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Cost of carry, financial constraints, and dynamics of corporate cash holdings

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ABSTRACT

This paper provides new evidence on how the cost of carry is linked to corporate cash policy in the presence of financial frictions. Using both time-series and firm-level data for US public and private manufacturing firms, we find a negative correlation between cash holdings and the cost of carry for financially unconstrained firms. We find no evidence of such a relation for financially constrained firms. Our results suggest that financial constraints play an important role in adjusting cash to changes in the cost of carry. We introduce a simple model in which firms differ in their cost function of external finance, where the constrained firms' highly curved cost function drives a steeper cash demand, leading to their lower cash sensitivity to the cost of carry.

1. Introduction

What determines corporate cash holdings? Both firm characteristics and macroeconomic conditions drive the observed changes in corporate cash holdings through time. The effect of macroeconomic factors on firms' financial behavior has received increasing attention in the academic literature and the financial press. This paper investigates how changes in the interest rates will trigger adjustments in firms' cash holdings through their effect on the cost of carrying cash and provides new evidence that financial constraints play an important role in the adjustment of corporate cash.

Earlier studies in this literature view cash as a non-interest-bearing asset. Therefore, cash is a costly factor of production, and the interest rate is simply the opportunity cost of holding it. This causes the corporate cash to co-move with the risk-free interest rates. However, although a large body of literature has explored this topic, there is no general agreement about the relationship between interest rates and corporate cash holdings. While Boileau and Moyen (2016) and Acharya et al. (2012) find a strong negative relationship between corporate cash and interest rates, Stone et al. (2018) find a positive relation. Moreover, Graham and Leary (2015) show that this relation is weak and insignificant, and, more recently, Gao et al. (2021) document a hump-shaped relation between interest rates and corporate cash demand.

However, recent literature criticizes the previous results and shows that firms became increasingly able to hedge the interest rate

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sensitivity of the cost of their liquid-assets portfolios by investing in interest-bearing assets over the last decades. In particular, Azar et al. (2016) argue that between 1945 and 1980, when cash was not interest bearing and the interest rate was increasing, corporate cash holdings became increasingly costly, and the cash ratio was declining. When the regulations restricting firms to keep cash in non-interest bearing accounts were gradually lifted, they started to use a combination of safe and liquid financial instruments such as Treasury bills to protect their assets against inflation. Therefore, the cost of carrying cash started to decrease, and the cash ratio became increasing. They show that changes in the cost of carry alone can explain much of the observed variation of U.S. corporate cash holdings dynamics. Graham and Leary (2018), however, show that the cost of carry explains very little of the time-series variation of aggregate cash over the past century. They find that changes in aggregate corporate cash from 1920 to 2014 are primarily driven by macroeconomic variables, corporate profitability and investment, and since 2000, repatriation taxes, but not by variations in the cost of carry.

We contribute to this literature by showing that this relation depends on the level of financial constraints facing firms. The main finding of our study suggests that the negative correlation between the cash holdings and the cost of carry is restricted to unconstrained firms. Our empirical results suggest that financially unconstrained firms adjust their cash balances when the cost of carry changes, whereas constrained firms do not exhibit this propensity. Our finding, therefore, sheds more light on the channel through which the cost of carry affects the variations in corporate cash. In addition, it shows how the results in previous studies are connected, in particular Azar et al. (2016) and Graham and Leary (2018), which are the most closely related studies to ours. The negative correlation found by Azar et al. (2016) is probably related to their sample, which relies on publicly traded firms and neglects small and private firms, which are more likely to be financially constrained. Their findings are then biased toward large and medium-sized firms that exhibit a higher propensity to adjust cash when the cost of carry changes. On the other hand, Graham and Leary (2018) use aggregate data that includes both small and large firms and suggest a weak correlation between the cost of carry and cash holdings. Their results, then, might be driven by the small cohort of firms.

Therefore, the heterogeneous relation between cash ratio and the cost of carry that we observe between small and large firms complements the findings of the recent studies. We also present a simple model to demonstrate how the cost of carry has heterogeneous impacts on constrained and unconstrained firms through their effect on the cost of holding cash. The primary mechanism is as follows.

On the one hand, there is always an incremental benefit of holding one more unit of liquid assets since being short of liquid assets is costly. A firm that faces a liquidity shortage has to raise external funds for its operational and investment purposes, which is costly when access to capital markets is limited. This cost is smaller for unconstrained firms with a flatter external finance cost function. On the other hand, however, holding liquid assets is costly. We can reasonably assume that a portion of corporate cash is held in non-interest-bearing accounts and, therefore, firms face an opportunity cost of holding cash equals the fraction of cash held in non-interest-bearing accounts multiplied by the interest rate (the rate of interest-bearing assets, e.g., T-bill rate). Given that the marginal benefit of holding cash is diminishing with respect to the amount of cash held (Opler et al., 1999), the marginal cost of holding cash exceeds the marginal benefit as the cost of carry increases. Therefore, firms respond to increases in the cost of carry by reducing their cash. Moreover, we discuss that unconstrained firms have a flatter marginal cost function of cash shortage driven by their flatter external finance cost function (Farre-Mensa and Ljungqvist, 2016). Therefore, the response of unconstrained firms is more pronounced when the cost of carry changes. In other words, the constrained firms' highly curved cost function drives a steeper cash demand, leading to their lower cash sensitivity. Our empirical analysis verifies this hypothesis using both time-series and firm-level data.

Moreover, our paper contributes to the literature that links financing friction to corporate cash dynamics and, in particular, attempts to explain the cash build-up from 1980 to 2010. The main argument of these studies is that the marginal benefit of holding cash accounts for differences in cash policies between constrained and unconstrained firms (Opler et al., 1999; Denis, 2011). In an environment where external finance is costly, these benefit-based theories argue that firms hold cash to build financial slack to avoid the adverse consequences of shocks to earnings or investment opportunities (Kaplan and Zingales, 1997; Stein, 2003; Almeida et al., 2004; Almeida et al., 2011). In other words, firms increase their financial flexibility by holding liquid assets since holding an additional dollar of liquid assets decreases the probability of facing a liquidity shortage (Denis, 2011; Kim et al., 1998; Opler et al., 1999). While a lot of research has been conducted on the benefit-based explanations, no study has been conducted on the link between financial frictions and the cost-based explanation of cash dynamics. The cost-based explanation suggests that changes over time in the net cost of financing liquid assets can explain the long-run dynamics of corporate cash holdings.[1] We complement this literature by introducing a new mechanism linking financial frictions and the cost-based explanation of cash dynamics. The cost-based explanation suggests that changes over time in the net cost of financing liquid assets can explain the long-run dynamics of corporate cash holdings. Here, we look at the cost of carrying cash in the presence of financial constraints. We then extend the recent literature on the cost-based explanation of cash dynamics by shedding additional light on the cost of carry hypothesis (that time variation in the cost of holding liquid assets implies the long-run dynamics of corporate cash holdings) when firms face borrowing constraints.

In this paper, we use the US Census Bureau Quarterly Financial Report (QFR), which covers the statistics of US manufacturing firms in different size classes at quarterly frequencies since the 1950s.[2] The main advantage of the QFR is that it includes both publicly and privately held firms, where private firms dominate the lower tier of its sample size distribution. Since firms of different sizes might be

[1] These studies indicate that benefit-based theories leave unexplained the even more pronounced decrease in cash ratio from 1945 to 1980, as well as the international variation of corporate liquid asset holdings (see Azar et al., 2016).

[2] QFR is unexplored data since it was only available in hard copies prior to 1988, and there are some changes in its size brackets during the time. We extended it back to 1956 by collecting data from various issues of the QFR books and microfiches. We then transformed all the data into electronic versions and integrated them into unified forms.

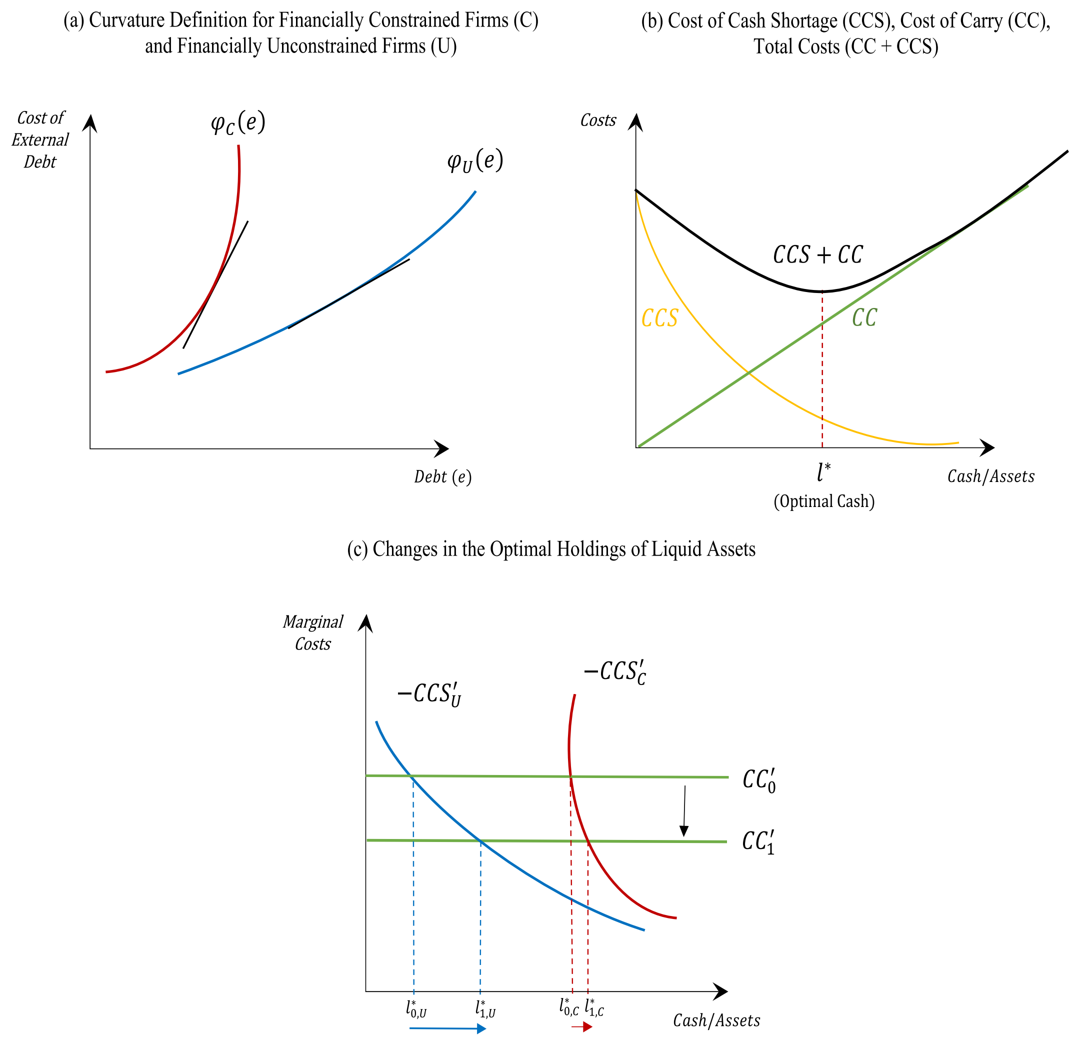

Fig. 1. Financial constraints, cost of carry, and optimal holdings of liquid assets.
Panel (a) illustrates the extent of financial constraints a firm faces in terms of the curvature of cost function ($\phi(e)$) for two hypothetical firms. The firm on the left is financially constrained ($\phi_C(e)$) and the firm on the right is financially unconstrained ($\phi_U(e)$) according to the curvature definition. Panel (b) portrays the optimal amount of liquid assets when firms consider both the cost of cash shortage and the cost of carry. Panel (c) illustrates the responses of firms to changes in the cost of carry. Considering that the optimal amount of cash held (l^*) is given by the intersection of the marginal cost of carry (CC') and the negative marginal cost of liquid asset shortage (CCS') curves, a reduction in the marginal cost of holding cash leads to a considerably more increase in the optimal corporate cash holdings for the financially unconstrained firms.

essentially heterogeneous in terms of financial constraint and access to liquidity, understanding their cash policies allows us to understand how financial factors may drive firms' liquidity management. In general, private and smaller firms (that are more likely to be bank-dependent and financially constrained) are not traded publicly and are omitted in most existing studies. Therefore, analyzing the cash holdings dynamics of small versus large firms provides new insights into the role of financial frictions in the cash policy of firms. Another advantage of QFR is that it provides data over a long horizon, back to 1956, when the cash ratio has had a non-linear trend.

We also complement our analysis by using a sample of US public firms from Compustat between 1984 and 2014 and analyze the response of financially constrained versus unconstrained firms to changes in the cost of carry. We use four alternative approaches to sorting firms into financially constrained and unconstrained using annual payout ratio, firm size, debt rating, and Kaplan-Zingales index. The results confirm our previous findings that the negative and significant relationship between cash and cost of carry is restricted to financially unconstrained firms. The overall message of our analysis based on both QFR and Compustat data is that variations in the cost of carry can explain only the cash dynamics of large and unconstrained firms.

We perform extensive robustness checks and provide further discussions regarding the alternative definitions of the cash ratio, alternative proxies for the cost of carry, alternative model specifications, alternative data frequency, and manufacturing firms and find little change in our results. We also show that excluding the largest firms, especially those in the top 1%, from the other large/

unconstrained firms has minimal impact on our results. It is important because recent empirical studies have provided evidence that the size of very large firms is so enormous that the behavior of the aggregate series is liable to be dominated by their behavior.[3] In addition, while we conduct several robustness checks and control several firm characteristics and other macroeconomic variables, our estimations, in general, might involve identification issues, particularly omitted variables bias and reverse causality. We first attempt to mitigate the potential endogeneity concern that could arise because of the existence of an omitted variable. The most likely omitted variable is productivity. We, therefore, control three measures of productivity: firm-level productivity (firm-level TFP), asset productivity (sales/assets), and macroeconomic productivity (output-to-capital ratio) to address the concerns about the existence of an omitted variable and find that the results are highly robust to the inclusion of each productivity variable.[4] Another endogeneity concern is reverse causality, and it is possible to think about the feedback channel from aggregate corporate data to macroeconomic conditions. Although our time-series analysis might suffer from this reverse causality bias, our firm-level analysis is not prone to this source of endogeneity because the financial decision of a single firm has a negligible effect on macroeconomic conditions.

The structure of this paper is as follows. Section 2 describes our simple theory and empirical hypothesis. Section 3 describes the time-series data and our measurement of small and large firms, provides a descriptive analysis of the time-series trends in cash holdings, and reports our empirical results using time-series data. Section 4 describes the firm-level data and measures of financial constraints and presents our results using firm-level data. Section 5 concludes.

2. Theory and empirical hypothesis

To formalize the main idea of this paper, we introduce a simple model to demonstrate how changes in the cost of carry have heterogeneous impacts on constrained and unconstrained firms through their effect on the cost of holding cash. First, we consider a quadratic cost function for firms that need to raise external finance.[5]

$$\phi(e) = \lambda_1 e + \lambda_2 e^2 \tag{1}$$

where e is the amount of external finance raised and $\phi(e)$ is the proposed cost function capturing the cost at which a firm can raise e units of capital in the capital markets. See Riddick and Whited (2009) for a detailed discussion.

We then apply the curvature definition of financial constraints proposed by Farre-Mensa and Ljungqvist (2016) and characterize the extent of financial constraints a firm faces in terms of the curvature of $\phi(e)$. Based on the curvature definition, we distinguish between constrained and unconstrained firms according to the curvature of their cost functions. A firm is then defined as financially constrained if it faces a highly curved (i.e., steeper) cost function. This notion is shown in panel (a) of Fig. 1. The figure shows the external supply of fund curves faced by two hypothetical firms, where financially constrained firms face a steeper cost function. In other words, a firm is financially constrained if raising an additional dollar of the external fund is very costly since it faces a (close to) vertical supply of external fund curve. More formally:

$$(\partial\phi^c(e)/\partial e)(e/\phi^c(e))\rangle(\partial\phi^u(e)/\partial e)(e/\phi^u(e)),$$

where c and u stand for constrained and unconstrained firms. For the sake of simplicity, we assume that λ_1 is equal between constrained and unconstrained firms ($\lambda_1^c = \lambda_1^u$), and only λ_2 drives the heterogeneity in their cost functions. Therefore, the curvature definition of financial constraint implies[6]:

$$\lambda_2^c > \lambda_2^u. \tag{2}$$

Finally, we consider a simple two-stage economy and explain how firms optimize their cash portfolio. In this model, firms accumulate cash in stage one and invest in stage two. All firms face two costs: the "cost of cash shortage (CCS)" and the "cost of carry (CC)". As widely discussed in the literature, a motive for holding cash is avoiding the cost of cash shortage when access to capital markets is costly (Foley et al., 2007; Bates et al., 2009). Let I denote the amount of fund a firm requires for its operational and investment purposes, and l denote the amount of cash held, where both I and l are normalized by total assets. A firm then faces liquidity shortage

[3] See, e.g., Covas and Den Haan (2011), Autor et al. (2017, 2020), and Van Reenen (2018), among others.

