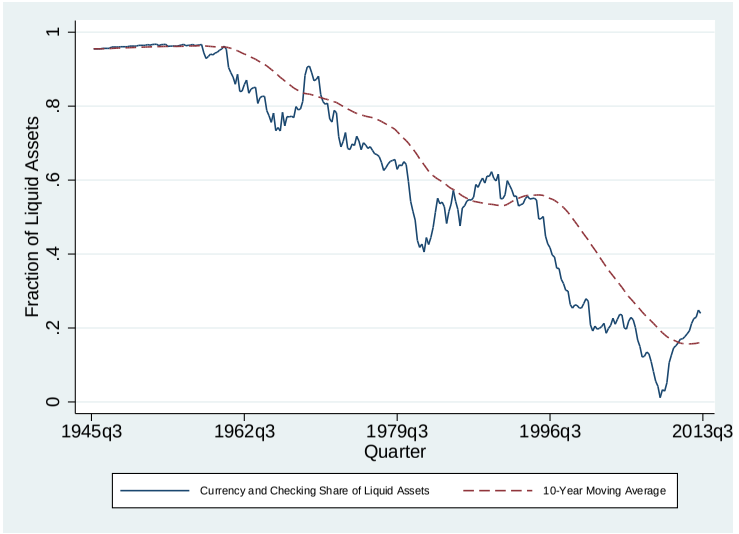
(b) Shift in the marginal cost of holding cash

Figure 1: Two possible explanations for changes in optimal holdings of liquid assets.

The upper 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 lower 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.

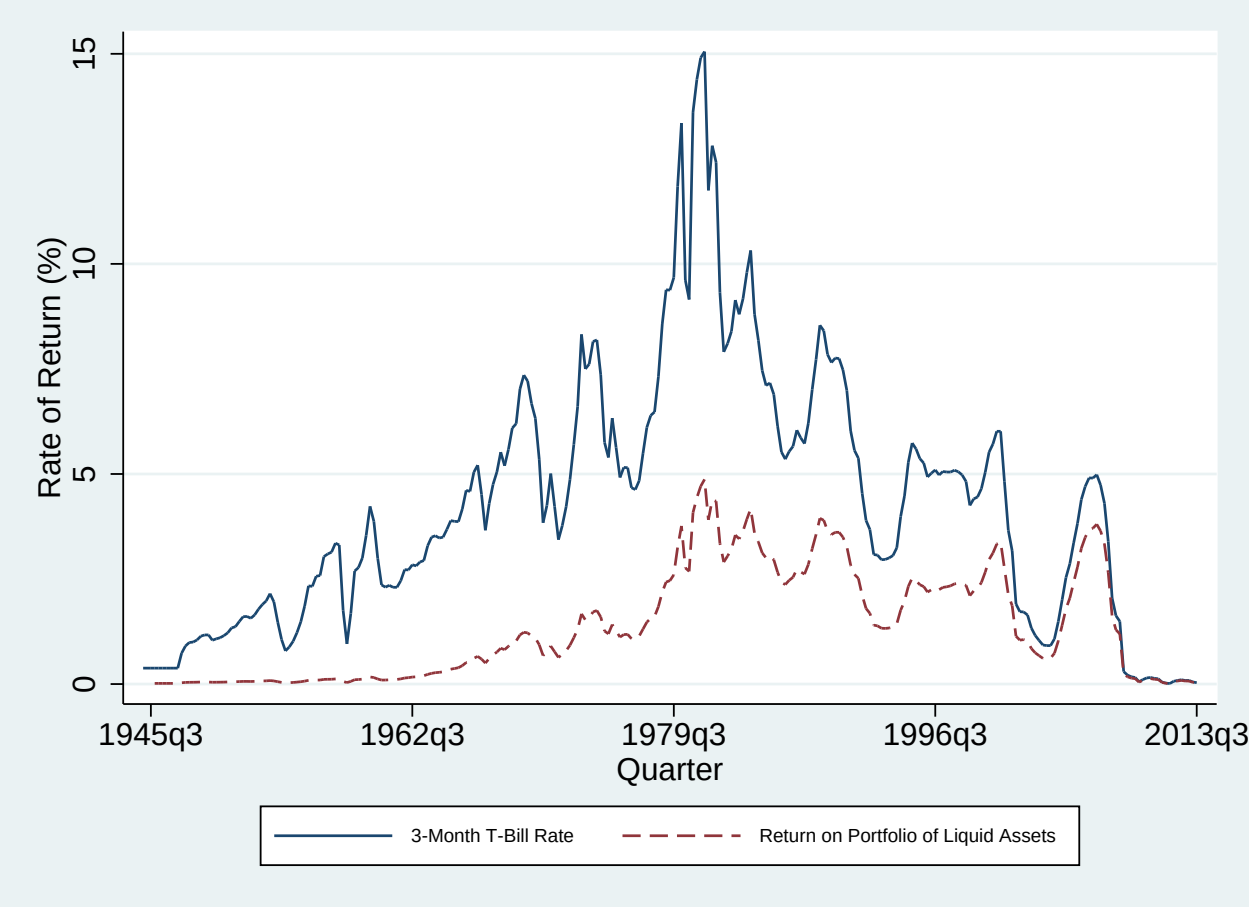
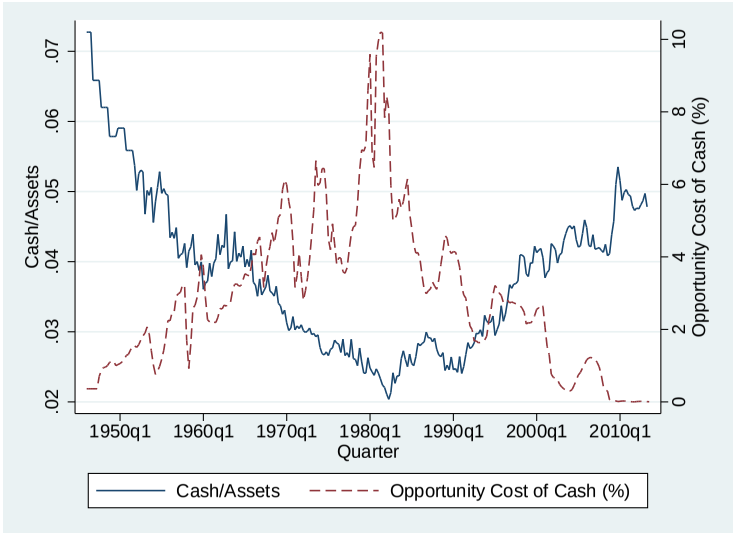
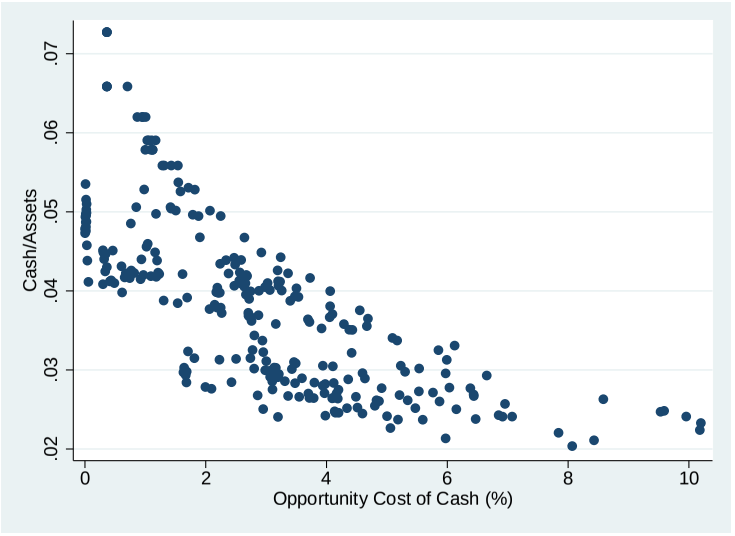


Figure 3: T-Bill return and return of the aggregate corporate liquid asset portfolio.