[4] For firm-level productivity definition and details of its construction, see Appendix C.

[5] To maintain simplicity, we restrict our attention to a straightforward model to highlight the paper's main idea. We, therefore, do not account for the equilibrium differences between constrained and unconstrained firms and their implications for optimal cash holdings. In particular, the model ignores the equilibrium differences in the demand for liquidity and the investment opportunity sets between constrained and unconstrained firms, which likely also differ in their sensitivity to he cost of carry.

[6] Here we used the curvature definition of financial constraint in which a constrained firm has a more curved cost of the external finance function. However, an alternative definition of financial constraint can be based on the idea that the constrained firm faces a larger wedge between the costs of internal and external funds, or simply the cost of external finance is larger for the constrained firm (see Farre-Mensa and Ljungqvist, 2016). In this case, the cost function curve for constrained firms may not be more curved but shifted up relative to unconstrained firms. Then, keeping $\lambda_1^c = \lambda_1^u$ assumption, the difference between the constrained and unconstrained firms is $\lambda_2^c > \lambda_2^u$ as well. Therefore, both definitions of financial constraint coincide.

when $l < I$, and burdens the cost of cash shortage (or the cost of raising external funds) which equals to $\phi(I - l)$. This cost is zero when $I \leq l$.[7]

Holding liquid assets, however, is costly. We can reasonably assume that firms hold part of their cash reserves in non-interest-bearing accounts and, therefore, there is an opportunity cost of holding cash. Let the opportunity cost of holding l units of cash is il, where i is the cot of carry. The firm then solves the following optimization problem for holding cash (panel (b) of Fig. 1 illustrates this optimization graphically):

$$\min_{l}\left(\lambda_1(I-l)+\lambda_2(I-l)^2\right)+il \tag{3}$$

here, we argue how the relationship between changes in the cos of carry and cash holdings differs across constrained and unconstrained firms. We fairly assume that the cost of carry is similar for both firms, and it is independent of the amount of liquidity a firm holds.[8,9] Assuming I to be similar for both constrained and unconstrained firms, we show in Proposition 1 that $l(i)$ is more curved for the constrained firm, driven from the steeper cost function of this firm. Therefore, any changes in the cost of carry have a more considerable impact on the optimal cash holdings of the unconstrained firm. This notion is illustrated in the third panel of Fig. 1. Overall, a more curved cost function of the constrained firm (panel (a) of Fig. 1) leads to a steeper cash demand (panel (c) of Fig. 1).[10]

Proposition 1. *The optimal cash holdings of the unconstrained firm is more curved than the constrained firm with respect to a change in the cost of carry, such that:*

$$\frac{\partial l^u}{\partial i} < \frac{\partial l^c}{\partial i} < 0 \tag{4}$$

Proof. See Appendix A ■

This proposition implies that while both firms respond negatively to the cost of carry changes, the response is more pronounced for the unconstrained firm.

In our model, it is costly for firms to be short of liquid assets, and hence there is always an incremental benefit of holding one more unit of liquid assets to prevent cash shortage. On the other hand, holding cash generates an opportunity cost in terms of keeping a non-interest-bearing asset. Therefore, firms have to equate the marginal cost and marginal benefit of holding cash. More formally, the first-order condition (5) implies the negative marginal cost of cash shortage equals the marginal cost of holding cash (cost of carry)[11]:

$$\frac{\partial CCS}{\partial i}+\frac{\partial CC}{\partial i}=0\Rightarrow -\frac{\partial CCS}{\partial i}=\frac{\partial CC}{\partial i} \tag{5}$$

In this context, we interpret Proposition 1 in terms of the curvature of the marginal cost function of liquid asset shortage (CCS') so that the unconstrained firm has the flatter curve. As the interest rate decreases, both firms respond by increasing their cash holdings. This response is more pronounced for the firm with a flatter marginal cost function of liquid asset shortage, which is the unconstrained firm. In other words, while the interest rate is the same, the heterogeneous responses of firms to interest rate changes are mainly driven by differences across the marginal cost of cash shortage. In the following sections, we empirically test this theoretical prediction using both time-series and firm-level data.

3. Time-series analysis

3.1. Data and measurement of small and large firms

This section describes the data and the procedure of constructing the time series for small and large firms.

[7] Here we assume that I is deterministic. The same results will prevail if we consider a more general scheme in which I draws from a Bernoulli distribution with parameter p, where $I \in \left\{\underline{I}, \bar{I}\right\}$ and $I = \bar{I}$ with probability p. Without loss of generality, we let $\underline{I} = 0$. Therefore, the expected cost of cash shortage is $p\phi(I - l)$ which induces similar results as the deterministic case.

[8] Our assumption that the cost of carry is independent of the amount of liquidity held is valid as long as firms with different levels of liquidity invest in similar-yielding assets, thus driving the similar per unit cost for their liquidity as a whole.

[9] Since our focus is primarily on the credit supply channel, we choose to do this in the most straightforward fashion possible by ignoring the credit demand channel and its implications. However, the cost of carry is also tied to credit demand and aggregate productivity shocks, affecting firms' real investment and consequently their financing and cash holdings.

[10] To see how the curvature of the marginal cost function matters, see Ottonello and Winberry (2020), who investigate the role of financial frictions in determining the investment channel of monetary policy. They show that low-risk firms are more responsive to monetary shocks because they face a flatter marginal cost curve for financing investment. Low-risk firms–those with higher distance to default– also have higher credit ratings.

[11] Since the cost of carry is a linear function of the amount of cash held, the marginal cost of carry is li.

Table 1
Summary statistics for time-series variables (small and large firms): 1956–2017.

	Small firms				Large firms				
Variable	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Observations
Cash/assets (%)	9.618	1.161	7.477	12.65	5.879	2.28	3.18	14.573	247
Cash flow volatility	0.004	0.002	0.001	0.009	0.003	0.002	0.001	0.009	244
Cash flow/assets	0.023	0.006	0.011	0.044	0.02	0.008	0.002	0.044	246
Sales/assets (%)	44.356	8.293	27.651	55.214	25.035	5.566	12.846	33.745	247
STD/assets (%)	5.887	1.293	3.28	8.668	2.939	0.794	1.571	4.673	247
LTD/assets (%)	20.389	5.274	8.397	29.063	19.817	3.904	12.293	28.247	247
Investment/assets (%)	42.035	7.721	33.813	59.112	63.513	9.950	45.434	79.639	246
Capex/assets (%)	20.405	5.467	11.336	30.391	16.941	5.883	9.823	28.314	247
NWC/assets (%)	28.675	5.56	17.839	37.182	14.019	10.501	1.565	33.042	247
LTD maturity	0.14	0.021	0.097	0.178	0.062	0.013	0.041	0.098	247

The sample includes manufacturing firms drawn from the US Census Bureau Quarterly Financial Report (QFR) from 1956 to 2017. For variable definitions and details of their construction, see Appendix C.

3.1.1. The quarterly financial report

In this paper, we use the US Census Bureau Quarterly Financial Report (QFR) of manufacturing firms. The QFR program has collected and released statistics of US firms at quarterly frequencies since 1956.[12] Currently, this program covers manufacturing, mining, wholesale trade, retail trade, and some service industries. The Bureau of Economic Analysis uses the QFR data as a primary source to estimate corporate profits for the National Income and Product Accounts (NIPA).[13] The QFR reports the income statements, balance sheets, and related financial and operating ratios for US firms broken down by asset size and industry, based upon a sample survey. At present, the QFR semi-aggregated statistics are released in 8 asset size brackets; under 5, 5–10, 10–25, 25–50, 50–100, 100–250, 250–1000, and over 1000 (all in million dollars).[14]

While most existing studies of cash dynamics are restricted to public firms that are typically large, the QFR allows more general results in the sense that we can explore differences in the cash holdings dynamics of small and large firms. We use QFR due to some advantages of this dataset for our research purposes. One advantage is that it contains a wide range of historical data from 1956 to the present involving potentially informative movements of long-term cash dynamics. Another advantage of QFR is the quarterly frequency of the reported data. Many macroeconomic variables such as interest rates are originally being observed and reported at quarterly frequencies. QFR permits us to use the informational content of such macroeconomic time-series. Finally, the key advantage of QFR is that it covers both small and large firms. For example, relative to Compustat, QFR includes both publicly and privately held firms where private firms dominate the lower tier of its sample size distribution. These private, small, and bank-dependent firms are more likely to be financially constrained firms that are excluded in other publicly released firm-level datasets.

3.1.2. Measurement of small and large firms

We construct our small and large groups using a similar version of the procedure applied in Gertler and Gilchrist (1994). We introduce sales as our indicator of firm size and aggregate all firm size classes into small and large groups. As the QFR brackets are classified based on asset size, we sort the classes from the smallest asset bracket to the largest. We then accumulate their sales beginning from the smallest asset class until we reach the 30^{th} percentile of the total sales in each period, our cutoff for small firms. Large firms are above the 30^{th} percentile of total sales.

Table 1 presents summary statistics of small and large firms. This table shows that there is a negative relation between the magnitude of variables and the size. As a percentage of assets, the cash holdings, sales, short-term debt, and net working capital is almost twice for small firms. However, the investment is proportionally larger for large firms. Appendix 7 details our measurement of small and large firms.

[12] The QFR program is conducted under the authority of Title 13 of the United States Code, Section 91, which requires that financial statistics of business operations be collected and published quarterly. The law imposes a joint obligation on corporations to respond and on the US Census Bureau to maintain the confidentiality of information reported (http://www.census.gov/econ/qfr/historic.htmlhttp://www.census.gov/econ/qfr/historic.html).

[13] Data collected by the QFR are also widely used by the Federal Reserve Board to assess industrial debt structure, liquidity, and profitability; and the Treasury Department to estimate corporate tax liability. In addition, the Council of Economic Advisors and Congressional Committees utilize key indicators derived from QFR data as they design economic policies and draft legislation; the Federal Trade Commission (FTC) utilizes the series as a basic reference point in analyzing the financial performance of American industries, and banking institutions and financial analysts draw upon the series in making investment evaluations.

[14] There were some changes in size brackets and reported data items in 1974, 1980 and 1988. All these data we integrated into unified forms and transformed into electronic versions for the purpose of this study. This data was only available in hard copies prior to 1988. We extended the data back to 1956 by collecting data from various issues of the QFR books and microfiches. We collected all balance sheet and income statement items. An extensive robustness analysis was conducted to verify the accuracy of the collected data.

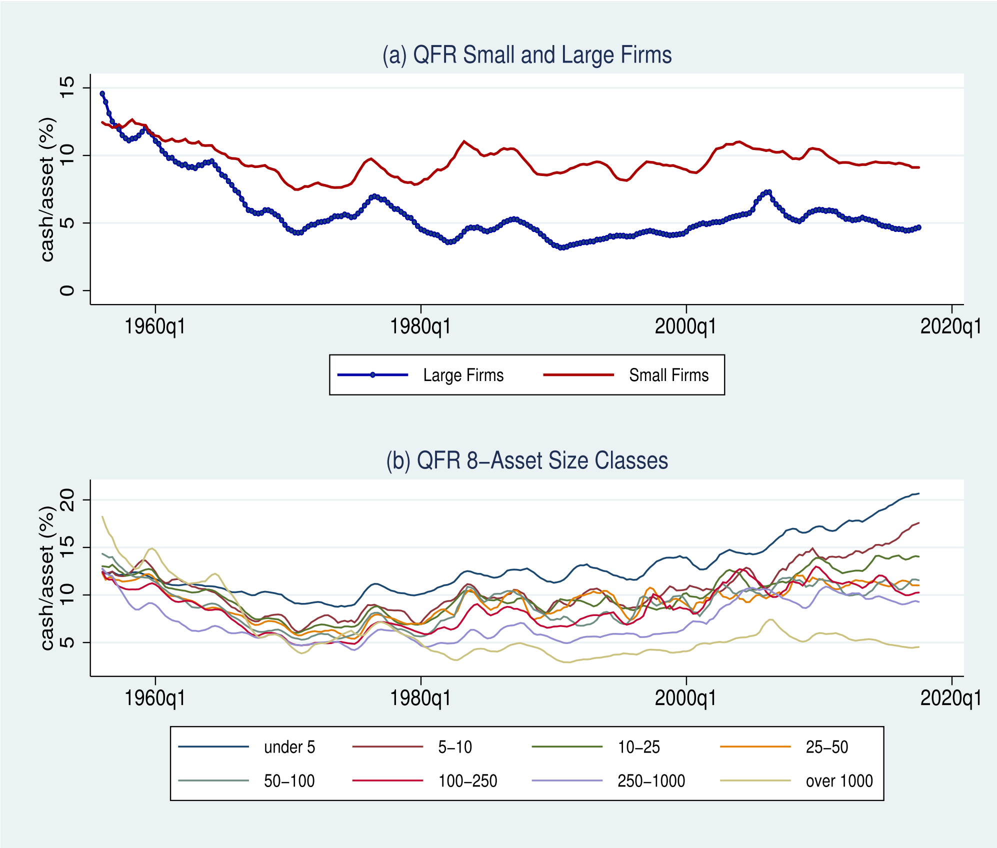

Fig. 2. Cash-to-assets ratios of QFR manufacturing firms.
Panel (a) plots cash-to-assets ratios of QFR small and large manufacturing firms. As shown here, the cash ratio for both groups has roughly a non-linear pattern over the last six decades. Apart from the non-linear pattern of the cash ratio, there appear to be two types of heterogeneity between the average cash ratio of small and large firms. First, small firms hold proportionally more cash than large firms in all episodes. Second, the cash-to-assets ratio of large firms is relatively more volatile than small firms, with the coefficient of variation of small and large firms 12% and 37%. Panel (b) plots cash-to-assets ratios of QFR 8-asset size classes. It shows that the secular variations in cash ratios are driven neither by specific classes of firms nor by our definition of small and large firms.

3.2. Time-series trends in cash: 1956–2017

In this part, we analyze the long-run dynamics of corporate cash holdings. Fig. 2 plots cash-to-assets ratios of QFR small and large manufacturing firms. As shown in Panel A, the cash ratio for both groups has roughly a non-linear pattern over the last six decades, appearing to follow four distinguishable trends. At the beginning of the sample period between 1956 and 1971, the ratios are strongly decreasing, and on average, it falls by 10.4 percentage points for large firms (from 14.6% in 1956Q1 to 4.2% in 1971Q1) and 4.94 percentage points for small firms (from 12.44% in 1956Q1 to 7.5% in 1970Q1).[15] Then, it stops, and the trend becomes quite volatile but stationary until the end of 1989 for both groups, with an average ratio of about 6% for all firms. In the third period between 1990 and 2006, consistent with the existing empirical literature, the upward trend increases by 4.23 percentage points for large firms and 2.6 percentage points for small firms.[16] Finally, the trends reverse after the 2008 crisis and continue until the most recent data, and decrease by 2.88 percentage points for large firms (from 7.41% in 2006Q1 to 4.53% in 2017Q3) and 1.15 percentage points for small firms (from 10.42% in 2006Q1 to 9.27% in 2017Q3). The decreased cash ratio in recent decades is more pronounced among large firms. Apart from the non-linear pattern of the cash ratio, there appear to be two types of heterogeneity between the average cash ratio of small and large firms. First, small firms have a higher cash-to-assets ratio than large firms in all episodes.[17] Second, the cash-to-assets

[15] Panel A of Figure 1 in Graham and Leary (2018) shows very similar results to that of Figure 2. Using CRSP database, they show that cash ratio falls by a similar magnitude between 1956 and 1971 (from 13% in 1956Q1 to 6% in 1971Q1).
[16] Note that in the third period between 1990 and 2006, the cash ratio has increased more for smallest-size classes (those with below $50 million in assets). This is consistent with the previous findings that small firms have a faster cash build-up over this period (e.g., Bates et al., 2009).
[17] Denis and Sibilkov (2010) argue that constrained firms are more likely to save cash out of their cash flows since the marginal investment of constrained firms is associated with greater value increase than that of unconstrained firms.