Data on the components of the nonfinancial corporate sector's liquid assets portfolio is from the Fed Flow of Funds. The T-Bill approximates the cost of capital o 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 for the sector to calculate a rolling 20-year average of the share of liquid assets held in currency and checking accounts. We assume the currency and checking component of the liquid assets portfolio has a zero nominal return. We proxy for the risk-adjusted 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.



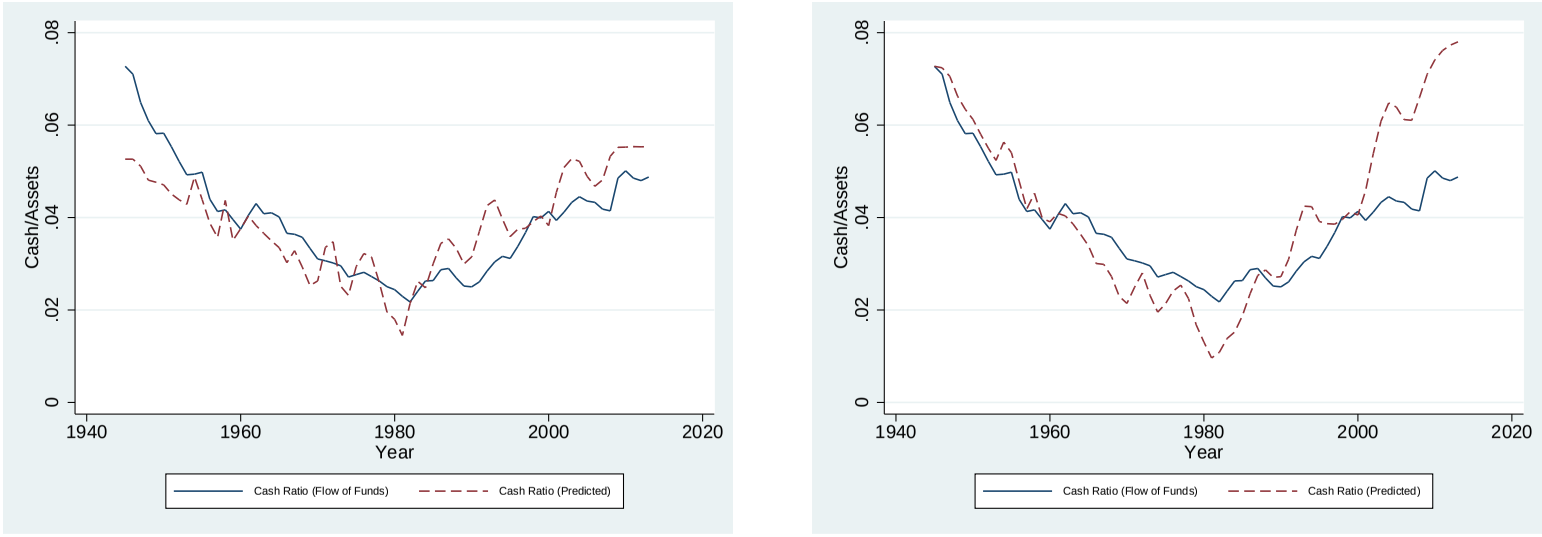
(a) Time series



(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. To approximate the return on liquid assets, we use Fed flow of funds data on the composition of liquid assets for the sector to calculate a rolling 20-year average of the share of liquid assets held in currency and checking accounts. We assume the currency and checking component of the liquid assets portfolio has a zero nominal return. We proxy for the risk-adjusted return on all other components using the nominal three-month T-Bill rate. Each dot in the scatterplot is the average opportunity cost across for a given year using the same data as in the time-series graph.



(a) Prediction based on static regressions

(b) Prediction based on dynamic regressions

Figure 5: Predicted versus actual values of the corporate cash-to-asset ratio, 1945-2013, annual data.

We calculate the predicted response of corporate cash holdings to variations in opportunity costs, holding all other factors constant. The static calculations in panel A use the estimated effect from specification 5 in Table 2. We normalize the predicted series so that its average value in logs is equal to the average value for the actual series. For the dynamic prediction in panel B, we use the estimate from specification 5 in Table 3. We calculate predicted values starting with the cash ratio in 1945 and applying the estimated dynamic model, holding all factors constant except for opportunity cost. We calibrate the constant so that the mean log cash ratio implied by the dynamic model (given the average level of the opportunity cost) is equal to the mean log cash ratio in the data.

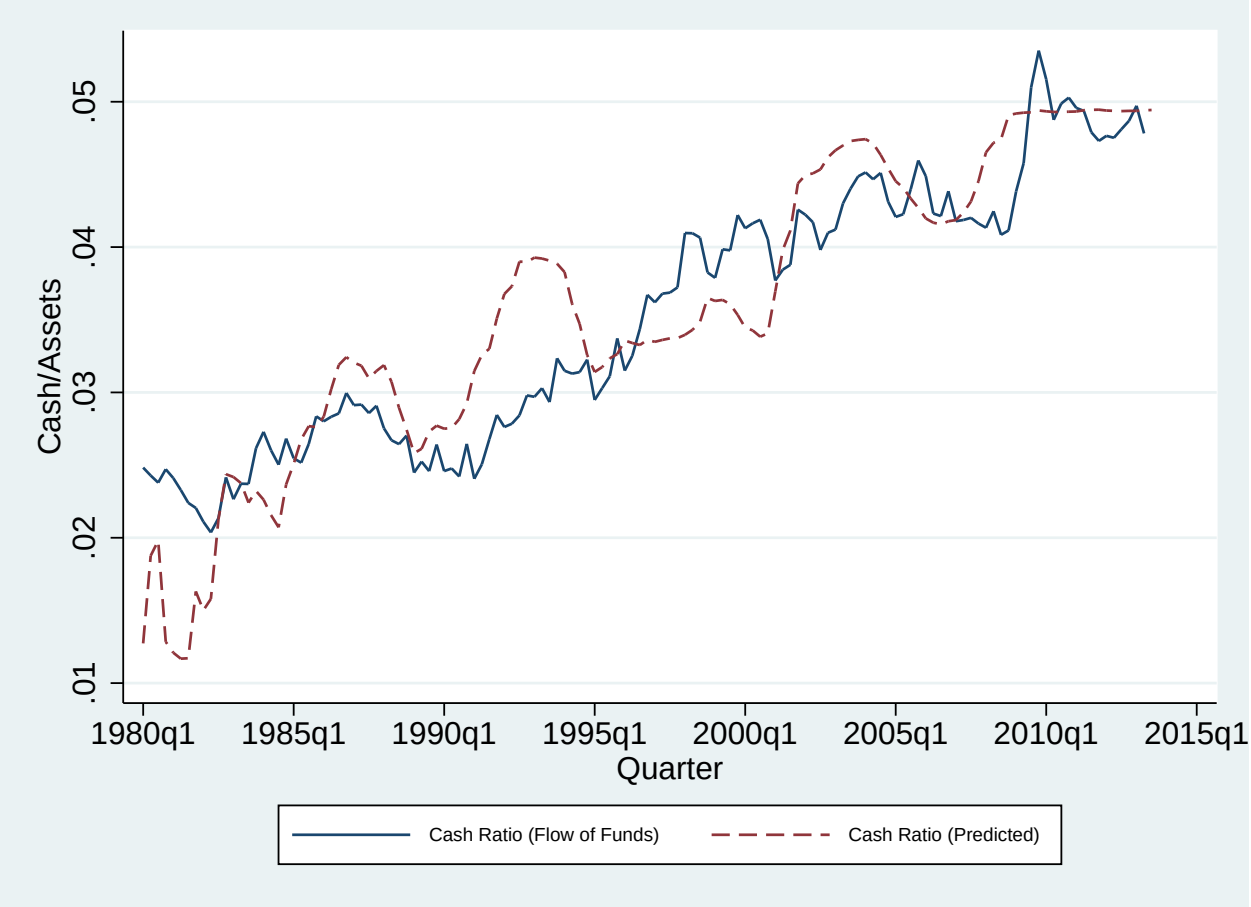


Figure 6: Predicted versus actual cash-to-asset ratio, 1980-2013, quarterly data.

We calculate the predicted response of corporate cash holdings to variations in opportunity costs, holding all other factors constant. The calculations use the estimated effect from specification 5 in Table 2. 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.