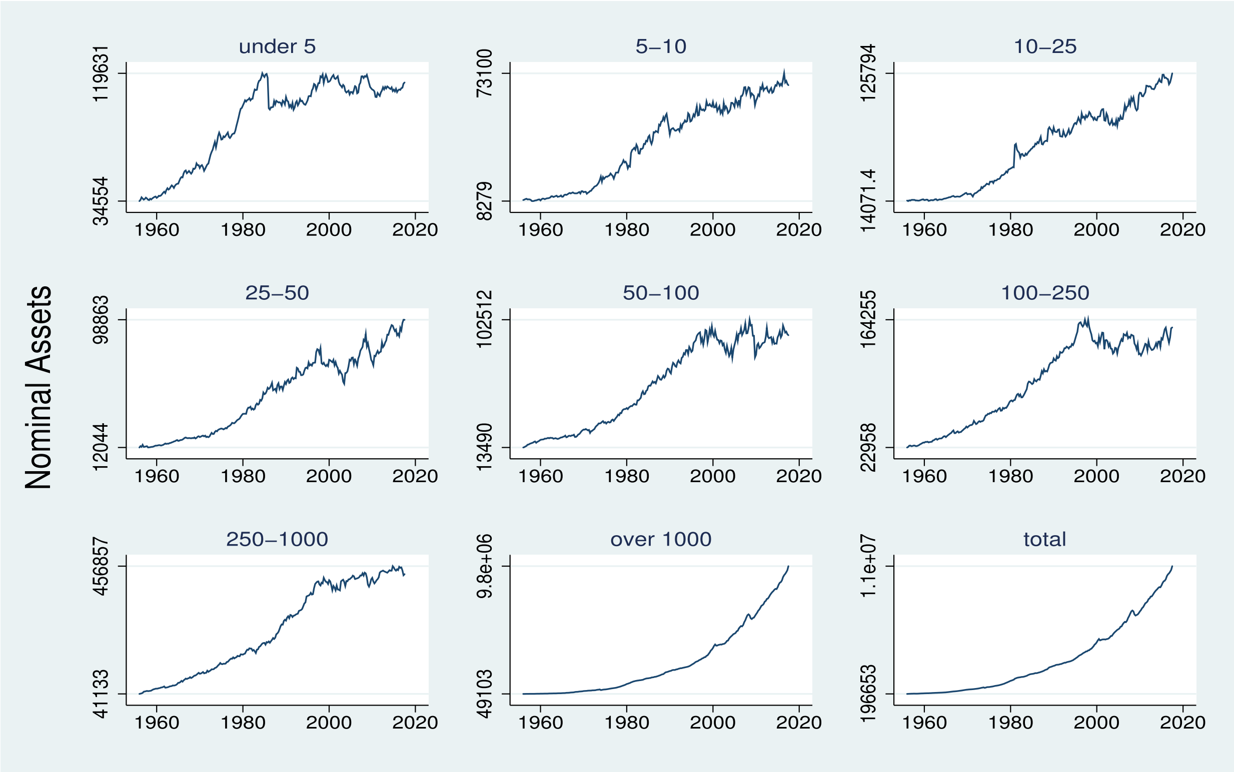

Fig. 3. Nominal assets in each size group.
This figure presents time-series plots of the nominal asset in 8-asset size brackets, implying that asset variations do not drive the nonlinear pattern.

ratio of large firms is relatively more volatile than small firms, with the coefficient of variation of small and large firms 12% and 37%. Panel B of Fig. 2 plots cash-to-assets ratios of QFR 8-asset size classes and shows that the secular variations in cash ratios are driven neither by specific classes of firms nor by our definition of small and large firms. In addition, Fig. 3 presents time-series plots of nominal assets in 8-asset size brackets, implying that asset variations do not drive the nonlinear pattern.

The overall message of the graphical analysis is that the cash ratios have substantial variations over the last six decades. While small firms hold cash proportionally about twice that of large firms, they tend to be relatively more conservative in changing their cash reserves. Having a higher cash-to-assets ratio is consistent with the findings of the majority of related studies in this literature. Almeida et al. (2004), Denis and Sibilkov (2010), Farre-Mensa and Ljungqvist (2016), and Stone et al. (2018) all suggest that financially constrained firms hold proportionally more cash than their unconstrained counterparts. In particular, Almeida et al. (2004) verify this fact for manufacturing firms. The standard argument in this strand of literature is that the wedge between internal and external costs of raising funds created by information asymmetry leads constrained firms to have higher precautionary incentives to hold cash. However, Gao et al. (2013) provide evidence that private firms hold, on average, about half as much cash as public firms do. Analyzing a sample of public and private US firms over 1995–2011, they attribute the difference to the much higher agency costs in the public firms. They argue that although private firms have stronger precautionary motives due to financing frictions, the effect of agency costs from being public, net of the reduced effect of financing frictions, leads public firms to hold cash reserves that are approximately 4% of assets higher than are those of similar private firms. They suggest that public firms face more severe agency problems and their managers prefer to hold more internal slack to have freedom from external monitoring. However, they implement propensity score-matching in which public and private firms are matched in which each private firm in their sample is matched with a public firm in the same industry and closest in size (total assets). This matching procedure decreases the large difference in the size distribution between the public and private groups. Therefore, their results do not conflict with our findings that small firms have a higher cash ratio.

3.3. Cost of carry hypothesis

Azar et al. (2016) show that firms became increasingly able to hedge the cost of carry sensitivity of the cost of their liquid-assets portfolios by investing in interest-bearing assets over the last decades. In particular, firms started to use a combination of safe and liquid financial instruments such as Treasury bills, money market funds, commercial paper, and other short-term securities instead of keeping cash to protect their assets against inflation. We, therefore, use the spread between the nominal risk-free T-bill rate and the return on the corporate sector liquid assets portfolio to measure the cost of carrying cash. As the fraction of liquid assets held in interest-bearing accounts becomes larger, the cost of carry becomes a more informative proxy for the opportunity cost of holding cash

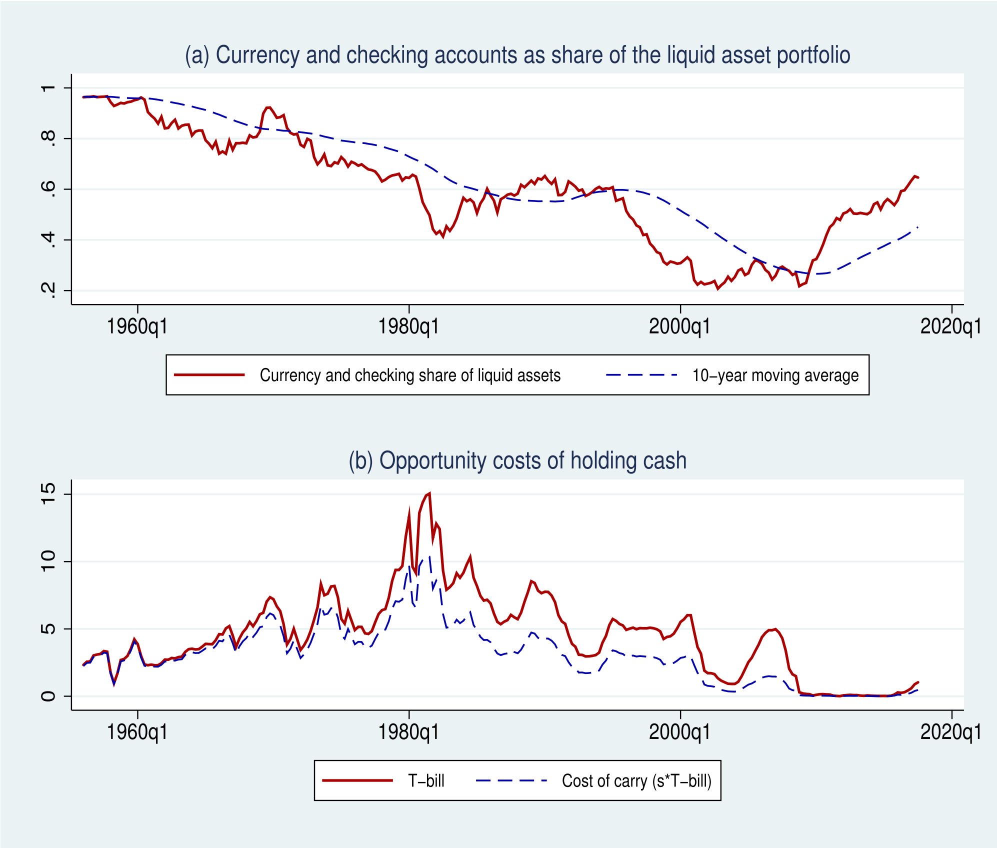

Fig. 4. Currency and checking accounts as share of the liquid asset portfolio.
This figure plots the currency and checking accounts as a share of the liquid asset portfolio along with the 10-year-lagged moving average (excluding the current quarter). The fraction of liquid assets held in currency and checking accounts decreased from close to 100% in the 1950s to about 20% in the early 2010s, and the trend reversed after the 2008 financial crisis and reached 65% in 2018. The bottom panel portrays the 3-month T-bill rate along with the cost of carry calculated in (6).

than the simple T-bill rate.[18] We follow Azar et al. (2016) and measure the cost of carry as the fraction of cash held in non-interest-bearing accounts multiplied by the T-bill rate.[19]

To be more formal, we calculate the cost of carry as:

$$Cost\ of\ carry = \overline{\mathbf{s}}_{t-\Delta} \quad . \quad \textbf{T-Bill}_t \tag{6}$$

where $\overline{\mathbf{s}}_{t-\Delta}$ denotes the 10-year lagged average excluding the current quarter of $\mathbf{s}_t$, and $\mathbf{s}_t$ is the share of liquid assets held in currency and checking accounts. T-Bill is the 3-month T-bill rate. We use the Fed's Flow of Funds data to calculate the fraction of non-interest-bearing liquid assets (currency and checking accounts) as a share of total liquid assets. Fig. 4 plots the currency and checking accounts as a share of the liquid asset portfolio along with the 10-year-lagged moving average. The fraction of liquid assets held in currency and checking accounts decreased from close to 100% in the 1950s to about 20% in the early 2010s, and the trend reversed after the 2008 financial crisis and reached 65% in 2018. This might be a consequence of the Great Recession, which shows that some of the interest-bearing instruments are not as safe as previously thought. The bottom panel of Fig. 4 portrays the 3-month T-bill rate along with the cost of carry calculated in (6).

3.4. Time-series determinants of cash: 1956–2017

To explore the long-run determinants of corporate cash holdings, we estimate the following linear time-series regression for small and large firms and also for the large/small differential (large-small) cash ratio over the period 1956Q1 to 2017Q3:

[18] In a related study, Curtis et al. (2017) consider inflation as the cost of holding any type of liquid assets that are not protected against inflation and show that inflation is an important driver of corporate cash dynamics from 1960.

[19] The cash held in non-interest-bearing accounts is equal to the liquid assets held in currency and checking accounts.

Table 2
Time-series determinants of cash: 1956–2017.

	(1)			(2)		
	Δln(*Cash/Assets*)			Δ(*Cash/Net Assets*)		
	Small	Large	Diff. (L-S)	Small	Large	Diff. (L-S)
Size-specific factors						
CFL volatility	0.182	−0.297	−0.452	0.012	−0.023	−0.036
	(0.97)	(−1.12)	(−1.39)	(0.67)	(−1.21)	(−1.40)
E[CFL]	0.361*	0.136	−0.315	0.039*	0.020	−0.015
	(1.73)	(0.24)	(−0.52)	(1.96)	(0.54)	(−0.37)
Sales/assets	0.909	3.309*	1.629	0.105	0.159*	0.089
	(0.72)	(1.90)	(1.18)	(0.91)	(1.76)	(0.83)
STD/assets	0.730	0.239	−0.313	0.053	−0.002	−0.063
	(0.98)	(0.65)	(−0.37)	(0.84)	(−0.07)	(−0.96)
LTD/assets	0.615	0.561	−0.529	0.081	0.054	−0.005
	(0.99)	(0.80)	(−0.69)	(1.41)	(1.46)	(−0.10)
LTD maturity	−0.838**	0.089	0.736	−0.072**	0.005	0.086*
	(−2.00)	(0.13)	(1.08)	(−2.00)	(0.13)	(1.71)
Investment/assets	−0.695***	−1.160***	−0.486*	−0.067***	−0.074***	−0.006
	(−7.39)	(−4.42)	(−1.75)	(−8.27)	(−3.73)	(−0.29)
E[Investment/assets]	0.764***	−0.453	−1.227**	0.072***	−0.028	−0.100***
	(3.79)	(−1.28)	(−2.99)	(3.97)	(−1.31)	(−3.58)
Capex/assets	1.349***	0.236	−1.385**	0.126***	0.005	−0.108**
	(3.36)	(0.37)	(−2.51)	(3.48)	(0.14)	(−2.60)
NWC/assets	0.363	−3.072**	−3.181**	0.029	−0.164*	−0.204*
	(0.39)	(−2.43)	(−2.31)	(0.33)	(−2.33)	(−1.96)
Macroeconomic factors						
Cost of carry	−0.351	−2.662***	−2.204***	−0.037	−0.125***	−0.093*
	(−0.95)	(−5.37)	(−4.16)	(−1.11)	(−4.42)	(−2.39)
Real GDP growth	0.170	0.572***	0.404**	0.013	0.035***	0.022
	(1.56)	(3.35)	(2.00)	(1.21)	(3.58)	(1.47)
EPU	−0.059	−0.158	−0.157	−0.005	−0.016	−0.008
	(−0.32)	(−0.45)	(−0.40)	(−0.29)	(−0.78)	(−0.31)
BAA-AAA spread	0.951**	0.893**	−0.106	0.090**	0.049**	−0.039
	(3.10)	(3.18)	(−0.25)	(3.18)	(2.92)	(−1.20)
Corp. tax rate	−0.026	1.992**	1.794*	0.011	0.114**	0.113*
	(−0.04)	(2.34)	(1.85)	(0.21)	(2.39)	(1.73)
Observations	238	238	476	238	238	476
Adjusted R^2	0.46	0.44	0.44	0.46	0.43	0.44

The sample includes manufacturing firms drawn from the US Census Bureau Quarterly Financial Report (QFR) from 1956 to 2017. In order to ease the comparison of economic magnitudes of the estimated coefficient across variables, as well as small and large firms, we scale all explanatory variables by their time-series standard deviation. We estimate OLS regression with Newey and West (1987) standard errors that are robust to heteroscedasticity and eight quarters of autocorrelation, which also allows us to use a dummy variable approach with the interaction term to estimate the heterogeneous effects of the explanatory variables on small and large firms (Diff. (L-S)). For variable definitions and details of their construction, see Appendix C. *t*-statistics are in parentheses. Statistical significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

$$Cash_{j,t} = \alpha_j + \delta_j X_{j,t} + \beta_j Macro_t + \gamma_j \mathbf{cc}_t + \varepsilon_{j,t} \tag{7}$$

where $j=$ Large, Small, Diff. (L-S). *Cash* is the cash-to-assets ratio, *X* is a set of size-specific characteristics, *Macro* is a set of macroeconomic factors, and **cc** is the cost of carry calculated in (6). For all variable definitions and details of their construction, see Appendix C.

We estimate (7) in both log-difference (Δ *ln* (*CASH/A*)) and first-difference (Δ(*CASH/A*)), separately for small and large firms and the large/small differential cash ratio.[20] In order to ease the comparison of economic magnitudes across variables, as well as small versus large firms, we scale all explanatory variables by their time-series standard deviation. We estimate OLS regression with Newey and West (1987) standard errors that are robust to heteroscedasticity and eight quarters of autocorrelation, which also allows us to use a dummy variable approach with the interaction term to estimate the heterogeneous effects of the explanatory variables on small and large firms (and Diff. (L-S)). We focus on the contribution of two groups of variables; size-specific and macroeconomic variables, particularly the cost of carry. The regression results are shown in Table 2; the first three columns present the log-difference specification (1), and the last three columns show the first-difference specification (2).

[20] We use first-difference to prevent results from being driven by a common trend since many of the aggregate series are highly persistent, raising the possibility of spurious regression. In addition, using log-difference which captures the percentage change allows us to compare the magnitude of coefficients across small and large firms.

3.4.1. Size-specific factors

We first discuss the contribution of size-specific variables. The vector X in (7) is a set of size-specific characteristics, including aggregate cash flow volatility, debt maturity, short- and long-term debt normalized by assets, expected levels of cash flows, investment and its contemporaneous realizations, capital expenditure, and networking capital normalized by assets.[21] Among these variables, investment expenditure is the only significant factor for both small and large firms in all specifications. Following Graham and Leary (2018), we distinguish between firms' expected levels of cash flow and investment and their contemporaneous realizations. As would be expected, contemporaneous investment expenditure negatively affects the cash holdings of both small and large firms. However, expected investment expenditure has a positive effect only for small firms since if small firms face a cash shortage, they have to give up profitable investment opportunities. Large firms are not sensitive to expected investment expenditures. It is potentially related to their better access to debt markets and lower precautionary motives. This implies that saving for investment is a determinant of cash policy for constrained firms (see also Opler et al., 1999).

Recent literature suggests that consistent with a precautionary motive, cash flow volatility is a key determinant for the up-ward cash trend from 1980 to 2008 (Bates et al., 2009). However, our results show that over the long sample horizon of this study, the effect of cash flow volatility on cash holdings is weak and insignificant.[22,23] Finally, we test the hypothesis of Harford et al. (2014) who suggest that shortening the debt maturity increases firms refinancing risk, and consequently, their demand for cash to mitigate this risk. Our results indicate that changes in aggregate long-term debt maturities are significant for small firms, only. The coefficients on capital expenditures and net working capital are largely consistent with what the existing literature reports. Next, we explore the role of macroeconomic conditions.