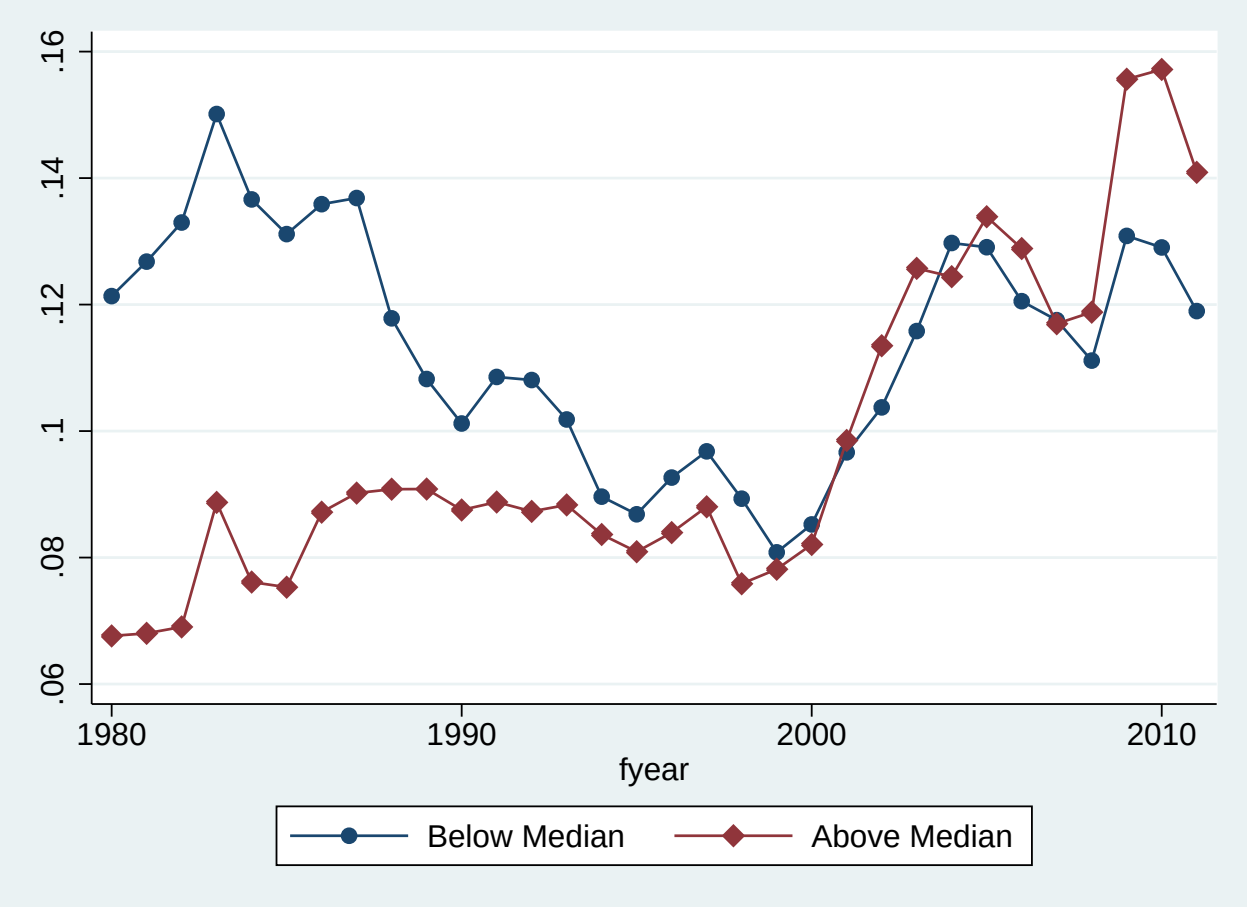


Figure 7: Time-series of actual cash-to-asset ratios of Compustat firms by share of non-interest bearing assets of the cash portfolio (Compustat CH/CHE), from 1980 to 2011.

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 cash holdings, i.e. most of their liquid assets were invested in currency and checking accounts, but not in savings accounst 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. These firms' opportunity cost of holding cash depends less on interest rates according to our hypothesis.

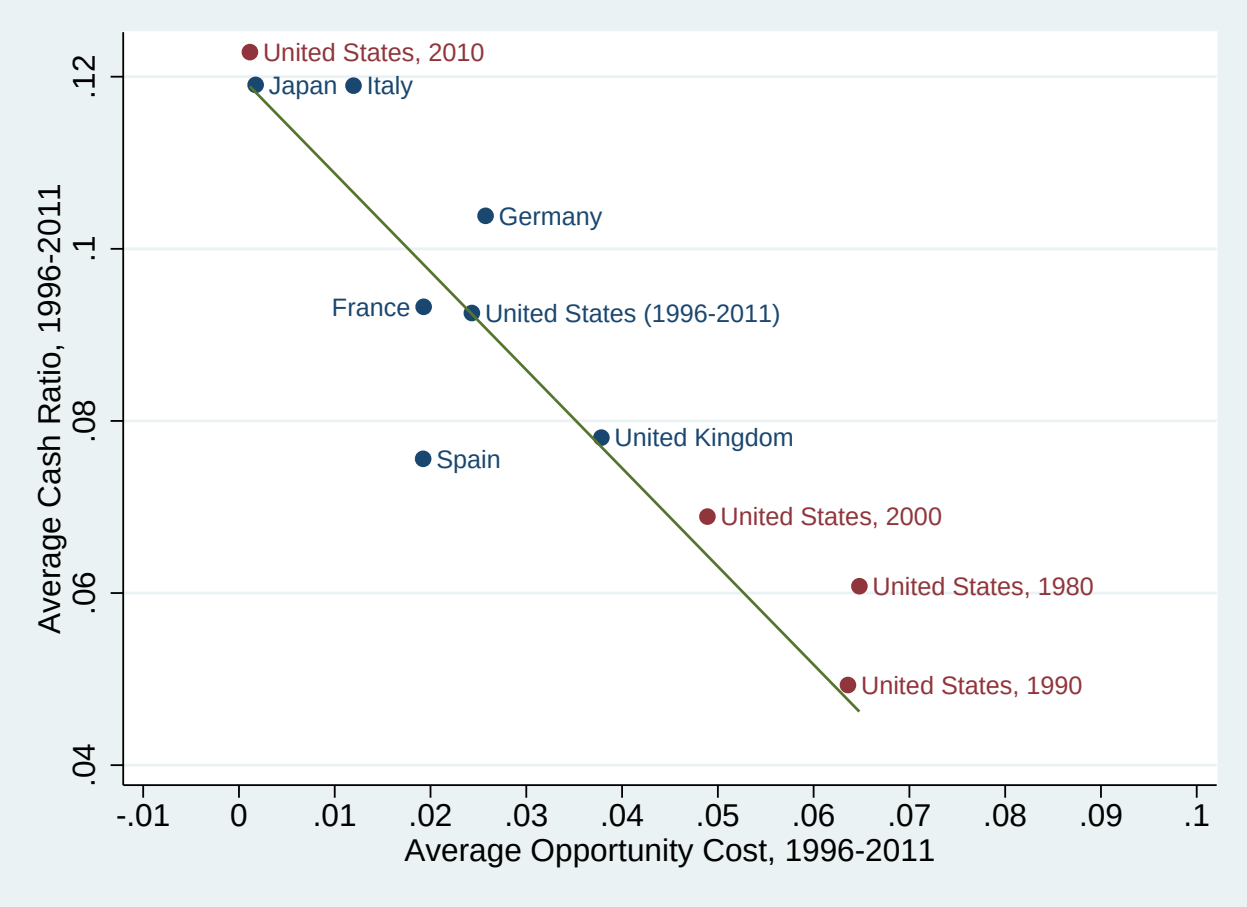


Figure 8: Average cash-to-asset ratio versus average opportunity cost, by country.

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 calculated an asset-weighted average of the cash to assets ratio and of opportunity cost for each country-year. Then we average across years. Regression line is estimated using only country averages for the period 1996-2011.

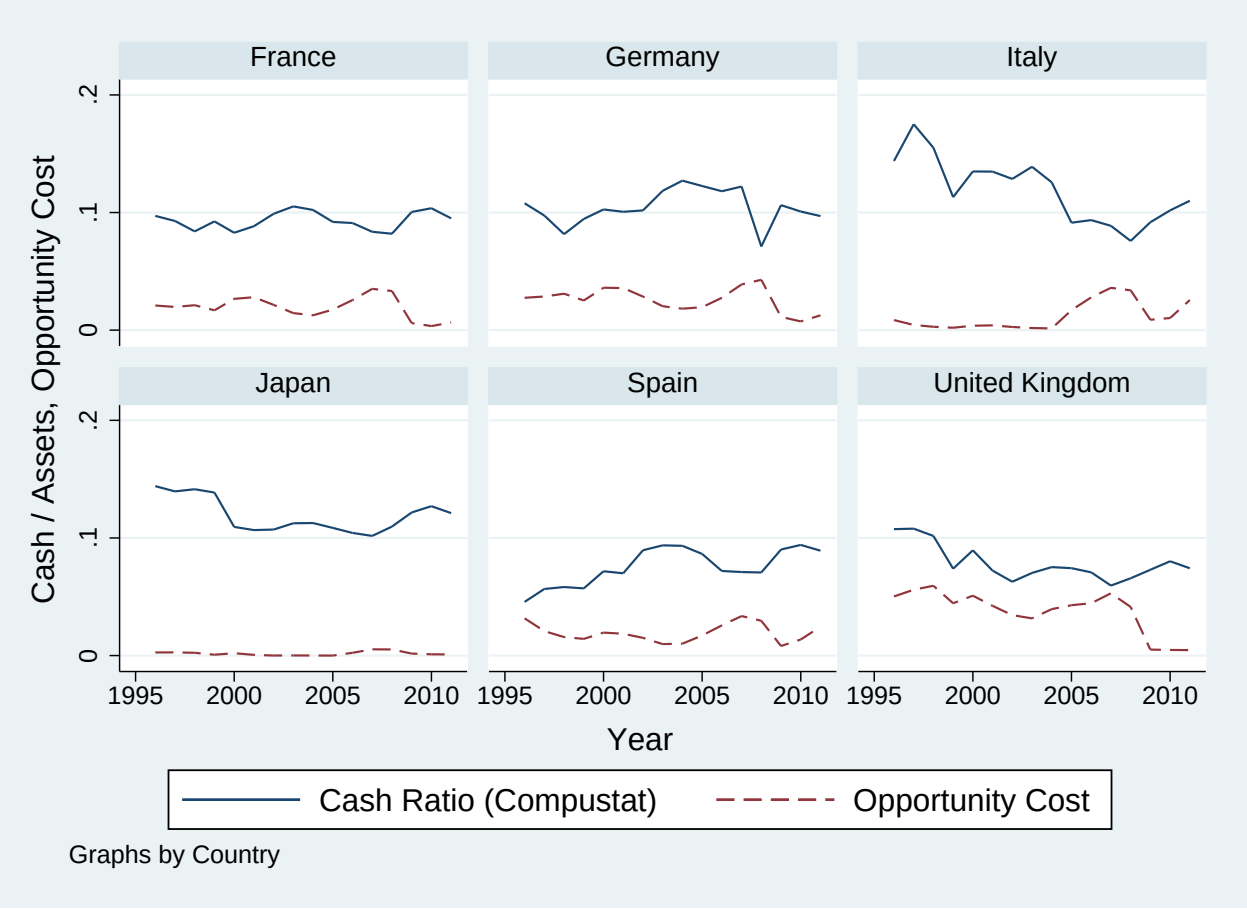


Figure 9: Cash-to-asset ratio and opportunity cost over time, by country.

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 caluclated 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.

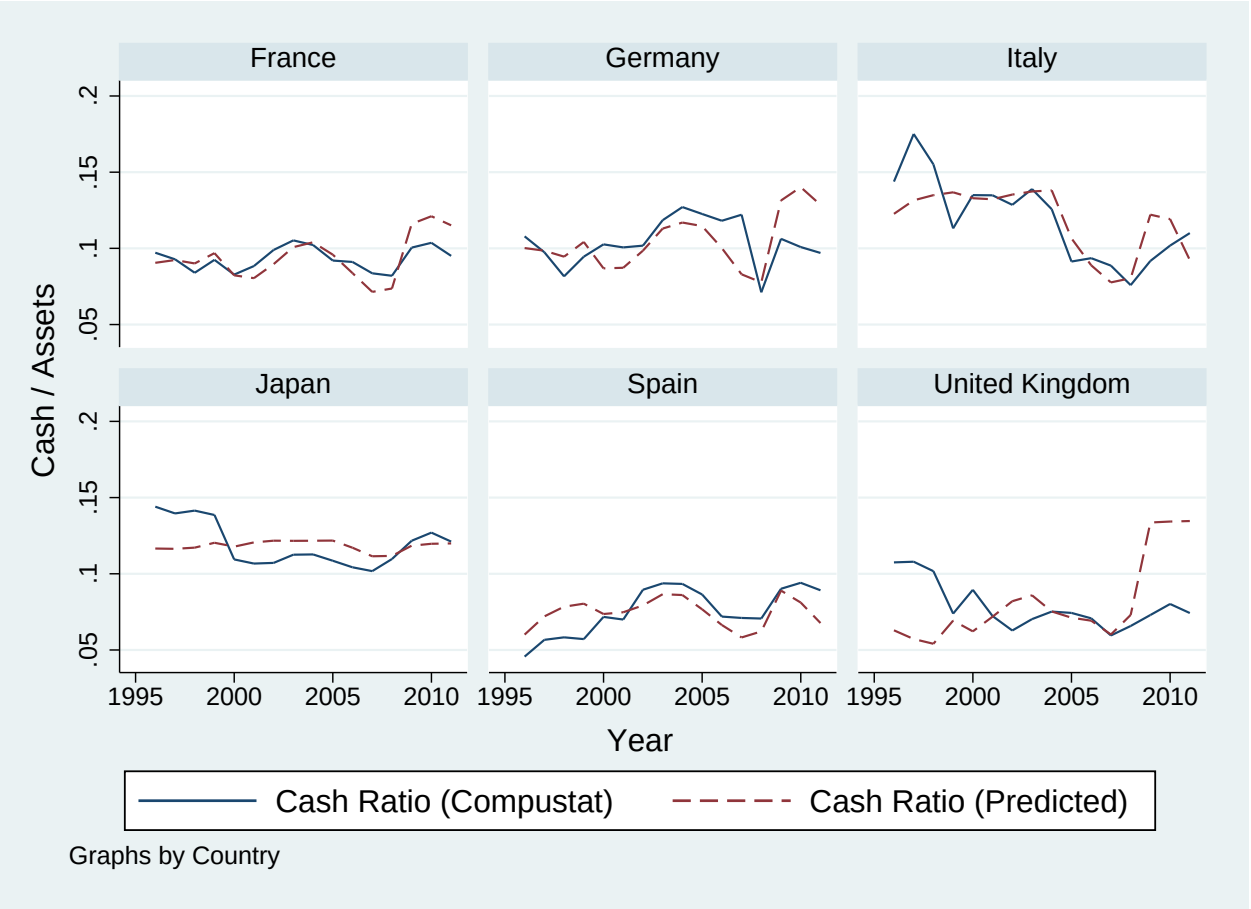


Figure 10: Predicted versus actual cash-to-asset ratio, 1996-2011, by country.

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.

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 (4). Standard errors are clustered by firm in specifications (5) and (6). Variable definitions are provided in the appendix.