3.4.2. Macroeconomic factors

Recent research in corporate finance emphasizes that macroeconomic conditions have a profound impact on corporate financing decisions.[24] Macroeconomic conditions may influence cash holdings by affecting the opportunity cost of holding cash, influencing investment opportunities, or affecting uncertainty in ways not captured by the firm- or industry-level variables. In addition, the evidence in the previous section shows that size-specific variables have little explanatory power for aggregate cash holdings of large firms suggesting that changes over time in macroeconomic variables could lead to sizable changes in optimal cash holdings of large firms resulting in shifts in cash. Hence, despite the effect of the cost of carry, we include a set of macroeconomic variables in our econometric framework to investigate which macroeconomic variables might explain the variation in cash. Following Graham and Leary (2018), we include the economic policy uncertainty index of Baker et al. (2016) to capture aggregate uncertainty, real GDP growth as a measure of aggregate investment opportunities, and the top statutory US federal corporate income tax rate to capture variations in the tax cost of holding cash. Another macroeconomic factor that influences the cash holdings is the default-premium (the default spread). We use the difference between Moody's average yield on BAA- and AAA-rated bonds, which is an instrument widely used for the default spread (Fama and French, 1989; Gilchrist and Zakrajšek, 2012; Eckbo et al., 2000; Harrison and Weder, 2006).

Our estimates on the default spread are highly significant and robust across small and large firms and in both first-difference and log-difference specifications. From the log-difference specifications (1) in Table 2, a 1 standard deviation increase in the default spread is associated with an increase in the growth rate of the cash ratio of 0.95 percentage points for small firms, and 0.89 percentage points for large firms. The results are similar in the first difference specification (2). This positive relation is consistent with the findings of previous studies (Acharya et al., 2012; Bates et al., 2009). Finally, real GDP growth has a significant positive coefficient on the cash ratio of large firms, only. Our findings highlight the heterogeneous impact of macroeconomic variables on the cash policy of small and large firms.

3.4.3. Cost of carry

The main aim of this paper is to investigate the extent to which changes in the cost-of-carry affect the cash dynamics of small/constrained and large/unconstrained firms. From the log-difference specification, a 1 standard deviation increase in the cost of carry is associated with a 2.66 percentage points decrease in the growth rate of the cash ratio for large firms and is significant at the 1% level. From the first-difference specification, the coefficient on the cost of carry is 0.125 and significant at the 10% level. While we find a robust negative correlation between corporate cash holdings and the cost of carry for large firms, we find no evidence of such correlation for small firms. The estimated coefficients for the difference between small and large firms (Diff. (L-S)) are highly significant and robust across both specifications (Table 2, Columns 3 and 6).

The overall message from our time-series analysis is that while macroeconomic variables play a more important role in explaining the cash dynamics of large firms over the last six decades, small firms are relatively more driven by size-specific variables.

We check the robustness of our results using the size-specific cost of carry. Since we use the Fed's Flow of Funds data in (6), there

[21] The choice of size-specific variables to determine optimal financial behavior of firms have been widely discussed in corporate finance. In an influential paper, Titman and Wessels (1988) classify the determinants of capital structure choice to asset structure, non-debt tax shields, growth, uniqueness, industry classification, size, earnings volatility, and profitability.

[22] For each group of QFR firms, aggregate cash flow volatility is defined as the variance of *cash flow/assets* over the previous four years.

[23] Note that since our time-series are aggregated, the computed volatilities capture aggregate variations in cash flows and do not account for idiosyncratic firm-level volatilities.

[24] See, e.g., Korajczyk and Levy (2003), Erel et al. (2011), Bhamra et al. (2010), Levy and Hennessy (2007), Hackbarth et al. (2006), and Baum et al. (2006), among others.

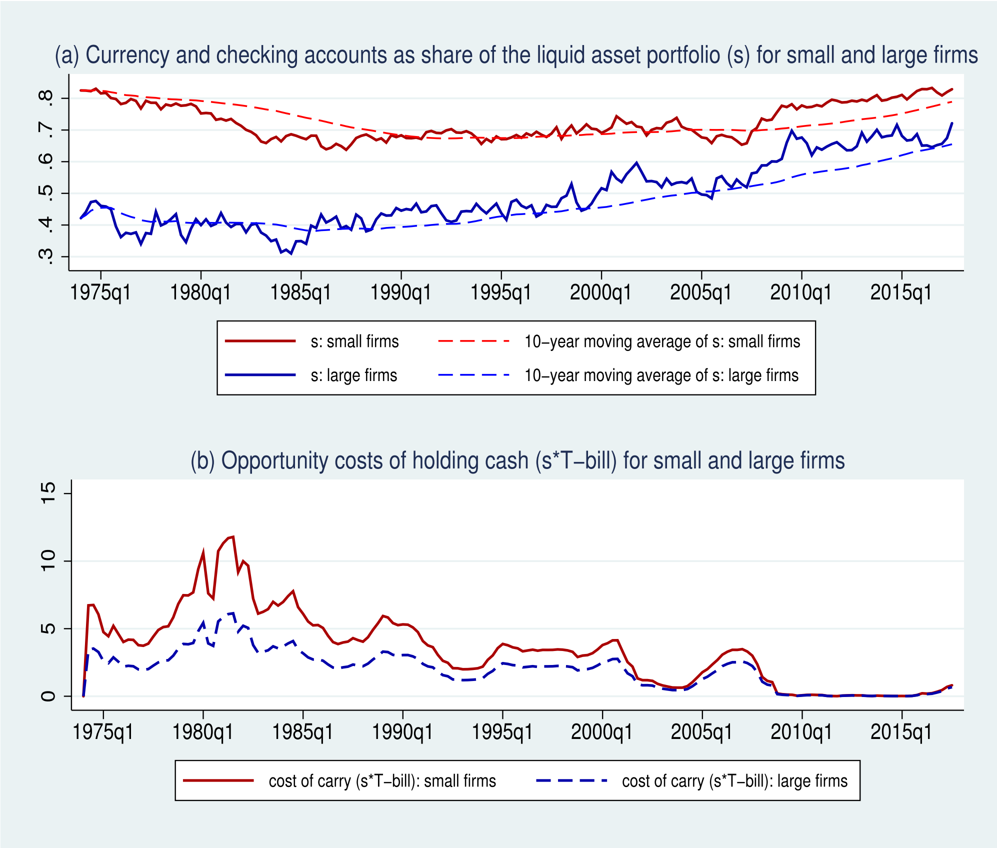

Fig. 5. Currency and checking accounts as share of the liquid asset portfolio for small and large firms: 1974–2017.
This figure plots the currency and checking accounts as a share of the liquid asset portfolio along with the 10-year-lagged moving average (excluding the current quarter) for small and large firms. Small firms have a higher fraction of non-interest-bearing liquid assets as a share of total liquid assets than large firms in all episodes. The bottom panel portrays the cost of carry for small and large firms calculated in (6).

might be a macro variable that drives both the cost of carry and firms' cash ratios. To alleviate this concern, we construct size-specific measures of the cost of carry for small and large firms using QFR data.[25] The quarterly size-specific cost of carry is thus defined as the fraction of cash held in the immediately negotiable medium of exchange (sum of cash and demand deposits in the U.S. and time deposits in the U.S.) compared with the fraction held in interest-bearing assets (U.S. Government and other securities), separately for small and large firms. Fig. 5 plots the currency and checking accounts as a share of the liquid asset portfolio (s) along with the 10-year-lagged moving average (excluding the current quarter) for small and large firms from 1974 to 2017. Due to data limitations, we are unable to compute the share prior to 1974.[26]

As shown in Fig. 5(a), small firms have a higher fraction of non-interest-bearing liquid assets as a share of total liquid assets than large firms in all episodes. Beginning in the 1970s, the share was about 79% for small firms and 41% for large firms. The difference is reduced over time, and the share became about 82% for small firms and 68% for large firms in the latter part of the sample. The reduction is mostly due to the increasing fraction of liquid assets held in currency and checking accounts for large firms. The heterogeneity between small and large firms in the average fraction held in interest-bearing assets is consistent with their different operational reasons. As discussed in Azar et al. (2016), depending on operational parameters, firms choose an optimal mix of non-interest-bearing currency for their immediate transaction needs and interest-bearing liquid assets for their intermediate liquidity needs. This optimal mix differs across firm types, small firms with higher cash-to-assets ratio (Fig. 2) hold more of their liquid assets in currency and checking accounts, and large firms save a higher fraction of their liquid assets in interest-bearing accounts. Fig. 5(b) shows the cost of carry for small and large firms, and, as one would expect, the cost of carry is higher for small firms with higher s.

We now estimate the response of corporate cash holdings to variations in the size-specific cost of carry. As shown in Table 3, the results for small and large firms are similar to our previous results. Changes in the size-specific cost of carry have a significant effect on

[25] In the next section, we also use a firm-level measure of cost of carry.

[26] The QFR data distinguishes between the composition of corporate liquid-asset holdings only after 1974. The main reason for this restriction is related to Regulation Q which put severe restrictions on the types of liquid assets firms could hold until the early 1980s (for detailed discussion see Azar et al., 2016).

Table 3
Time-series determinants of cash: 1974–2017.

	(1)			(2)		
	Δ*ln*(*Cash/Assets*)			Δ(*Cash/Net Assets*)		
	Small	Large	Diff. (L-S)	Small	Large	Diff. (L-S)
Size-specific factors						
CFL volatility	0.212	−0.223	−0.299	0.018	−0.018	−0.032
	(1.33)	(−0.48)	(−0.59)	(1.23)	(−0.69)	(−1.07)
E[CFL]	0.041	−0.318	−0.707	0.010	0.002	−0.020
	(0.11)	(−0.37)	(−0.78)	(0.29)	(0.04)	(−0.37)
Sales/assets	−2.771**	3.651*	4.260**	−0.228**	0.209*	0.369**
	(−2.33)	(1.71)	(2.34)	(−2.03)	(1.68)	(2.85)
STD/assets	2.970***	0.587	−1.441	0.248**	−0.000	−0.218**
	(3.80)	(0.78)	(−1.29)	(3.31)	(−0.00)	(−2.88)
LTD/assets	−0.894	0.697	0.149	−0.054	0.066	0.075
	(−0.99)	(0.67)	(0.13)	(−0.63)	(1.28)	(0.90)
LTD maturity	0.190	0.516	−0.398	0.014	0.008	−0.029
	(0.31)	(0.57)	(−0.43)	(0.24)	(0.19)	(−0.41)
Investment/assets	−0.602***	−0.432	0.177	−0.059***	−0.012	0.048
	(−3.51)	(−0.71)	(0.28)	(−3.57)	(−0.38)	(1.37)
E[Investment/assets]	1.159**	−1.029	−2.118**	0.107**	−0.089*	−0.193***
	(3.19)	(−1.24)	(−2.26)	(3.29)	(−2.08)	(−3.54)
Capex/assets	1.664**	0.172	−2.052**	0.150**	0.002	−0.166**
	(3.31)	(0.28)	(−2.89)	(3.26)	(0.07)	(−3.24)
NWC/assets	0.234	−5.697**	−4.806	0.030	−0.377**	−0.371*
	(0.17)	(−2.11)	(−1.62)	(0.23)	(−2.36)	(−1.86)
Macroeconomic factors						
Size-specific cost of carry	−0.208	−2.694***	−2.327**	−0.025	−0.121**	−0.091*
	(−0.57)	(−3.62)	(−2.86)	(−0.74)	(−3.05)	(−1.78)
Real GDP growth	0.259*	0.753**	0.509	0.024*	0.035**	0.011
	(1.76)	(2.66)	(1.57)	(1.77)	(2.74)	(0.60)
EPU	−0.373**	−0.684**	−0.427	−0.0322*	−0.0337**	−0.005
	(−2.19)	(−2.37)	(−1.18)	(−1.93)	(−2.13)	(−0.22)
BAA_AAAnm	0.993**	1.268***	0.132	0.094***	0.063***	−0.035
	(3.28)	(4.46)	(0.31)	(3.48)	(4.68)	(−1.18)
Corp. tax rate	0.178	2.785**	1.803*	0.0233	0.153**	0.104
	(0.29)	(3.13)	(1.96)	(0.40)	(3.16)	(1.58)
Observations	169	169	338	169	169	338
Adjusted R^2	0.57	0.42	0.46	0.57	0.41	0.50

The sample includes manufacturing firms drawn from the US Census Bureau Quarterly Financial Report (QFR) from 1974 to 2017. In order to ease the comparison of economic magnitudes of the estimated coefficient across variables, as well as small and large firms, we scale all explanatory variables by their time-series standard deviation. We estimate OLS regression with Newey and West (1987) standard errors that are robust to heteroscedasticity and eight quarters of autocorrelation, which also allows us to use a dummy variable approach with the interaction term to estimate the heterogeneous effects of the explanatory variables on small and large firms (Diff. (L-S)). For variable definitions and details of their construction, see Appendix C. *t*-statistics are in parentheses. Statistical significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

the cash ratio for large firms, while there is no evidence of such an impact for their small counterparts. In particular, from the log-difference specification, a 1 standard deviation increase in the size-specific cost of carry is associated with a 2.69 percentage points decrease in the growth rate of the cash ratio for large firms and significant at the 1% level. From the first-difference specification, the coefficient on the size-specific cost of carry is 0.121 and significant at the 5% level. The estimated coefficients for the difference between small and large firms (Diff. (L-S)) are highly significant and robust across both specifications (Table 3, Columns 3 and 6).

While Azar et al. (2016) provide a framework that attempts to convince that the cost of carry is the key determinant of corporate cash holdings and not the interest rates, it's worth considering the response of corporate cash holdings to variations in the interest rate as a robustness check. In addition, some studies (e.g., Stone et al., 2018, and Gao et al., 2021) suggest variations in interest rates as a key determinant of corporate cash dynamics over the last decades. We use the average annualized 3-month T-bill rates to proxy the interest rates. As shown in Table 4, the results are highly robust to this alternative proxy for the opportunity cost of keeping cash.

4. Firm-level evidence: 1984–2014

4.1. Sample selection

In this section, we shed additional light on the cost of carry hypothesis and the role of financial market imperfections in shaping the dynamics of corporate cash holdings. We analyze the response of constrained versus unconstrained firms to changes in the cost of carry. For this purpose, we use a sample of public companies in the US with financial data. We use four alternative approaches for

Table 4
Time-series determinants of cash: 1956–2017.

	(1)			(2)		
	Δln(*Cash/Assets*)			Δ(*Cash/Net Assets*)		
	Small	Large	Diff. (L-S)	Small	Large	Diff. (L-S)
Size-specific factors						
CFL volatility	0.164	−0.335	−0.468	0.009	−0.025	−0.036
	(0.89)	(−1.18)	(−1.39)	(0.57)	(−1.23)	(−1.36)
E[CFL]	0.337	−0.376	−0.784	0.037*	−0.004	−0.038
	(1.65)	(−0.70)	(−1.37)	(1.89)	(−0.12)	(−0.97)
Sales/assets	0.899	3.504**	1.803	0.104	0.167*	0.099
	(0.74)	(2.04)	(1.32)	(0.95)	(1.83)	(0.97)
STD/assets	0.740	0.559	−0.017	0.054	0.013	−0.048
	(1.01)	(1.56)	(−0.02)	(0.87)	(0.60)	(−0.76)
LTD/assets	0.635	0.421	−0.690	0.083	0.047	−0.014
	(1.01)	(0.61)	(−0.93)	(1.43)	(1.28)	(−0.28)
LTD maturity	−0.861**	−0.022	0.652	−0.075**	−0.001	0.083
	(−2.04)	(−0.03)	(0.95)	(−2.05)	(−0.02)	(1.64)
Investment/assets	−0.700***	−1.008***	−0.335	−0.068***	−0.067***	0.002
	(−7.33)	(−3.92)	(−1.24)	(−8.28)	(−3.52)	(0.09)
E[Investment/assets]	0.787***	−0.291	−1.097**	0.075***	−0.021	−0.095***
	(3.81)	(−0.81)	(−2.63)	(4.05)	(−0.96)	(−3.38)
Capex/assets	1.318**	0.346	−1.249**	0.122**	0.009	−0.099**
	(3.20)	(0.58)	(−2.21)	(3.33)	(0.31)	(−2.32)
NWC/assets	0.433	−3.050**	−3.215**	0.036	−0.162**	−0.210**
	(0.51)	(−2.35)	(−2.37)	(0.45)	(−2.24)	(−2.12)
Macroeconomic factors						
T-bill	−0.416	−2.885***	−2.338***	−0.044	−0.135***	−0.097**
	(−1.05)	(−4.98)	(−3.85)	(−1.25)	(−3.97)	(−2.23)
Real GDP growth	0.177*	0.657***	0.479**	0.014	0.039***	0.025*
	(1.67)	(3.86)	(2.40)	(1.32)	(3.76)	(1.68)
EPU	−0.072	−0.208	−0.191	−0.007	−0.018	−0.009
	(−0.40)	(−0.60)	(−0.48)	(−0.37)	(−0.89)	(−0.35)
BAA-AAA spread	0.976**	1.116***	0.081	0.093**	0.059***	−0.031
	(3.21)	(3.96)	(0.19)	(3.32)	(3.61)	(−0.96)
Corp. tax rate	0.009	2.028**	1.787*	0.015	0.116**	0.111*
	(0.01)	(2.32)	(1.82)	(0.28)	(2.37)	(1.70)
Observations	238	238	476	238	238	476
Adjusted R^2	0.46	0.43	0.44	0.46	0.42	0.44

The sample includes manufacturing firms drawn from the US Census Bureau Quarterly Financial Report (QFR) from 1956 to 2017. In order to ease the comparison of economic magnitudes of the estimated coefficient across variables, as well as small and large firms, we scale all explanatory variables by their time-series standard deviation. We estimate OLS regression with Newey and West (1987) standard errors that are robust to heteroscedasticity and eight quarters of autocorrelation, which also allows us to use a dummy variable approach with the interaction term to estimate the heterogeneous effects of the explanatory variables on small and large firms (Diff. (L-S)). For variable definitions and details of their construction, see Appendix C. *t*-statistics are in parentheses. Statistical significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

sorting firms into financially constrained and unconstrained. If our previous results are robust, we expect differences in the behavior of large versus small firms to hold across unconstrained versus constrained firms. Therefore, we expect unconstrained firms to exhibit more sensitivity to changes in the cost of carry than their constrained counterparts.