	(1) ln(Cash/Net Assets)	(2) Cash/Net Assets	(3) ln(Cash/Net Assets)	(4) Cash/Net Assets	(5) ln(Cash/Net Assets)	(6) Cash/Net Assets
Opportunity Cost	-16.42***	-0.962***	-11.80***	-0.662***	-12.48***	-0.600***
	(2.275)	(0.0918)	(2.455)	(0.106)	(1.581)	(0.115)
Log of Real Assets	-0.392***	-0.0378***	-0.282***	-0.0177***	-0.358***	-0.0350***
	(0.0660)	(0.0117)	(0.0415)	(0.00317)	(0.0641)	(0.0128)
Industry Sigma			0.568	0.0187	0.755	0.230
			(0.725)	(0.0526)	(1.895)	(0.278)
Cash Flow / Assets			0.193	-0.00774	-0.0789	-0.0447*
			(0.370)	(0.0222)	(0.302)	(0.0238)
NWC / Assets			-3.158***	-0.258***	-1.586***	-0.130***
			(0.413)	(0.0191)	(0.384)	(0.0397)
R&D / Sales			0.210***	0.0508***	0.228***	0.0445***
			(0.0647)	(0.0100)	(0.0642)	(0.0101)
Dividend Dummy			-0.103	-0.00332	-0.00299	0.000921
			(0.0805)	(0.00601)	(0.0775)	(0.00869)
Market to Book			0.0746***	0.00812***	0.0892***	0.00820***
			(0.0210)	(0.00237)	(0.0214)	(0.00268)
Capex			-4.039***	-0.277***	-3.554***	-0.343***
			(0.388)	(0.0270)	(0.566)	(0.0992)
Leverage			-2.016***	-0.147***	-1.454***	-0.0946***
			(0.245)	(0.0132)	(0.222)	(0.0225)
Acquisition Activity			-1.023***	-0.107***	-1.118***	-0.114***
			(0.252)	(0.0174)	(0.236)	(0.0241)
Firm FE	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓
Multiple Imputation					✓	✓
Observations	92,206	92,206	79,624	79,624	92,206	92,206
R-squared	0.175	0.138	0.206	0.208		
Number of Firms	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 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 (4). Standard errors are clustered by firm in specifications (5) and (6). Variable definitions are provided in the appendix.

	(1) ln(Cash/Net Assets)	(2) Cash/Net Assets	(3) ln(Cash/Net Assets)	(4) Cash/Net Assets	(5) ln(Cash/Net Assets)	(6) Cash/Net Assets
Opportunity Cost	-11.49***	-0.570***	-8.766***	-0.441***	-8.668***	-0.345***
	(1.606)	(0.127)	(1.370)	(0.0685)	(1.109)	(0.105)
Lagged ln(Cash/Net Assets)	0.595***		0.555***		0.581***	
	(0.0183)		(0.0113)		(0.0185)	
Lagged (Cash/Net Assets)		0.715***		0.571***		0.703***
		(0.0627)		(0.0154)		(0.0611)
Log of Real Assets	-0.176***	-0.0116***	-0.140***	-0.00803***	-0.173***	-0.0120***
	(0.0234)	(0.00164)	(0.0180)	(0.00151)	(0.0262)	(0.00249)
Industry Sigma			-0.268	-0.0167	-0.235	0.0353
			(0.405)	(0.0290)	(0.799)	(0.0585)
Cash Flow / Assets			0.327	0.0226	0.0969	0.00607
			(0.258)	(0.0161)	(0.198)	(0.0141)
NWC / Assets			-1.946***	-0.158***	-0.957***	-0.0706***
			(0.236)	(0.0139)	(0.246)	(0.0215)
R&D / Sales			0.0236	0.00987**	0.0268	0.000536
			(0.0432)	(0.00489)	(0.0401)	(0.00706)
Dividend Dummy			-0.0240	0.000266	0.0293	0.00321
			(0.0494)	(0.00340)	(0.0487)	(0.00359)
Market to Book			0.0412***	0.00405***	0.0457***	0.00297*
			(0.0133)	(0.00149)	(0.0138)	(0.00175)
Capex			-4.268***	-0.311***	-3.487***	-0.282***
			(0.268)	(0.0207)	(0.339)	(0.0322)
Leverage			-0.911***	-0.0633***	-0.633***	-0.0278**
			(0.147)	(0.00719)	(0.120)	(0.0129)
Acquisition Activity			-2.628***	-0.216***	-2.420***	-0.205***
			(0.209)	(0.0200)	(0.179)	(0.0156)
Firm FE	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓
Multiple Imputation					✓	✓
Observations	88,071	88,071	76,062	76,062	88,071	88,071
R-squared	0.477	0.596	0.465	0.499		
Number of Firms	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. Industry-level (firm-level) opportunity cost is the T-Bill rate times the industry average of (the firm's) fraction of cash that is held in immediately negotiable media of exchange (CH/CHE). Firm-level opportunity cost is defined as the T-Bill rate times CH/CHE. Specification (3) instruments firm-level opportunity cost by T-Bill rate times the firm's average level of CH/CHE over the years 1970-1979. In the difference-in-difference specifications (4) and (5), firms below the median or in the lowest quintile by (Compustat CH/CHE) on average in the 1970s are "treated"; the control groups are assigned symmetrically. "Post" treatment 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.

	(1)	(2)	(3)	(4)	(5)
	Dependent Variable: ln(Cash/Net Assets)				
	WLS	WLS	Instrumental Variable	Diff-in-diff (median)	Diff-in-diff (quintiles)
Industry-Level Opportunity Cost	-21.55***				
	(3.873)				
Firm-Level Opportunity Cost		-15.28***	-14.36***		
		(1.913)	(4.541)		
Above-median CH/CHE × post				1.076***	
				(0.195)	
Highest-quintile CH/CHE × post					1.951***
					(0.196)
Log of Real Assets	-0.283***	-0.294***	-0.266***	-0.338***	-0.580***
	(0.0419)	(0.0360)	(0.0443)	(0.0629)	(0.0601)
Industry Sigma	0.414	1.162	0.810	-0.138	0.0318
	(0.774)	(0.814)	(0.936)	(2.028)	(2.388)
Cash Flow / Assets	0.168	0.203	0.180	2.470*	6.996***
	(0.371)	(0.347)	(0.516)	(1.378)	(1.518)
NWC / Assets	-3.043***	-2.946***	-3.185***	-3.460***	-5.061***
	(0.422)	(0.428)	(0.595)	(0.617)	(0.611)
R&D / Sales	0.219***	0.196***	1.244**	10.37***	8.326***
	(0.0695)	(0.0666)	(0.616)	(2.502)	(1.882)
Dividend Dummy	-0.120*	-0.0935	-0.175**	-0.368*	-0.226
	(0.0731)	(0.0696)	(0.0779)	(0.190)	(0.194)
Market to Book	0.0900***	0.0825***	0.105**	-0.0658	-0.572***
	(0.0258)	(0.0266)	(0.0463)	(0.100)	(0.130)
Capex	-3.534***	-3.656***	-5.096***	-5.547***	-5.939***
	(0.377)	(0.390)	(0.501)	(1.216)	(1.000)
Leverage	-1.832***	-1.675***	-2.136***	-1.288***	-0.766
	(0.225)	(0.208)	(0.246)	(0.474)	(0.479)
Acquisition Activity	-1.324***	-1.393***	-1.711***	0.211	-0.262
	(0.231)	(0.234)	(0.267)	(1.377)	(1.242)
Firm FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
Observations	74,209	74,209	28,760	688	306
R-squared	0.229	0.275	0.333	0.357	0.651
Number of Firms	4,921	4,921	1,572	344	153

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 held in currency and checking accounts by the 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 rolling 21-year average 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

- CHincludes
  - 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
- CHEincludes 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

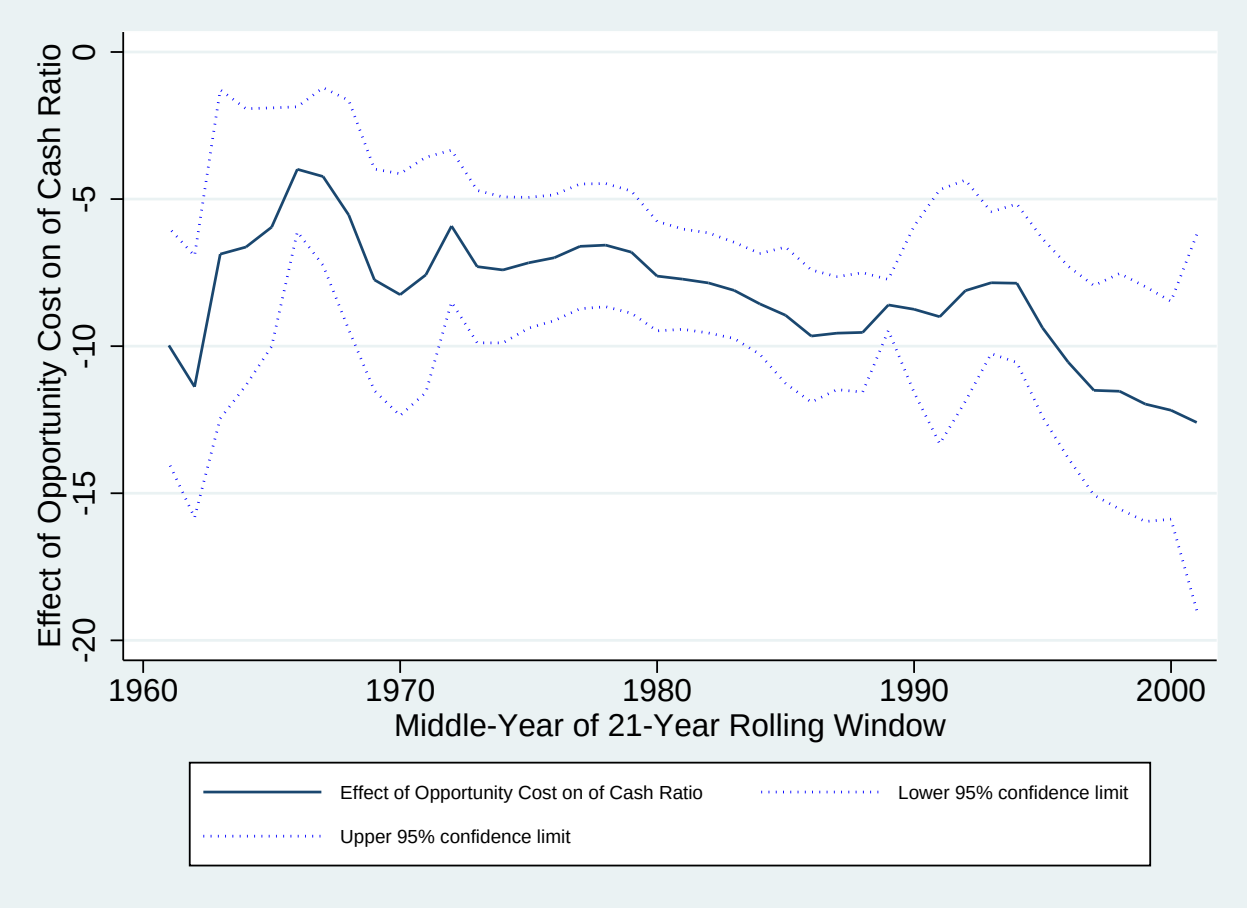
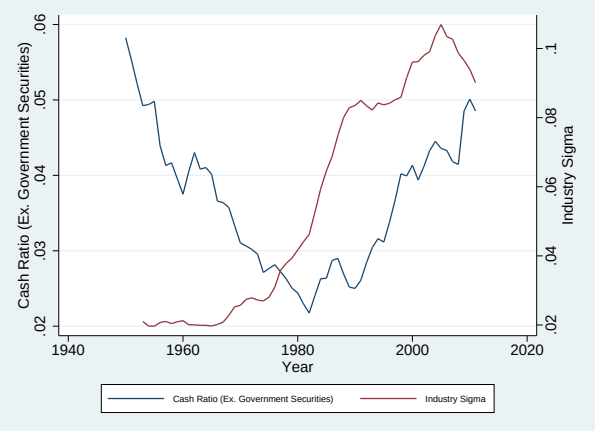
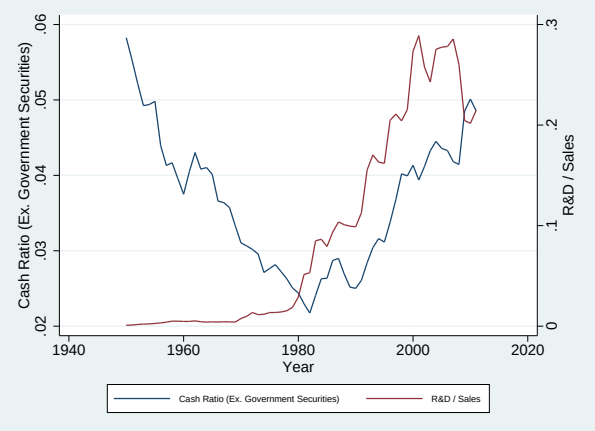


Figure B.1: Rolling Regressions of Firm-Level Money Demand.

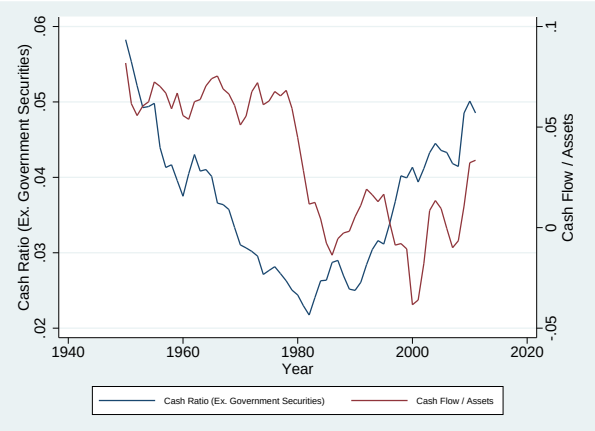
The estimated effects of the opportunity cost on the cash ratio are based on rolling regressions of the log cash ratio as a function of opportunity cost, log of assets, a cubic time trend, and firm fixed effects. The window includes ten years before and ten years after the year indicated in the x axis. 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 at the firm and year level.