We use a sample of all Compustat firm-year observations between 1984 and 2014, except financial firms (SIC codes 6000–6999) and utilities (SIC codes 4900–4999). The sample period is limited by the availability of Compustat data on S&P long-term issuer credit rating that is used to construct a measure of financial constraint. We exclude all firms with the negative book value of assets and negative sales. We also do a separate analysis for manufacturing firms (SIC codes 2000–3999). Following the existing literature (Bates et al., 2009), we winsorize the outliers in control variables as follows. Leverage is winsorized to fall between zero and one. R&D/sales, acquisitions/assets, cash flow volatility, and capital expenditures/assets are winsorized at the 1% level. The bottom tails of net working capital/assets and cash flow/assets are winsorized at the 1% level, and the top tail of the market-to-book ratio is winsorized at the 1% level. These sample selection criteria result in 89,182 firm-year observations corresponding to 6849 unique firms.

4.2. Measures of financial constraints

Among several criteria in the literature for sorting firms into financially constrained and unconstrained (Farre-Mensa and Ljungqvist, 2016; Denis and Sibilkov, 2010), we use *payout ratio*, *firm size*, *debt rating*, and *Kaplan-Zingales index* as proxies for financial constraint.[27] We follow Denis and Sibilkov (2010) to sort our sample using these proxies.

4.2.1. Payout ratio

Financially unconstrained firms should have a systematic propensity to pay a dividend, whereas constrained firms should not exhibit this propensity. Therefore, each year, we assign those firms in the bottom (top) three deciles of the annual cash payout ratio distribution to the financially constrained (unconstrained) group. We follow Almeida et al. (2004) and Denis and Sibilkov (2010) and define the payout ratio as the ratio of dividends and common stock repurchases to operating income. We also assign observations with positive payout and zero or negative cash flow to the highest payout ratio.[28]

4.2.2. Firm size

This index resembles that of our previous measurement of QFR small and large firms. We rank firms based on their asset size each year over the period 1984–2014. We then assign to the financially constrained (unconstrained) group those firms in the bottom (top) three deciles of the firm size distribution. The rationale for size as a good observable measure of financial constraints is the assumption that smaller firms are younger and more opaque, then they are more likely to face borrowing constraints (Almeida et al., 2004).

4.2.3. Debt rating

We classify firms as financially unconstrained if they have had their S&P Long-term Senior Debt Rating available and their debt is not in default (rating of "D" or "SD").[29] Firms are classified as constrained if they have debt outstanding that year but have never had their public debt rated before (or the long-term debt rating is unavailable). Firms with no outstanding debt are also classified as unconstrained (Denis and Sibilkov, 2010). As discussed by Almeida et al. (2004), the advantage of this measure over the former two is that it gauges the market's assessment of a firm's credit quality.

4.2.4. Kaplan-Zingales index

Finally, we construct an index of firm financial constraints based on results in Kaplan and Zingales (1997). We follow the literature and first define the following linearization to the data to construct an index of the likelihood that a firm faces financial constraints (Almeida et al., 2004; Farre-Mensa and Ljungqvist, 2016):

$$\begin{aligned} KZIndex = \quad & -1.001909 \times CashFlow + 0.2826389 \times Q + 3.139193 \times Leverage \\ & -39.3678 \times Dividends - 1.314759 \times CashHoldings \end{aligned}$$

where CashFlow=$[(ib + dp)/L.\,ppent]$, Q=$[(at + prcc\_f \times csho - ceq - txdb)/at]$, Leverage=$[(dltt + dlc)/(dltt + dlc + seq)]$, Dividends=$[(dvc + dvp)/L.\,ppent]$, and CashHoldings=$[che/L.\,ppent]$, all variables in italics are Compustat data items. We then assign firms in the top (bottom) three deciles of the previous year *KZIndex* ranking as financially constrained (unconstrained).

In all four indicators, we allow firms to change their status over the sample period by ranking them annually.

4.3. Cross-tabulations and summary statistics

Table 5 reports cross-tabulations of the four measures used in our analysis for all US public firms from 1984 to 2014, except financial firms (SIC codes 6000–6999) and utilities (SIC codes 4900–4999). It shows the number of firm-years under each of the financial constraints categories and the association among the various classification schemes, illustrating how the four measures produce similar classifications. The numbers in parentheses display the fraction of firm-years classified as constrained/unconstrained under one measure that would also be classified as constrained/unconstrained under each of the other three measures. For instance, according to the payout ratio, there are 37,080 financially constrained firm-years and 17,981 (49%), 24,263 (65%), and 12,852 (35%) of them are also constrained according to firm size, bond ratings, and Kaplan-Zingales, respectively. In other words, most small firms without bond ratings have low payouts where the greatest agreement is between the firm size and bond rating indices. Generally, there

[27] Although there is no general agreement on which measure is the best proxy for financial constraints, *payout ratio* and *debt rating* are among the most commonly used measures in the literature (see Almeida et al. (2021) for a more recent discussion). In addition, some studies argue that *Kaplan-Zingales index* does a relatively poor job of characterizing the cross-sectional variation of cash policies for financially constrained versus unconstrained firms (Almeida et al., 2004; Whited and Wu, 2006; Hadlock and Pierce, 2010; Farre-Mensa and Ljungqvist, 2016). In particular, since cash holdings themselves are a component of the index.

[28] Our results are similar if we define nondividend payers (constrained firms) as firms with a history of zero dividends on common stock and dividend payers (unconstrained firms) as firms with a history of nonzero dividends on the common stock, going as far back as 1984 (Farre-Mensa and Ljungqvist, 2016).

[29] To construct this measure, we use Compustat variable *splticrm* which is S&P Domestic Long Term Issuer Credit Rating. This item ranges from *AAA* to *D* (default) in 22 classes.

Table 5
Cross-tabulations of firm-level financial constraints measures: 1984–2014.

Financial constraints	Payout ratio		Firm size		Bond ratings		Kaplan-Zingales	
Criteria	C	U	C	U	C	U	C	U
1. Payout Ratio								
C	37,080		17,981	4924	24,263	12,695	12,852	6784
	(1.000)		(0.485)	(0.133)	(0.654)	(0.342)	(0.347)	(0.183)
U		26,887	3955	12,730	11,912	14,882	2682	11,207
		(1.000)	(0.147)	(0.473)	(0.447)	(0.554)	(0.100)	(0.417)
2. Firm Size								
C			26,755		20,817	5892	8010	6519
			(1.000)		(0.778)	(0.220)	(0.299)	(0.244)
U				26,754	6098	20,555	6306	6602
				(1.000)	(0.228)	(0.768)	(0.236)	(0.247)
3. Bond Ratings								
C					49,642		13,440	10,785
					(1.000)		(0.271)	(0.217)
U						39,226	9090	11,719
						(1.000)	(0.232)	(0.299)
4. Kaplan-Zingales								
C							22,546	
							(1.000)	
U								22,547
								(1.000)

This table reports cross-tabulations of the four measures used in our analysis for 89,182 firm-years for 6849 US public firms from 1984 to 2014, except financial firms (SIC codes 6000–6999) and utilities (SIC codes 4900–4999); firm-years with non-positive values for the book value of total assets or sales revenue, and; firms with less than 10 periods of observations. This table illustrates the extent to which the measures produce overlapping classifications. We assign the letter (C) for constrained firms and (U) for unconstrained firms in each row/column to facilitate visualization, w. The numbers in parentheses display the fraction of firm-years classified as constrained/unconstrained under one measure that would also be classified as constrained/unconstrained under each of the other three measures. For instance, according to the payout ratio, there are 37,080 financially constrained firm-years and 17,981 (49%), 24,263 (65%), and 12,852 (35%) of them are also constrained according to firm size, bond ratings, and Kaplan-Zingales, respectively. In other words, most small firms without bond ratings have low payouts where the greatest agreement is between the firm size and bond rating indices. Generally, there is a positive association among the sample splits generated by the four measures of financial constraints. However, the Kaplan-Zingales index correlates the least with the other three measures, which is not surprising considering the diversity of the average cash ratio for constrained/unconstrained firms as reported in Fig. 6 and reported in the previous studies (Almeida et al., 2004; Farre-Mensa and Ljungqvist, 2016). For definitions of financial constraint criteria, see Subsection 4.2.

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Fig. 6 plots the average cash-to-assets ratios for constrained and unconstrained US public firms using the above classification criteria.[30] Consistent with our results in Subsection 3.2 and several prior studies (Kim et al., 1998; Opler et al., 1999; Harford, 1999; Almeida et al., 2004), firms with greater difficulties in obtaining external capital (constrained firms) accumulate more cash.[31] In fact, cash holdings are more valuable for financially constrained firms than for unconstrained firms (Pinkowitz and Williamson, 2002; Faulkender and Wang, 2006; Denis and Sibilkov, 2010; Bates et al., 2018). However, the Kaplan-Zingales index generates the opposite level of average cash ratio for constrained/unconstrained firms, where unconstrained firms have a higher cash ratio. This figure resembles those results of Almeida et al. (2004), Denis and Sibilkov (2010), and Farre-Mensa and Ljungqvist (2016).

Table 6 shows summary statistics for US public firms between 1984 and 2014 that are classified as constrained and unconstrained according to each of the four measures of financial constraints. The alternative measures, mainly the first three ones, produce classifications with similar statistics. For example, constrained firms hold proportionally more cash, have negative cash flows, rely more on short-term debt, invest more in R&D, have higher market-to-book ratios, and have significantly smaller book assets, which are consistent with previous studies (Almeida et al., 2004; Denis and Sibilkov, 2010).

[30] We find time-series patterns very similar for manufacturing firms. However, in general, manufacturing firms have a higher cash-to-assets ratio than the average of public firms. In addition, except for the Kaplan-Zingales index, the observed cross-sectional heterogeneity in cash holdings is more pronounced among financially constrained firms.

[31] Denis (2011) provides a review of the related studies.

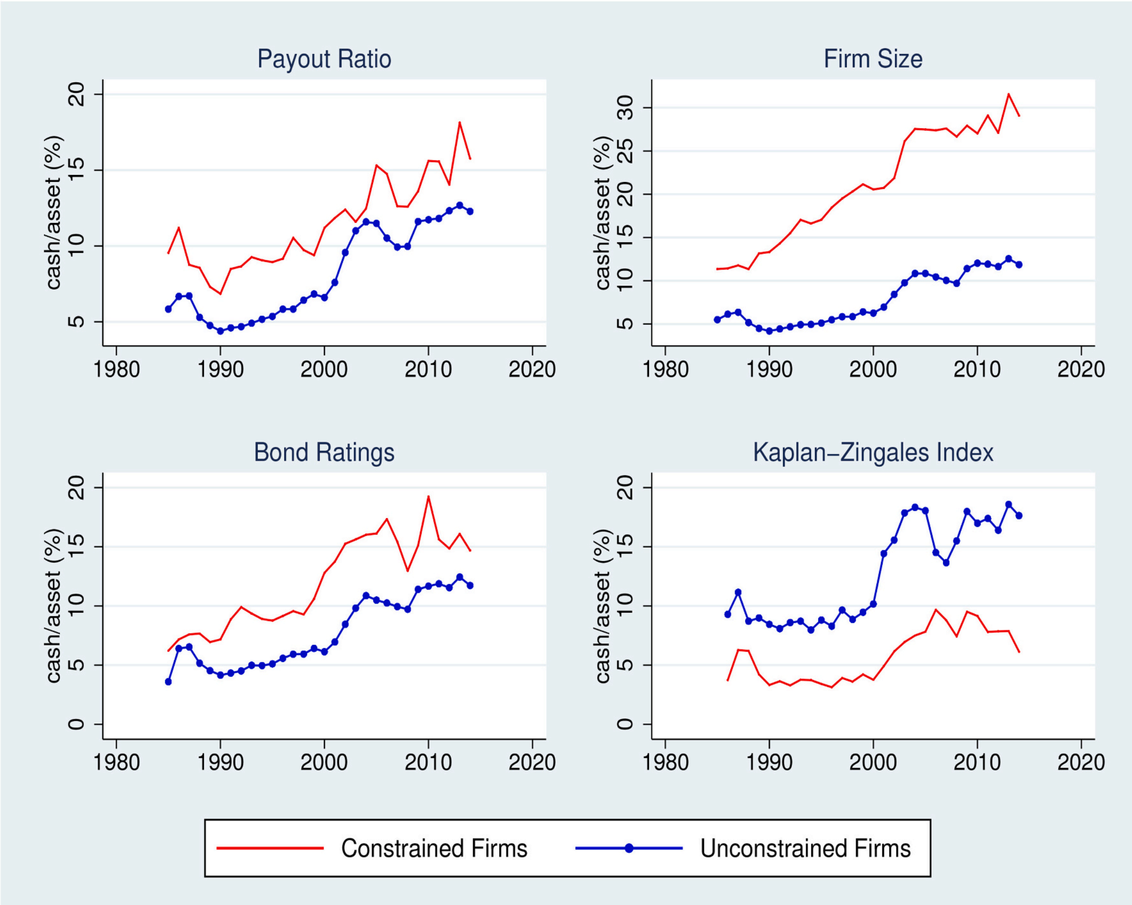

Fig. 6. Aggregate cash ratios of constrained and unconstrained firms.
This figure plots the aggregate cash-to-assets ratios for constrained and unconstrained US public firms using four classification criteria from 1984 to 2014. Aggregate cash-to-assets is defined each year as the cross-sectional sum of total cash and short-term investments (variable *che*) divided by total book assets (variable *at*). Consistent with our results in Subsection 3.2 and several prior studies (Kim et al., 1998; Opler et al., 1999; Harford, 1999; Almeida et al., 2004), firms with greater difficulties in obtaining external capital (constrained firms) accumulate more cash. In fact, cash holdings are more valuable for financially constrained firms than for unconstrained firms (Pinkowitz and Williamson, 2002; Faulkender and Wang, 2006; Denis and Sibilkov, 2010; Bates et al., 2018). However, the Kaplan-Zingales index generates the opposite level of average cash ratio for constrained/unconstrained firms, where unconstrained firms have a higher cash-to-assets ratio. This figure resembles those results of Almeida et al. (2004), Denis and Sibilkov (2010), and Farre-Mensa and Ljungqvist (2016).

4.4. Financial constraints and dynamics of corporate cash holdings: 1984–2014

We estimate the effect of the cost of carry on cash ratios for financially constrained and unconstrained firms. Following Opler et al. (1999) and Azar et al. (2016), we run static regression models where cash-to-assets ratio is a function of macroeconomic factors (*Macro*), cost of carry (**cc**), firm-level control variables (X), a cubic time trend ($f(t)$), and firm fixed effects (ν_j).

$$Cash_{j,t} = \alpha + \beta Macro_t + \gamma \mathbf{cc}_t + \delta X_{j,t} + f(t) + \nu_j + \varepsilon_{j,t} \tag{8}$$

where *Cash* is the cash-to-assets ratio. We also estimate the model using the logarithm of cash to net assets and also dynamic regressions using the lagged values of the dependent variable to allow for partial adjustment of the cash ratio to the equilibrium level. Like the time-series regression, *Macro* is a set of macroeconomic factors, including the spread between rates on Moody's BAA corporate bond and Moody's AAA corporate bond (the default spread), economic policy uncertainty, and real GDP growth. We use two alternative measures of **cc**: cost of carry as defined in (6), and firm-level cost of carry. X is a set of firm-specific explanatory variables including acquisitions, cash flow volatility, cash flows, short- and long-term debt, capital expenditure, R&D, market to book, and log of real assets. See Appendix C for the variable definitions and details of their construction. In all specifications, regressions are estimated using firm fixed effects and clustered standard errors.

In Table 7, we use the cost of carry, which is the nominal 3-month T-bill rate multiplied by the fraction of corporate cash held in non-interest-bearing accounts, as defined in (6). We also run static regressions with the cash-to-assets ratio as the dependent variable.

Table 6
Summary statistics for firm-level variables (constrained and unconstrained firms): 1984–2014.