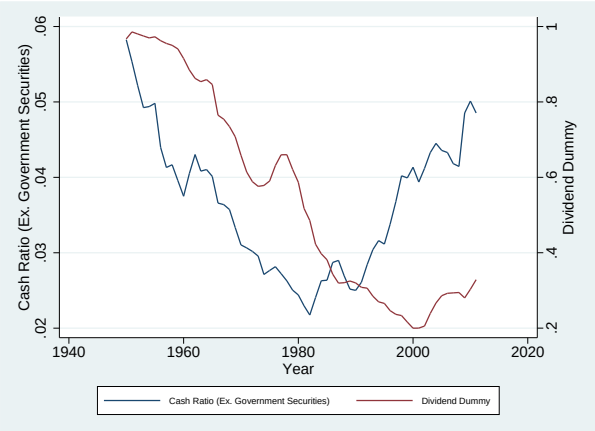
(a) Cash flow volatility



(b) R&D



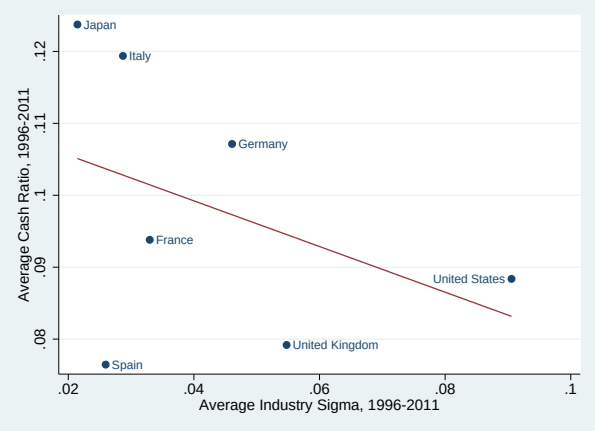
(c) Cash flow / assets



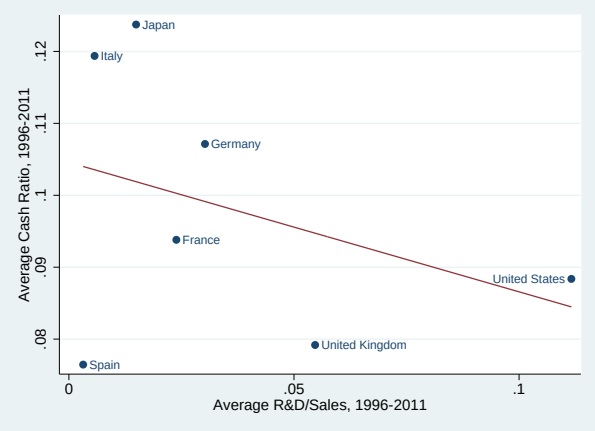
(d) Dividend dummy

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

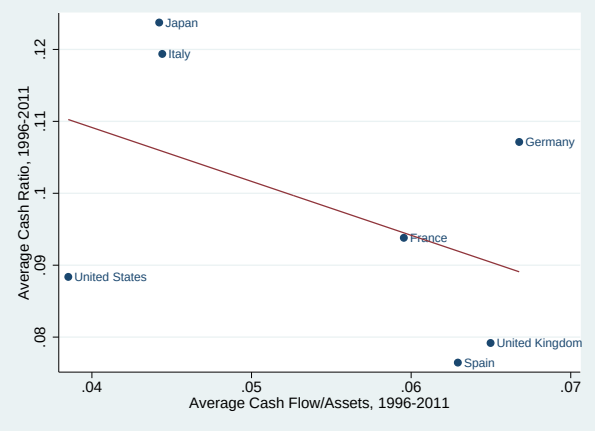
Data comprises all Compustat firms except financials and utilities. All variables are calculated as in Bates, Kahle, and Stulz (2009).



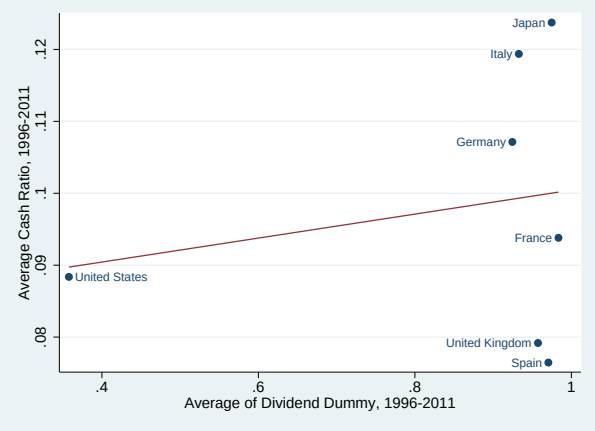
(a) Cash flow volatility



(b) R&D



(c) Cash flow / assets



(d) Dividend dummy

Figure B.3: Scatter plots of cash holdings versus explanatory papers from existing papers, 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 (4). Standard errors are clustered by firm in specifications (5) and (6). Variable definitions are provided in the appendix.

	(1) ln(Cash/Net Assets)	(2) Cash/Net Assets	(3) ln(Cash/Net Assets)	(4) Cash/Net Assets	(5) ln(Cash/Net Assets)	(6) Cash/Net Assets
Opportunity Cost	-16.91***	-1.000***	-12.20***	-0.682***	-13.01***	-0.636***
	(1.911)	(0.0592)	(2.112)	(0.0928)	(1.618)	(0.118)
Log of Real GDP	2.537***	0.197*	2.705***	0.136***	2.459***	0.165**
	(0.889)	(0.104)	(0.824)	(0.0489)	(0.650)	(0.0738)
Log of Real Assets	-0.398***	-0.0382***	-0.287***	-0.0180***	-0.363***	-0.0353***
	(0.0666)	(0.0119)	(0.0419)	(0.00320)	(0.0649)	(0.0129)
Industry Sigma			0.265	0.00337	0.449	0.209
			(0.712)	(0.0534)	(1.877)	(0.271)
Cash Flow / Assets			0.167	-0.00903	-0.0751	-0.0445*
			(0.363)	(0.0217)	(0.295)	(0.0235)
NWC / Assets			-3.153***	-0.258***	-1.586***	-0.130***
			(0.410)	(0.0191)	(0.383)	(0.0398)
R&D / Sales			0.209***	0.0507***	0.231***	0.0446***
			(0.0646)	(0.0101)	(0.0649)	(0.0101)
Dividend Dummy			-0.104	-0.00334	-0.00556	0.000749
			(0.0801)	(0.00595)	(0.0768)	(0.00869)
Market to Book			0.0757***	0.00818***	0.0894***	0.00822***
			(0.0206)	(0.00236)	(0.0212)	(0.00266)
Capex			-4.019***	-0.276***	-3.540***	-0.343***
			(0.388)	(0.0274)	(0.562)	(0.0991)
Leverage			-2.013***	-0.147***	-1.455***	-0.0946***
			(0.247)	(0.0133)	(0.224)	(0.0226)
Acquisition Activity			-1.101***	-0.111***	-1.191***	-0.119***
			(0.254)	(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
R-squared	0.178	0.141	0.210	0.210		
Number of Frims	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 (4). Standard errors are clustered by firm in specifications (5) and (6). Variable definitions are provided in the appendix.

	(1) ln(Cash/Net Assets)	(2) Cash/Net Assets	(3) ln(Cash/Net Assets)	(4) Cash/Net Assets	(5) ln(Cash/Net Assets)	(6) Cash/Net Assets
Opportunity Cost	-15.02***	-0.713***	-11.47***	-0.584***	-11.29***	-0.423***
	(2.699)	(0.205)	(2.285)	(0.110)	(1.558)	(0.155)
Lagged ln(Cash/Net Assets)	0.596***		0.554***		0.581***	
	(0.0187)		(0.0116)		(0.0182)	
Lagged Cash/Net Assets		0.716***		0.572***		0.703***
		(0.0621)		(0.0154)		(0.0606)
Log of Real GDP	-0.375	-0.0389	0.109	-0.0162	-0.0624	-0.0225
	(0.703)	(0.0548)	(0.613)	(0.0335)	(0.422)	(0.0309)
Log of Real Assets	-0.177***	-0.0116***	-0.140***	-0.00800***	-0.173***	-0.0119***
	(0.0242)	(0.00173)	(0.0183)	(0.00152)	(0.0266)	(0.00253)
Industry Sigma			-0.333	-0.0178	-0.298	0.0350
			(0.389)	(0.0293)	(0.792)	(0.0567)
Cash Flow / Assets			0.323	0.0226	0.0981	0.00610
			(0.255)	(0.0159)	(0.196)	(0.0141)
NWC / Assets			-1.935***	-0.157***	-0.950***	-0.0702***
			(0.237)	(0.0139)	(0.248)	(0.0215)
R&D / Sales			0.0243	0.00992**	0.0278	0.000543
			(0.0435)	(0.00491)	(0.0403)	(0.00704)
Dividend Dummy			-0.0227	0.000351	0.0299	0.00325
			(0.0496)	(0.00342)	(0.0490)	(0.00360)
Market to Book			0.0439***	0.00417***	0.0485***	0.00308*
			(0.0134)	(0.00149)	(0.0139)	(0.00175)
Capex			-4.202***	-0.309***	-3.429***	-0.280***
			(0.266)	(0.0206)	(0.337)	(0.0322)
Leverage			-0.901***	-0.0627***	-0.627***	-0.0275**
			(0.147)	(0.00718)	(0.121)	(0.0129)
Acquisition Activity			-2.621***	-0.215***	-2.413***	-0.204***
			(0.205)	(0.0200)	(0.180)	(0.0158)
Firm FE	✓	✓	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓	✓	✓
Multiple Imputation					✓	✓
Observations	88,071	88,071	76,062	76,062	88,071	88,071
R-squared	0.477	0.596	0.465	0.499		
Number of Firms	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: 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	-6.379***	-11.84***	-11.91***	-10.90***	-12.63***	-10.92***	-11.35***	-13.42***	-12.65***	-9.834***
	(1.692)	(2.478)	(3.085)	(1.994)	(2.362)	(2.661)	(2.427)	(3.389)	(3.078)	(2.492)
Log of Real Assets	0.0523	-0.288***	-0.313***	-0.225***	-0.285***	-0.282***	-0.293***	-0.250***	-0.253***	-0.297***
	(0.0320)	(0.0423)	(0.0628)	(0.0417)	(0.0834)	(0.0388)	(0.0490)	(0.0552)	(0.0578)	(0.0476)
Industry Sigma	3.139***	0.529	0.768	0.499	-0.326	0.627	0.819	-0.396	1.353*	0.489
	(1.002)	(0.730)	(3.039)	(0.870)	(1.275)	(0.936)	(0.846)	(1.611)	(0.812)	(1.084)
Cash Flow / Assets	0.239	0.117	0.612	-0.186	0.147	0.320	0.258	0.0529	-0.435	0.637
	(0.147)	(0.404)	(0.706)	(0.295)	(0.267)	(0.681)	(0.438)	(0.359)	(0.436)	(0.481)
NWC / Assets	-2.305***	-3.222***	-3.543***	-2.560***	-2.891***	-3.316***	-3.252***	-2.877***	-3.511***	-2.983***
	(0.153)	(0.430)	(0.654)	(0.303)	(0.348)	(0.556)	(0.641)	(0.280)	(0.695)	(0.486)
R&D / Sales	0.199***	0.211***	0.553	0.187***	0.174***	0.381	0.201***	0.473**	-58.28***	0.254***
	(0.0294)	(0.0786)	(0.362)	(0.0566)	(0.0602)	(0.255)	(0.0723)	(0.194)	(17.19)	(0.0693)
Dividend Dummy	0.145*	-0.105	-0.127	-0.101	-0.0425	-0.154	-0.0943	-0.122	-0.149	-0.0776
	(0.0770)	(0.0818)	(0.112)	(0.0939)	(0.123)	(0.0972)	(0.101)	(0.0962)	(0.103)	(0.120)
Market to Book	0.0911***	0.0757***	0.0970*	0.0629***	0.143***	0.0665***	0.0724***	0.0789***	0.119***	0.0591***
	(0.0122)	(0.0218)	(0.0538)	(0.0192)	(0.0359)	(0.0227)	(0.0269)	(0.0261)	(0.0417)	(0.0223)
Capex	-2.217***	-4.090***	-4.750***	-3.295***	-3.156***	-4.401***	-4.158***	-4.037***	-2.983***	-5.879***
	(0.238)	(0.401)	(0.642)	(0.383)	(0.710)	(0.501)	(0.467)	(0.801)	(0.478)	(0.747)
Leverage	-3.217***	-1.997***	-1.998***	-2.073***	-1.856***	-2.139***	-1.933***	-2.280***	-1.673***	-2.498***
	(0.158)	(0.251)	(0.342)	(0.215)	(0.385)	(0.265)	(0.297)	(0.220)	(0.310)	(0.317)
Acquisition Activity	-1.525***	-1.030***	-0.700**	-1.553***	-0.200	-1.390***	-0.842***	-1.678***	-0.536	-1.438***
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	0.208	0.214	0.205	0.207	0.212	0.200	0.234	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.3: 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	-10.36***	-11.57***	-12.86***	-9.894***	-10.73***	-12.15***	-9.883***	-12.44***	-14.89***	-8.680***
	(3.107)	(2.512)	(3.125)	(1.841)	(2.533)	(3.024)	(1.258)	(3.112)	(2.994)	(2.559)
Log of Real Assets	-0.207***	-0.315***	-0.304***	-0.268***	-0.417***	-0.204***	-0.209***	-0.322***	-0.191***	-0.336***
	(0.0321)	(0.0471)	(0.0675)	(0.0461)	(0.0636)	(0.0419)	(0.0506)	(0.0579)	(0.0505)	(0.0592)
Industry Sigma	0.654	0.459	1.052	-0.656	-0.912	1.094	1.460	0.0245	0.620	0.823
	(1.136)	(0.812)	(0.943)	(1.154)	(1.074)	(0.970)	(0.976)	(0.901)	(1.065)	(0.988)
Cash Flow / Assets	0.267	0.130	0.302	-0.0119	-0.178	0.557	0.819	-0.0894	1.311*	-0.679*
	(0.219)	(0.468)	(0.542)	(0.443)	(0.342)	(0.595)	(0.581)	(0.447)	(0.700)	(0.403)
NWC / Assets	-2.394***	-3.360***	-2.850***	-3.325***	-3.130***	-3.060***	-2.875***	-3.302***	-3.596***	-2.713***
	(0.228)	(0.484)	(0.338)	(0.652)	(0.336)	(0.666)	(0.371)	(0.633)	(0.673)	(0.421)
R&D / Sales	0.228***	0.878*	0.561	0.165**	0.0699	0.451***	0.292***	0.218**	0.316***	0.151
	(0.0467)	(0.505)	(1.100)	(0.0733)	(0.0659)	(0.144)	(0.0935)	(0.0919)	(0.0820)	(0.118)
Dividend Dummy	0.826**	-0.108	-0.210**	0.0332	0.0655	-0.246**	-0.0353	-0.148	-0.169	-0.0904
	(0.402)	(0.0827)	(0.0986)	(0.0961)	(0.108)	(0.0971)	(0.0956)	(0.0984)	(0.124)	(0.0908)
Market to Book	0.0460	0.0827***	0.243***	0.0512***	0.0603*	0.0787***	0.0615***	0.0565	0.0507*	0.0947***
	(0.0317)	(0.0278)	(0.0816)	(0.0192)	(0.0309)	(0.0275)	(0.0187)	(0.0507)	(0.0299)	(0.0269)
Capex	-1.186***	-4.717***	-4.305***	-3.523***	-4.299***	-4.065***	-4.437***	-3.670***	-4.200***	-3.778***
	(0.361)	(0.458)	(0.515)	(0.492)	(1.268)	(0.440)	(0.721)	(0.455)	(0.563)	(0.625)
Leverage	-1.615***	-2.086***	-1.823***	-2.270***	-2.128***	-1.944***	-3.060***	-1.731***	-1.918***	-2.020***
	(0.213)	(0.271)	(0.350)	(0.275)	(0.374)	(0.266)	(0.331)	(0.289)	(0.354)	(0.305)
Acquisition Activity	-1.192***	-1.028***	-1.048***	-1.087***	-0.776***	-1.331***	-1.871***	-0.637**	-1.629**	-0.924***
	(0.287)	(0.265)	(0.303)	(0.375)	(0.281)	(0.273)	(0.370)	(0.267)	(0.791)	(0.223)
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	0.217	0.208	0.223	0.253	0.196	0.273	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.4: 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	-9.581***	-11.06***	-20.62***	-13.35**
	(2.361)	(1.599)	(4.297)	(5.234)
Log of Real Assets	-0.268***	-0.176***	-0.410***	-0.296***
	(0.0539)	(0.0550)	(0.0723)	(0.0821)
Industry Sigma	-0.0598	3.133*	-2.417	1.508
	(1.143)	(1.748)	(5.457)	(1.060)
Cash Flow / Assets	0.355	-0.285	-2.121***	0.556
	(0.460)	(0.374)	(0.650)	(0.889)
NWC / Assets	-2.820***	-3.620***	-4.776***	-2.361***
	(0.456)	(0.435)	(1.213)	(0.367)
R&D / Sales	0.230***	0.222*	0.535*	0.569
	(0.0659)	(0.117)	(0.306)	(0.444)
Dividend Dummy	0.000453	-0.125	0.0995	-0.305*
	(0.118)	(0.121)	(0.168)	(0.157)
Market to Book	0.0852***	0.0688***	0.00160	0.220**
	(0.0256)	(0.0209)	(0.0159)	(0.0862)
Capex	-5.369***	-2.451***	-4.730***	-3.512***
	(0.616)	(0.675)	(1.474)	(0.675)
Leverage	-2.621***	-1.630***	-1.208***	-1.311***
	(0.319)	(0.273)	(0.348)	(0.498)
Acquisition Activity	-1.090***	-1.796***	-2.542**	-0.512
	(0.250)	(0.292)	(1.162)	(0.481)
Firm FE	✓	✓	✓	✓
Cubic Time Trend	✓	✓	✓	✓
Observations	45,009	13,197	7,051	14,367
R-squared	0.233	0.272	0.354	0.154
Number of Firms	2,646	972	427	904

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