		Payout ratio		Firm size		Bond ratings		Kaplan-Zingales	
		C	U	C	U	C	U	C	U
Cash/assets	Mean	0.191	0.147	0.219	0.101	0.150	0.178	0.094	0.269
	SD	0.225	0.166	0.237	0.126	0.186	0.212	0.148	0.234
Acquisition activity	Mean	0.017	0.021	0.009	0.029	0.020	0.021	0.014	0.026
	SD	0.055	0.053	0.040	0.065	0.059	0.056	0.048	0.063
Industry sigma	Mean	0.271	0.237	0.269	0.264	0.246	0.255	0.247	0.314
	SD	0.331	0.340	0.318	0.385	0.324	0.347	0.344	0.355
Cash flow/assets	Mean	−0.157	0.083	−0.255	0.084	−0.082	0.031	−0.134	−0.001
	SD	0.982	1.540	1.963	0.111	1.427	0.369	0.971	0.700
STD/assets	Mean	0.097	0.043	0.122	0.037	0.094	0.033	0.110	0.042
	SD	0.197	0.089	0.223	0.071	0.179	0.085	0.201	0.116
LTD/assets	Mean	0.196	0.178	0.133	0.265	0.175	0.226	0.303	0.109
	SD	0.249	0.188	0.214	0.203	0.201	0.240	0.246	0.175
Capex/assets	Mean	0.053	0.056	0.049	0.063	0.059	0.058	0.065	0.038
	SD	0.066	0.052	0.064	0.058	0.065	0.058	0.072	0.041
R&D/sales	Mean	0.328	0.062	0.476	0.034	0.247	0.169	0.216	0.311
	SD	1.657	0.580	2.080	0.286	1.460	1.158	1.426	1.579
Market to book	Mean	1.814	1.383	2.291	1.164	1.619	1.478	1.374	1.901
	SD	3.142	1.482	3.798	1.227	2.710	2.035	2.914	2.226
NWC/assets	Mean	−0.095	0.082	−0.175	0.050	−0.032	0.058	−0.125	0.042
	SD	1.044	0.302	1.290	0.143	0.959	0.260	1.086	0.568
LTD maturity	Mean	0.368	0.269	0.392	0.234	0.469	0.159	0.372	0.273
	SD	0.383	0.310	0.399	0.252	0.369	0.236	0.343	0.366
Real assets, $m	Mean	6.725	54.556	0.258	86.648	5.536	55.039	20.381	28.918
	SD	36.306	181.864	0.204	228.244	26.673	191.492	121.783	125.972
No. of firm-years		37,080	26,887	26,755	26,754	49,642	39,226	22,546	22,547

This table reports cross-tabulations of the four measures used in our analysis for 89,182 firm-years for 6849 US public firms from 1984 to 2014, except financial firms (SIC codes 6000–6999) and utilities (SIC codes 4900–4999); firm-years with non-positive values for the book value of total assets or sales revenue, and; firms with less than 10 periods of observations. We assign the letter (C) for constrained firms and (U) for unconstrained firms in each row/column to facilitate visualization. Except for the Kaplan-Zingales index, three other measures produce similar classifications of firms. For example, constrained firms hold more cash-to-assets, have negative cash flows, rely more on short-term debt, invest more in R&D, have a higher market-to-book ratio, and have significantly smaller book assets. For definitions of financial constraint criteria, see Subsection 4.2. For variable definitions and details of their construction, see Appendix C.

The cost of carry is the main explanatory variable, a cubic time trend, firm fixed effect, and several firm-level and macroeconomic variables as controls, exist in all specifications. The coefficients among unconstrained firms range from −0.54 (when using firm size) to −1.02 (when using the Kaplan-Zingales index). This implies that if the opportunity cost of holding cash increases by 1 percentage point, cash ratio of the average unconstrained firm decreases approximately between 0.54 and 1.02 percentage points. This effect is not significantly different from zero for constrained firms in all four indicators.

These results are consistent with our previous finding on the heterogeneous impacts of the cost of carry on cash holdings across size classes. As shown in Table 2, changes in the cost of carry significantly affect time-series of cash ratio for large firms, while there is no evidence of such an impact for small ones. Although a majority of QFR small firms are almost never publicly traded and excluded in Compustat, however, since the size is a proxy for credit constraint, we expect our Compustat constrained (unconstrained) group to exhibit a behavior similar to QFR small (large) group. Our results from Table 7 verify this idea by showing that unconstrained (but not constrained) firms accumulate cash as cost of carry drops.

In Fig. 7, we present the time series and confidence intervals of our estimates of the effect of cost of carry on cash holdings of both financially constrained and unconstrained firms. Following Azar et al. (2016), the procedure used is based on rolling regressions of the cash ratio as a function of cost of carry, log of assets, a cubic time trend, and firm fixed effects. The window includes 10 years on either side of the year indicated on the horizontal axis. The effects are statistically significant only for unconstrained firms in all indicators except bond ratings.

As robustness checks, we run several additional regressions where the results are briefly presented in Table 8. We use alternative regression specifications, alternative measures of the cost of carry, and Compustat quarterly data. In the first regression reported in panel (1), we use the dynamic specification (with the lagged cash ratio) and run regressions of the cash-to-assets ratio as a function of the cost of carry, firm-level, and macroeconomic control variables used in Table 7, cubic time trend, and firm fixed effects. This specification allows us to determine if the results are driven by frictions in the adjustment of cash ratio. Similar results in the static and dynamic regressions would imply that such concerns are not crucial.

We then run the minimalist specification without any control variables and regress the cash-to-assets ratio on the cost of carry and a constant, controlling for cubic time trend and firm fixed effects. The idea for running the minimalist specification is to ascertain the robustness of our results in the simplest fashion possible. As presented in panel (2) and consistent with our hypothesis, the effect of the cost of carry is restricted to unconstrained firms. These results are robust to all alternative measures of financial constraint. In panel (3), we replicate our analysis using the logarithm of the cash-to-net assets as the dependent variable. The results are robust to this

Table 7
Determinants of cash (firm-level evidence): 1984–2014.

Cash/assets	Payout ratio		Firm size		Bond ratings		Kaplan-Zingales	
	C	U	C	U	C	U	C	U
Cost of carry	−0.273	−0.676***	−0.222	−0.542***	−0.166	−0.606***	−0.037	−1.018***
	(−1.53)	(−4.54)	(−1.02)	(−4.71)	(−1.42)	(−4.17)	(−0.27)	(−4.45)
Acquisition activity	−0.250***	−0.233***	−0.307***	−0.119***	−0.156***	−0.219***	−0.062***	−0.405***
	(−15.48)	(−14.35)	(−11.02)	(−12.58)	(−13.93)	(−17.78)	(−5.59)	(−22.64)
Industry sigma	0.009	0.001	0.014*	0.006**	−0.003	0.004	0.009**	−0.001
	(1.39)	(0.29)	(1.68)	(2.42)	(−0.76)	(1.06)	(2.06)	(−0.31)
Cash flow/assets	0.003	0.075***	0.001	0.024**	0.006*	0.001	0.007*	0.006
	(1.35)	(4.07)	(1.11)	(2.27)	(1.77)	(1.00)	(1.75)	(1.62)
STD/assets	−0.202***	−0.435***	−0.223***	−0.359***	−0.221***	−0.200***	−0.111***	−0.309***
	(−14.90)	(−12.59)	(−14.73)	(−11.36)	(−15.18)	(−11.44)	(−8.84)	(−8.48)
LTD/assets	−0.137***	−0.099***	−0.140***	−0.049***	−0.113***	−0.099***	−0.083***	−0.121***
	(−13.81)	(−7.37)	(−11.35)	(−4.52)	(−12.40)	(−9.44)	(−9.60)	(−6.69)
Capex/assets	−0.280***	−0.400***	−0.329***	−0.262***	−0.218***	−0.405***	−0.140***	−0.740***
	(−10.94)	(−13.09)	(−10.54)	(−11.11)	(−12.16)	(−15.56)	(−5.91)	(−13.66)
R&D/sales	0.007***	0.000	0.006***	0.011***	0.009***	0.004***	0.005**	0.008***
	(4.87)	(0.02)	(4.45)	(2.86)	(4.46)	(2.76)	(2.35)	(4.44)
Market to book	0.007***	0.009***	0.007***	0.013***	0.009***	0.007***	0.007***	0.008***
	(8.30)	(4.35)	(8.94)	(6.31)	(9.79)	(7.35)	(5.94)	(7.14)
NWC/assets	−0.009***	−0.249***	−0.012***	−0.333***	−0.033***	−0.007**	−0.003	−0.027**
	(−3.18)	(−7.47)	(−3.88)	(−11.41)	(−5.30)	(−2.23)	(−0.97)	(−2.13)
LTD maturity	−0.032***	−0.008*	−0.035***	−0.002	0.007**	−0.013***	−0.009**	−0.014***
	(−8.45)	(−1.92)	(−7.11)	(−0.76)	(2.34)	(−3.44)	(−2.43)	(−3.28)
Log of real assets	−0.005*	−0.012***	0.005	−0.022***	0.002	−0.007**	−0.007**	−0.009**
	(−1.91)	(−3.25)	(1.19)	(−6.99)	(0.71)	(−2.38)	(−2.32)	(−2.15)
Real GDP growth	−0.103	−0.052	−0.158	−0.014	−0.047	−0.042	−0.025	−0.130
	(−1.18)	(−0.73)	(−1.42)	(−0.30)	(−0.78)	(−0.65)	(−0.33)	(−1.31)
EPU	−0.001**	−0.003	−0.014**	−0.002	0.003	−0.013***	−0.006	−0.006
	(−2.05)	(−0.75)	(−2.18)	(−0.91)	(0.72)	(−3.63)	(−1.52)	(−1.34)
BAA-AAA spread	−1.358***	−0.770*	−2.389***	−0.088	−1.040***	−0.544	−0.263	−1.321**
	(−2.79)	(−1.88)	(−3.69)	(−0.33)	(−2.90)	(−1.49)	(−0.60)	(−2.47)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cubic time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,654	19,098	20,612	17,913	30,789	33,947	17,724	18,177
Adjusted R^2	0.100	0.168	0.108	0.184	0.106	0.076	0.071	0.136

The sample includes 89,182 firm-years for 6849 US public firms from 1984 to 2014, except financial firms (SIC codes 6000–6999) and utilities (SIC codes 4900–4999); firm-years with non-positive values for the book value of total assets or sales revenue; and firms with less than 10 periods of observations. We assign the letter (C) for constrained firms and (U) for unconstrained firms in each column to facilitate visualization. In all specifications, regressions are estimated using firm fixed effects and clustered standard errors. For definitions of financial constraint criteria, see Subsection 4.2. The dependent variable is the cash-to-asset ratio. We measure Cash as cash and short-term investments (Compustat item *che*). For variable definitions and details of their construction, see Appendix C. *t*-statistics are in parentheses. Statistical significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

dependent variable. The coefficients among unconstrained firms range from −8.75 (when using firm size) to −7.50 (when using bond ratings). Although constrained firms exhibit a significant sensitivity of cash holdings to the cost of carry in all four indicators, the magnitude of the coefficients for unconstrained firms is almost twice the coefficients for constrained firms.[32]

We also check the robustness of our results using the firm-level cost of carry. Since we use the Fed's Flow of Funds data in (6), there might be a macro variable that drive both the cost of carry and firms' cash ratios. To alleviate this concern, we follow Azar et al. (2016) and construct a firm-level measure of the cost of carry using micro-level data. The firm-level cost of carry is thus defined as the fraction of cash held in the immediately negotiable medium of exchange compared with the fraction held in interest-bearing assets. As shown in panel (4) of Table 8, the results for constrained and unconstrained firms are similar to our previous results. Changes in the firm-level cost of carry have a significant effect on the cash ratio for unconstrained firms, while there is no evidence of such an impact for their constrained counterparts. Next, we examine whether our results are affected by the use of quarterly firm data. As reported in panel (5), the effect of the cost of carry is restricted to unconstrained firms, and the sign of coefficients for constrained firms is still not significant, except for the bond ratings.

We check the robustness of the results by analyzing the response of manufacturing firms (SIC codes 2000–3999) to changes in the cost of carry. For this purpose, we use a sample of 46,420 firm-years observations for 3413 US public manufacturing firms between

[32] These findings are consistent with the findings of Azar et al. (2016) that small firms' demand for cash is less elastic than that of large firms. While both small and large groups have a significant estimated effect of cost of carry on the logarithm of the cash-to-net assets, when we assign to the financially constrained group those firms in the bottom decile of the asset distribution then the coefficients become statistically insignificant for small firms which is consistent with our hypothesis.

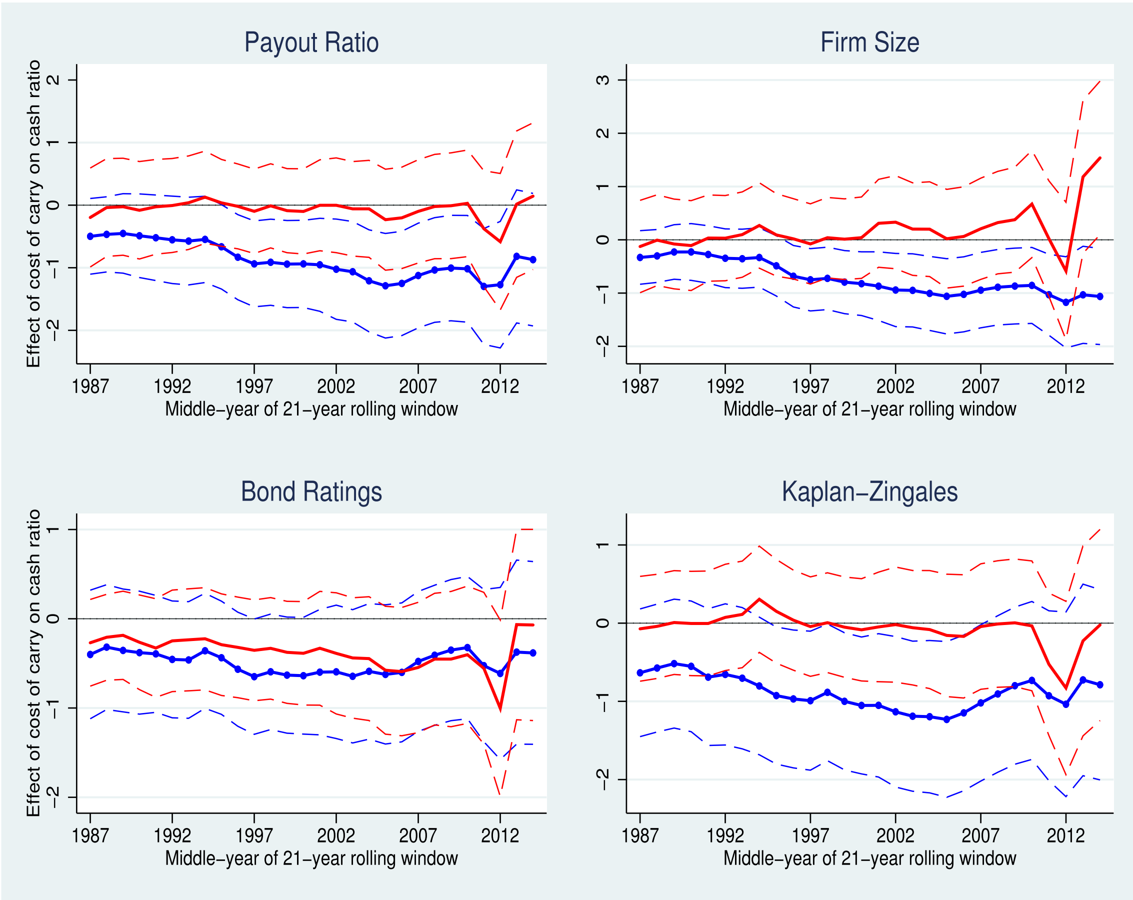

Fig. 7. Rolling regressions of firm-level money demand.
This figure plots the time series and confidence intervals of our estimates of the effect of cost of carry on cash holdings of both financially constrained and unconstrained firms. The procedure used is based on rolling regressions of the cash ratio as a function of cost of carry, log of assets, a cubic time trend, and firm fixed effects. The window includes 10 years either side of the year indicated on the horizontal axis.

1985 and 2014. We use firms belonging to manufacturing industries to explore the robustness of our initial times-series results from the QFR sample. Table 9 presents the results for manufacturing firms using similar identifications of those in Table 7. As shown in this table, changes in the cost of carry have a significant effect on the cash holdings of unconstrained manufacturing firms, while there is no evidence of such an impact for constrained firms.[33] The sign of coefficients for constrained firms is still not significant, except for the payout ratio.

We also examine whether a small subset of very large firms is driving our results. Recent empirical studies have provided evidence that the different behavior of firms in the top 10% and, in particular, by firms in the top 1% is remarkable.[34] Although small in number, the size of very large firms is so enormous that the behavior of the aggregate series is liable to be dominated by their behavior. For example, Covas and Den Haan (2011), conditioning on firm size, show that the use of aggregate data gives a misleading picture of the cyclicality of debt and equity issuance at the firm level. The amounts of funds raised by a small subset of very large firms are so big that they have a large impact on the results for the aggregate series. In their sample, the top 1% contains, on average, only 32 firms. Crouzet and Mehrotra (2020) also find that the top 1% of firms dominate the behavior of aggregate sales and investment fluctuations. Therefore, it is natural to ask whether a small subset of very large firms drives our results for unconstrained firms.

We exclude the largest firms, those in the top 1%, 5%, and 10%, from our definition of unconstrained firms based on the firm size index and reestimate model (8) to address potential concerns about the different behavior of very large firms. We assign the firms in the top three deciles of the firm size distribution to the financially unconstrained group, excluding those firms in the top 1%, 5%, and 10%.[35] Table 10 shows the results for US public (manufacturing) firms and verifies that excluding the largest firms from the other large

[33] Our results are also robust for services, retail trade, and "other" SIC industry divisions as a group.
[34] Autor et al. (2017, 2020) and Van Reenen (2018) emphasize the role of firm heterogeneity in the dynamics of the aggregate labor share and document empirical patterns to assess the fall of labor's share of GDP in recent decades based on the rise of "superstar firms".
[35] For example, when we exclude those firms in the top 10%, our unconstrained group is the 8^{th} and 9^{th} deciles of the firm size distribution.

Table 8
Determinants of cash with alternative regression specifications, alternative cost of carry, and quarterly data (firm-level evidence): 1984–2014.

(1)	Payout ratio		Firm size		Bond ratings		Kaplan-Zingales	
Cash/Assets	C	U	C	U	C	U	C	U
Cost of carry	−0.093	−0.310***	−0.241	−0.327***	−0.092	−0.259**	−0.053	−0.369**
	(−0.64)	(−2.89)	(−1.35)	(−3.88)	(−0.97)	(−2.46)	(−0.41)	(−2.27)
Lagged (cash/assets) (dynamic regression)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,117	18,510	18,479	17,558	28,288	32,335	17,724	18,177
Adjusted R^2	0.294	0.425	0.287	0.403	0.279	0.305	0.138	0.383
(2)	Payout Ratio		Firm Size		Bond Ratings		Kaplan-Zingales	
Cash/Assets	C	U	C	U	C	U	C	U
Cost of carry	−0.249*	−0.952***	0.013	−0.805***	−0.402***	−0.577***	−0.003	−1.017***
	(−1.85)	(−8.96)	(0.07)	(−10.39)	(−4.42)	(−5.50)	(−0.02)	(−5.42)
Control variables	No	No	No	No	No	No	No	No
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	37,073	26,877	26,751	26,737	44,440	44,490	22,540	22,544
Adjusted R^2	0.006	0.023	0.003	0.057	0.005	0.012	0.008	0.015
(3)	Payout Ratio		Firm Size		Bond Ratings		Kaplan-Zingales	
ln(Cash/Net Assets)	C	U	C	U	C	U	C	U
Cost of carry	−5.389***	−8.236***	−4.844**	−8.746***	−5.211***	−7.498***	−5.505***	−8.513***
	(−3.25)	(−5.23)	(−2.57)	(−5.39)	(−3.81)	(−5.74)	(−2.66)	(−5.07)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,340	19,021	20,348	17,846	30,491	33,714	17,483	18,121
Adjusted R^2	0.093	0.164	0.098	0.187	0.093	0.088	0.060	0.143
(4)	Payout Ratio		Firm Size		Bond Ratings		Kaplan-Zingales	
Cash/Assets	C	U	C	U	C	U	C	U
Firm-level cost of carry	−0.392*	−0.415***	0.006	−0.239*	−0.142	−0.453***	0.049	−0.548**
	(−1.87)	(−2.80)	(0.02)	(−1.79)	(−0.91)	(−3.17)	(0.30)	(−2.42)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,008	17,432	16,795	16,815	25,581	30,553	17,289	17,814
Adjusted R^2	0.102	0.173	0.110	0.186	0.104	0.081	0.073	0.135
(5)	Payout Ratio		Firm Size		Bond Ratings		Kaplan-Zingales	
Cash/Assets (Quarterly Data)	C	U	C	U	C	U	C	U
Cost of carry	−0.055	−0.529***	−0.055	−0.426***	−0.401***	−0.478***	−0.076	−1.124***
	(−0.42)	(−4.88)	(−0.34)	(−4.83)	(−4.50)	(−4.66)	(−1.05)	(−5.42)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	127,284	76,623	101,029	87,981	159,473	155,605	82,351	81,957
Adjusted R^2	0.074	0.173	0.084	0.147	0.075	0.058	0.039	0.087

The sample includes 89,182 firm-years for 6849 US public firms from 1984 to 2014, except financial firms (SIC codes 6000–6999) and utilities (SIC codes 4900–4999); firm-years with non-positive values for the book value of total assets or sales revenue, and; firms with less than 10 periods of observations. We assign the letter (C) for constrained firms and (U) for unconstrained firms in each column to facilitate visualization. In all specifications, regressions are estimated using firm fixed effects and clustered standard errors. For definitions of financial constraint criteria, see Subsection 4.2. Cash is measured as cash and short-term investments (Compustat item *che*). A cubic time trend and log of real assets are included in all specifications. Panel (1) is the dynamic specification (with the lagged cash ratio) and includes all control variables. Panel (2) is the minimalist specification without any control variables. Panel (3) replicates our analysis using the logarithm of the cash-to-net assets as the dependent variable. Panel (4) use the firm-level cost of carry. Panel (5) considers Compustat quarterly data. *t*-statistics are in parentheses. Statistical significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

firms has minimal impact on our main findings. Therefore a small subset of very large firms is not driving our results for the unconstrained group.

We now consider several measures of interest rates as alternative proxies for the opportunity cost of holding cash: the effective federal funds rate, and the 3-month, 6-month, and 2-year Treasury constant maturity rates. As shown in Table 11, our results are robust to alternative measures of interest rates. Finally, as in the cost of carry, we examine whether our baseline results (Table 7) hold up when we use Compustat quarterly data. The results in panel (4) of Table 11 show that the effect of interest rates is restricted to unconstrained firms.

Table 9
Determinants of cash (firm-level manufacturing evidence): 1984–2014.

Cash/Assets	Payout ratio		Firm size		Bond ratings		Kaplan-Zingales	
	C	U	C	U	C	U	C	U
Cost of carry	−0.441*	−0.241	−0.436	−0.474***	−0.082	−0.573***	−0.002	−0.807***
	(−1.77)	(−1.32)	(−1.53)	(−3.05)	(−0.51)	(−2.80)	(−0.01)	(−2.95)
Acquisition activity	−0.247***	−0.248***	−0.268***	−0.133***	−0.155***	−0.236***	−0.073***	−0.403***
	(−11.71)	(−12.96)	(−7.46)	(−9.78)	(−10.50)	(−14.47)	(−4.36)	(−17.47)
Industry sigma	0.013	0.013	0.033**	0.003	−0.002	0.007	0.032***	−0.001
	(1.08)	(1.60)	(1.98)	(0.54)	(−0.20)	(0.83)	(2.62)	(−0.03)
Cash flow/assets	0.009**	0.083***	0.010**	0.046**	0.015**	0.025***	0.008*	0.016
	(2.13)	(2.67)	(2.47)	(2.15)	(1.98)	(4.02)	(1.89)	(1.29)
STD/assets	−0.195***	−0.548***	−0.203***	−0.358***	−0.229***	−0.198***	−0.116***	−0.255***
	(−10.56)	(−12.94)	(−10.15)	(−9.83)	(−11.16)	(−8.07)	(−6.13)	(−5.53)
LTD/assets	−0.150***	−0.099***	−0.151***	−0.066***	−0.131***	−0.100***	−0.103***	−0.108***
	(−10.94)	(−5.36)	(−9.10)	(−3.96)	(−9.66)	(−6.81)	(−7.46)	(−4.41)
Capex/assets	−0.369***	−0.509***	−0.436***	−0.402***	−0.277***	−0.590***	−0.240***	−0.814***
	(−9.29)	(−11.14)	(−9.48)	(−9.84)	(−9.95)	(−13.03)	(−4.84)	(−11.96)
R&D/sales	0.007***	−0.007	0.007***	0.011***	0.009***	0.004***	0.005**	0.008***
	(4.48)	(−0.91)	(4.32)	(2.70)	(4.29)	(2.71)	(2.30)	(4.44)
Market to book	0.007***	0.010***	0.007***	0.012***	0.009***	0.007***	0.008***	0.009***
	(6.33)	(3.30)	(7.03)	(3.98)	(6.42)	(5.82)	(5.15)	(6.34)
NWC/assets	−0.010**	−0.404***	−0.012***	−0.354***	−0.038***	−0.015***	−0.001	−0.021
	(−2.38)	(−10.76)	(−2.85)	(−12.51)	(−4.01)	(−3.05)	(−0.13)	(−1.17)
LTD maturity	−0.032***	−0.011**	−0.036***	−0.001	0.007	−0.012**	−0.009	−0.016***
	(−6.10)	(−2.20)	(−5.40)	(−0.01)	(1.45)	(−2.50)	(−1.50)	(−2.81)
Log of real assets	0.003	−0.009*	0.015**	−0.021***	0.012***	0.003	0.002	0.005
	(0.86)	(−1.83)	(2.52)	(−4.22)	(2.92)	(0.73)	(0.45)	(0.90)
Real GDP growth	−0.267**	−0.061	−0.432***	−0.125*	−0.128	−0.111	−0.111	−0.180
	(−2.14)	(−0.65)	(−2.92)	(−1.87)	(−1.57)	(−1.21)	(−0.96)	(−1.45)
EPU	−0.016**	−0.002	−0.017**	−0.000	0.002	−0.016***	−0.009	−0.005
	(−2.34)	(−0.48)	(−2.03)	(−0.12)	(0.33)	(−3.09)	(−1.37)	(−0.84)
BAA-AAA spread	−1.469**	−0.092	−3.332***	−0.348	−0.807	−0.474	−0.394	−0.918
	(−2.16)	(−0.17)	(−4.01)	(−0.96)	(−1.56)	(−0.95)	(−0.56)	(−1.36)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cubic time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,784	10,652	12,020	8835	16,912	18,026	8466	10,963
Adjusted R^2	0.102	0.221	0.115	0.209	0.115	0.087	0.081	0.131

The sample includes 46,420 firm-years for 3413 US public manufacturing firms (SIC codes 2000–3999) from 1984 to 2014, except firm-years with non-positive values for the book value of total assets or sales revenue, and; firms with less than 10 periods of observations. We assign the letter (C) for constrained firms and (U) for unconstrained firms in each column to facilitate visualization. In all specifications, regressions are estimated using firm fixed effects and clustered standard errors. For definitions of financial constraint criteria, see Subsection 4.2. The dependent variable is cash-to-asset ratio. We measure Cash as cash and short-term investments (Compustat item *che*). For variable definitions and details of their construction, see Appendix C. *t*-statistics are in parentheses. Statistical significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

Table 10
Determinants of cash with alternative definitions of unconstrained firms (firm-level evidence): 1984–2014.

(2)	Firm size (unconstrained all firms)			Firm size (unconstrained manufacturing firms)		
Cash/Assets	Excl. top 1%	Excl. top 5%	Excl. top 10%	Excl. top 1%	Excl. top 5%	Excl. top 10%
Cost of carry	−0.462***	−0.438***	−0.525***	−0.435**	−0.443***	−0.466***
	(−3.47)	(−3.45)	(−4.50)	(−2.38)	(−2.66)	(−2.95)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,246	15,165	17,389	6160	7620	8568
Adjusted R^2	0.189	0.186	0.189	0.223	0.214	0.217

The sample excludes those firms in the top 1%, 5%, and 10% from our definition of unconstrained firms based on firm size index. In all specifications, regressions are estimated using firm fixed effects and clustered standard errors. For definitions of financial constraint criteria, see Subsection 4.2. Cash is measured as cash and short-term investments (Compustat item *che*). A cubic time trend and log of real assets are included in all specifications. *t*-statistics are in parentheses. Statistical significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

Overall, our micro-level analysis indicates that unconstrained firms have a propensity to save cash when the opportunity cost of holding cash declines. In contrast, constrained firms do not exhibit this propensity. These results mirror our semi-aggregate findings of differences between small and large firms, which favors access to credit markets to produce different behaviors across small and large firms.

These findings complement the previous studies on the cost-based explanations of cash dynamics. Azar et al. (2016) argue that

Table 11
Determinants of cash with alternative measures of interest rates and quarterly data (firm-level evidence): 1984–2014.

(1)	Payout ratio		Firm size		Bond ratings		Kaplan-Zingales	
Cash/Assets	C	U	C	U	C	U	C	U
Effective Federal Funds Rate	−0.120	−0.334***	−0.078	−0.282***	−0.0811	−0.264***	−0.071	−0.433***
	(−1.55)	(−5.24)	(−0.81)	(−5.85)	(−1.53)	(−4.34)	(−1.18)	(−4.74)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,654	19,098	20,612	17,913	30,789	33,947	17,724	18,177
Adjusted R^2	0.100	0.168	0.107	0.185	0.106	0.076	0.071	0.137
(2)	Payout Ratio		Firm Size		Bond Ratings		Kaplan-Zingales	
Cash/Assets	C	U	C	U	C	U	C	U
3-month T-bill rate	−0.146*	−0.386***	−0.095	−0.323***	−0.105*	−0.303***	−0.074	−0.502***
	(−1.65)	(−5.29)	(−0.86)	(−5.80)	(−1.74)	(−4.34)	(−1.06)	(−4.79)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,654	19,098	20,612	17,913	30,789	33,947	17,724	18,177
Adjusted R^2	0.100	0.168	0.108	0.185	0.106	0.076	0.071	0.137
(2)	Payout Ratio		Firm Size		Bond Ratings		Kaplan-Zingales	
Cash/Assets	C	U	C	U	C	U	C	U
6-month T-bill rate	−0.155*	−0.405***	−0.102	−0.341***	−0.118*	−0.323***	−0.081	−0.530***
	(−1.69)	(−5.33)	(−0.90)	(−5.90)	(−1.87)	(−4.48)	(−1.12)	(−4.87)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,654	19,098	20,612	17,913	30,789	33,947	17,724	18,177
Adjusted R^2	0.100	0.168	0.108	0.185	0.106	0.076	0.071	0.137
(3)	Payout Ratio		Firm Size		Bond Ratings		Kaplan-Zingales	
Cash/Assets	C	U	C	U	C	U	C	U
6-year T-bill rate	−0.203*	−0.485***	−0.168	−0.418***	−0.148**	−0.409***	−0.094	−0.647***
	(−1.86)	(−5.21)	(−1.25)	(−5.97)	(−1.98)	(−4.69)	(−1.09)	(−4.80)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	27,654	19,098	20,612	17,913	30,789	33,947	17,724	18,177
Adjusted R^2	0.100	0.168	0.108	0.185	0.106	0.076	0.071	0.137
(4)	Payout Ratio		Firm Size		Bond Ratings		Kaplan-Zingales	
Cash/Assets	C	U	C	U	C	U	C	U
3-month T-bill rate	0.042	−0.184***	0.063	−0.138***	−0.150***	−0.129***	−0.027	−0.316***
	(0.76)	(−4.10)	(0.86)	(−3.64)	(−3.61)	(−2.87)	(−0.81)	(−4.16)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	127,284	76,623	101,029	87,981	159,473	155,605	82,351	81,957
Adjusted R^2	0.074	0.173	0.084	0.147	0.074	0.058	0.039	0.086

The sample includes 89,182 firm-years for 6849 US public firms from 1984 to 2014, except financial firms (SIC codes 6000–6999) and utilities (SIC codes 4900–4999); firm-years with non-positive values for the book value of total assets or sales revenue, and; firms with less than 10 periods of observations. We assign the letter (C) for constrained firms and (U) for unconstrained firms in each column to facilitate visualization. In all specifications, regressions are estimated using firm fixed effects and clustered standard errors. For definitions of financial constraint criteria, see Subsection 4.2. Cash is measured as cash and short-term investments (Compustat item *che*). A cubic time trend and log of real assets are included in all specifications. Panels (1) to (4) use several other measures of interest rates: the effective federal funds rate, the 6-month, 2-year, 5-year Treasury constant maturity rates. Panel (5) considers Compustat quarterly data. *t*-statistics are in parentheses. Statistical significance at the 1%, 5%, and 10% levels is indicated by ***, **, and *, respectively.

since the early 1980s, the composition of the liquid-assets portfolios of US firms has progressively shifted toward interest-bearing assets, which led to a gradual decline in the cash sensitivity of interest rate. This mechanism is more prominent for large firms as they are more capable of employing sophisticated cash management practices and face lower transaction costs, and therefore, they became increasingly able to minimize their exposure to non-interest bearing accounts over time.

However, the proposed mechanism in this our study is not related to the composition of firms' liquid asset portfolios. Our analysis relies on the fact that unconstrained firms have a flatter marginal cost function of cash shortage driven by their flatter external finance cost function. Therefore, the sensitivity of cash to changes in the cost of carry is more pronounced for unconstrained firms. Therefore, even when the cost of carry is the same for constrained and unconstrained firms, unconstrained firms are the ones that respond to a marginal change in the cost of carry. In all, our analysis indicates that unconstrained firms have a propensity to save cash when the opportunity cost of holding cash declines, while constrained firms do not exhibit this propensity.

Table 12
Summary of robustness tests and alternative explanations.

Panel A: Summary of robustness tests

Test	Result
Alternative specifications of the model	We use first-difference in our analysis of aggregate data (Eq. 7) to prevent results from being driven by a common trend since many of the aggregate series are highly persistent, raising the possibility of spurious regression. For our analysis of firm-level data (Eq. 8), since we are controlling for a cubic time trend ($f(t)$), therefore we are identifying the effect of the cost of carry from variation in cash ratios and the cost of carry around their respective time trends and not from the time trends themselves. However, as a robustness check, we also run dynamic regressions with the lagged cash ratio as a regressor. Using the lagged values of the dependent variable helps us determine to which extent frictions in the adjustment of cash ratios that are correlated with variations in the cost of carry drive the results in the static regressions. Similar results obtained for the static (Table 7) and dynamic regressions (Table 8) would indicate such considerations are less central.
Alternative definitions of the cash ratio	In Panel (3) of Table 8, we use the logarithm of cash to net assets instead of the level of cash ratios to reduce the effect of extreme outliers; results are robust to this choice.
Alternative data frequency	We examine whether our results are sensitive to data frequency by using quarterly data for estimation. Panel (5) of Table 8 reports our estimated based on Compustat quarterly data and confirms our main result about the relationship between the cost of carry and corporate cash holdings for constrained and unconstrained firms.
Manufacturing firms	We check the robustness of the results by analyzing the response of Compustat manufacturing firms (SIC codes 2000–3999) to changes in the cost of carry. Table 9 indicates robust significant relations between cash and the cost of carry for unconstrained firms.
Excluding very large firms	We finally examine whether a small subset of very large firms is driving our results for unconstrained firms. To address potential concerns about the different behavior of very large firms, we exclude the largest firms, those in the top 1%, 5%, and 10%, from our definition of unconstrained firms based on firm size index and reestimate model (8). Table 10 shows that excluding the largest firms from the other large firms has minimal impact. Therefore a small subset of very large firms is not driving our results for the unconstrained group.

Panel B: Alternative explanations

Concern	Response
Is it plausible a non-linear (hump-shaped) relationship between interest rates and corporate cash?	We verify the sensitivity of our benchmark results (Tables 2 and 7) with respect to the plausible hump-shaped cash-interest relation. To rule out the possibility of such correlations in our aggregate and firm-level analysis, we experiment with an augmented model including the interest rate and its square to Eqs. (7) and (8). We do not find a statistically significant hump-shaped relationship between corporate cash holdings and interest rates in aggregate and firm-level data.
Does endogeneity matter?	Estimating the cash-interest relation generally involves identification issues, particularly reverse causality and omitted variables bias. The most likely omitted variable is productivity, and as reported in Graham and Leary (2018), macroeconomics productivity (as a measure of investment opportunities) has a large explanatory power on the time-series changes in aggregate corporate cash. Although we have controlled real GDP growth (another measure of investment opportunities), to mitigate this potential endogeneity concern, we include asset productivity (sales/assets) and macroeconomic productivity (output-to-capital ratio) in Eq. (7), and firm-level productivity (firm-level TFP) and macroeconomic productivity in Eq. (8) to address the concerns about the existence of an omitted variable. We find that the results are highly robust to the inclusion of each productivity variable. Another endogeneity concern is reverse causality, and it is possible to think about the feedback channel from aggregate corporate data to macroeconomic conditions. Although our time-series analysis might suffer from this reverse causality bias, our firm-level analysis is not prone to this source of endogeneity because the financial decision of a single firm has a negligible effect on macroeconomic conditions. For productivity definitions and details of their construction, see Appendix C.

While we conduct several robustness checks and control several firm characteristics and other macroeconomic variables, estimating the cash-interest relation generally involves identification issues, particularly omitted variables bias and reverse causality. First, we attempt to mitigate the potential endogeneity concern that could arise because of the existence of an omitted variable that would be correlated with both interest rates and firms' cash holdings. The most likely omitted variable is productivity, and as reported in Graham and Leary (2018), macroeconomics productivity (as a measure of investment opportunities) has a large explanatory power on the time-series changes in aggregate corporate cash. Although we have controlled real GDP growth (another measure of investment opportunities), we include asset productivity (sales/assets) and macroeconomic productivity (output-to-capital ratio), and firm-level productivity (firm-level TFP) and macroeconomic productivity in Eq. (8) to address the serious concerns about the existence of an omitted variable. We find that the results are highly robust to the inclusion of each productivity variable.[36] The second endogeneity concern is reverse causality, and it is possible to think about the feedback channel from aggregate corporate data to macroeconomic conditions. Although our time-series analysis might suffer from this reverse causality bias, our firm-level analysis is not prone to this source of endogeneity because the financial decision of a single firm has a negligible effect on macroeconomic conditions. In Table 12, we summarize the robustness tests and supplementary analyses that we described in the paper to increase confidence in our empirical

[36] For productivity definitions and details of their construction, see Appendix C.

strategy and address concerns about potential alternative explanations of our findings.

5. Conclusion

In this paper, we examine the extent to which the cost of carry affects corporate cash holdings in the presence of financial constraints. In particular, we answer how changes in the cost of carry have a differential impact on cash holdings across constrained and unconstrained firms. We provide a basic model that predicts changes in the marginal costs of holding cash drive variations in optimal corporate cash holdings and considerably more for financially unconstrained firms.

To test this hypothesis, we use the US Census Bureau Quarterly Financial Report (QFR), which covers the statistics of US public and private manufacturing firms in different size classes from 1955 to 2017. Our results suggest a robust negative correlation between corporate cash holdings and the cost of carry for large firms but not for small firms. We also use a sample of US public firms from Compustat between 1984 and 2014 and analyze the response of constrained versus unconstrained firms to changes in the cost of carry. We use four alternative approaches for sorting firms into financially constrained and financially unconstrained using payout ratio, firm size, debt rating, and Kaplan-Zingales index. The result of both time-series and firm-level analyses confirms that the negative and significant relationship between cash holdings and the cost of carry is restricted to large and unconstrained firms. This paper, therefore, extends the literature of corporate finance by showing that cost-based explanations for cash dynamics are relevant for firms with relatively easy access to capital markets.

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Appendix A. A Proof of Proposition 1

The first-order condition of 2 implies:

$$-\frac{\partial CCS}{\partial i} = \frac{\partial CC}{\partial i} \Rightarrow \lambda_1 + 2\lambda_2 e = i$$

where e is the amount of external funds raised by the firm. Substituting e with $I - l$ yields:

$$\lambda_1 + 2\lambda_2(I - l) = i$$

which gives:

$$l = \begin{cases} I & \textit{if} \quad i \le \lambda_1 \\ I - \dfrac{(i-\lambda_1)}{2\lambda_2} & \textit{if} \quad \lambda_1 < i \le \lambda_1 + 2\lambda_2 I \\ 0 & \textit{if} \quad i > \lambda_1 + 2\lambda_2 I \end{cases}$$

Note that we have the corner solution $l = 0$ for $i > \lambda_1 + 2\lambda_2 I$ (see panel (a) of Fig. A.1). Moreover, l never exceeds I such that $l = min\left\{I - \frac{(i-\lambda_1)}{2\lambda_2}, I\right\}$. This case $l = I$ occurs when $i < \lambda_1$ (see panel (b) of Fig. A.1).

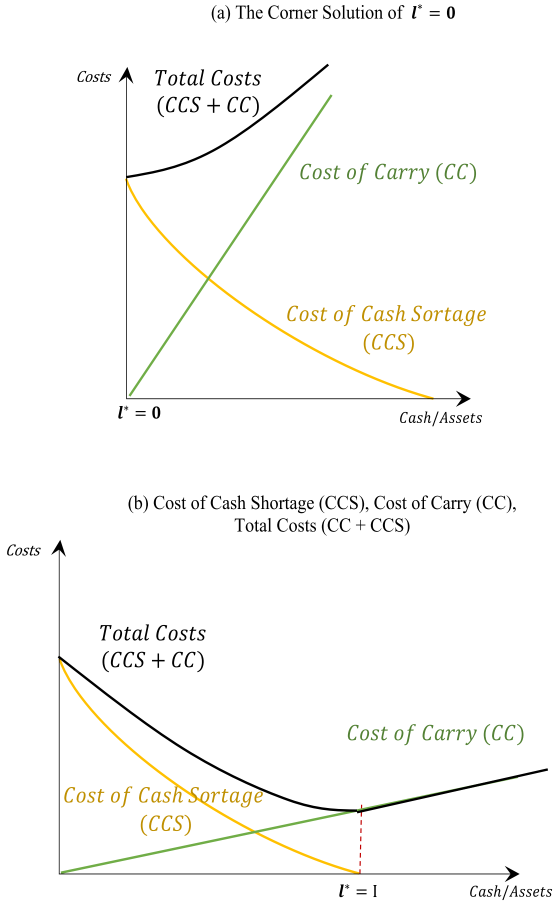

Fig. A.1. The optimal cash holdings of firms.
Panel (a) illustrates the corner solution of $l = 0$ for cash holdings. Panel (b) shows the condition that the specific solution $l = I$ appears.

Now we have to show that the optimal cash of the unconstrained firm is more sensitive to changes in the interest rates i. To be more precise, we show that the cash response of the unconstrained firm is larger (or equal) than the response of the constrained firm. For two extreme cases $l = 0$ and $l = I$, the optimal cash of both firms is not sensitive to small changes in i. However, under the mild condition $\lambda_1 < i \leq \lambda_1 + 2\lambda_2 I$ we have:

$$(\partial l / \partial i) = -\frac{1}{2\lambda_2}$$

Using 2 we then have:

$$0 > -\frac{1}{2\lambda_2^c} > -\frac{1}{2\lambda_2^u}.$$

This inequality means that the negative cash response of the unconstrained firm is larger than that of the constrained firm. Therefore, the proposition holds.

Appendix B. Measurement of small and large firms

Our procedure to categorize all QFR brackets into small and large firms is reported in Eskandari and Zamanian (2021). We quote the whole procedure from that paper as below:

We construct our small and large groups using a similar version of the procedure applied in Gertler and Gilchrist (1994). We introduce sales as our indicator of firm size and aggregate all firms into small and large groups. We sort the QFR classes from the smallest asset bracket to the largest and accumulate their sales beginning from the smallest asset class until we reach the 30th percentile of the total sales in each period, our cut-off for small firms. Large firms are those above this cut-off.

More formally, using the quarterly data from 1956 through 2008, we follow the procedure below to construct our size groups. Let S_{it} denotes total sales of firms in size category i in period t (after deflating by the GDP deflator). We define $\overline{S}_{it}$ as the accumulated assets for categories less than or equal to category i in period t normalized by total sales in that period. Where $N = 8$ denotes the number of size categories.

$$\overline{S}_{it} = \frac{\sum_{j=1}^{i} S_{jt}}{\sum_{j=1}^{N} S_{jt}}, \quad i = 1, \ldots, N_t$$

Then we compute the threshold value or cut-off i^* as,

$$i_t^* = \min_{i \in \{1, N_t\}} \{\overline{S}_{it} > 0.3\},$$

as well as the weights ω_t such that

$$\omega_t \overline{S}_{(i_t^*-1)_t} + (1-\omega_t)\overline{S}_{i_t^* t} = 0.3$$

As discussed by Gertler and Gilchrist (1994), this procedure reasonably adjusts for biases arising from shifting firms across categories over time. This shift is mainly caused because the measure of size in the QFR is nominal assets implying inflation causes firms to drift from low nominal asset categories to high ones over time. Using this procedure, we have a consistent definition of small and large firms over the whole period. Fig. B.1 depicts the cut-off that straddles this 30^{th} percentile over the period of analysis. The cut-off between small and large firms increases over time as the nominal assets of firms increase.[37] When the cut-off falls inside the largest category (i.e., $i_t^* = 8$), we set ω_t equal to one in calculating the variables for small firms. As Gertler and Gilchrist (1994) show, this grouping of small and large firms provides a measure of the size as a reasonable proxy for access to capital markets.

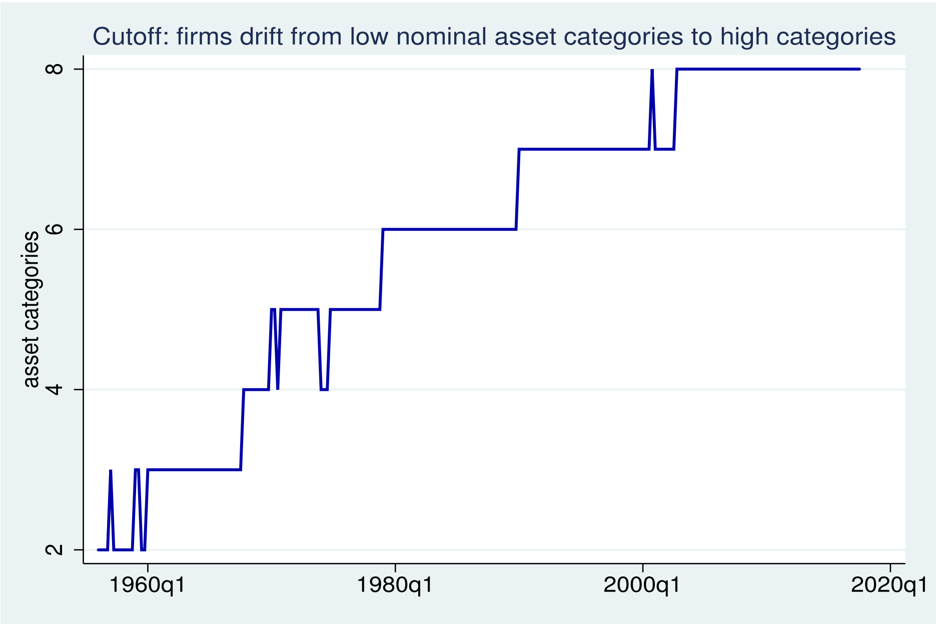

Fig. B.1. Percent of manufacturing sales by cumulative asset size.

This figure depicts the cutoff that straddles this 30^{th} percentile over the period of analysis. The cutoff between small and large firms increases over time as the amount of firms' nominal assets increases.

After getting the weights, we construct the time-series variables of interest for small and large firms as follows:

Let G to be any variable of interest and G_t^S and G_t^L denote the corresponding series of G for small and large firms,

$$G_t^S = \sum_{j=1}^{i_t^*-1} G_{j,t} + (1-\omega_t) G_{i_t^*,t}$$

and

$$G_t^L = \omega_t G_{i_t^*,t} + \sum_{j=i_t^*+1}^{N_t} G_{j,t}$$

[37] Note that the GDP deflator has no impact on the computation of the weights, ω_t.

Appendix C. Variable definitions

Time-series variables

All variables in brackets are QFR data items.

- *BAA-AAA spread*: Difference between the Moody's seasoned BAA corporate bond yield and Moody's seasoned AAA corporate bond yield (Source: FRED).
- *CASHTIM*: Sum of cash, demand deposits, and time deposits in the U.S. [*CASHTIM*].
- *Cash/assets*: Sum of total cash [*TOCASHSEC*] over total assets [*TOTASSET*].
- *Cash/net assets*: Sum of total cash [*TOCASHSEC*] over net assets, where net assets equal total assets [*TOTASSET*] minus cash holdings [*TOCASHSEC*].
- *CFL volatility*: For each group of QFR firms, aggregate cash flow volatility is defined as the variance of *cash flow/assets* over the previous four years.
- *Cash flow/assets*: For each group of QFR firms, operating cash flows is measured by: ($NIAT_t - \Delta TOCRASSET_t - \Delta TOCASHSEC_t + \Delta TOCRLIAB_t$) over total assets [*TOTASSET*], where [*NIAT*], [*TOCRASSET*], [*TOCASHSEC*], and [*TOCRLIAB*] indicate, respectively, net income after tax, total current asset, cash-holding, and total current liabilities.
- *Cost of carry*: Following Azar et al. (2016), we define *cost of carry* as the spread between the nominal risk free *T-bill* rate and the return on the corporate sector liquid-assets portfolio obtained from the Fed's Flow of Funds, see (6).
- *Corporate tax rate*: Top statutory US federal corporate income tax rate (Source: Statistics of Income (SOI) Tax Stats Historical Table 24, Internal Revenue Service (IRS)).
- *Econ policy uncertainty (EPU)*: Economic policy uncertainty index of Baker et al. (2016).
- *Investment/assets*: Quarterly change in fixed assets [*TOTASSET-TOCRASSET*] over total assets [*TOTASSET*].
- *Long-term leverage (LTD/assets)*: Sum of long-term loans from banks due in more than 1 year [*STBANK*], long-term bonds and debentures due in more than 1 year [*LTBNDDEBT*], other long-term loans due in more than 1 year [*LTOTHDEBT*], current portion of long-term loans from banks due in 1 year or less [*INSTBANKS*], current portion of long-term bonds and debentures due in 1 year or less [*INSTBONDS*], current portion of other long-term loans due in 1 year or less [*INSTOTHER*] over total assets [*TOTASSET*].
- *LTD maturity*: We proxy for debt maturity by dividing the sum of this year and next year installments [*INSTBANKS* + *INSTBONDS* + *INSTOTHER*] over the total outstanding long-term debt (*LTD*) of this year, and the same for LTD due in three years, all measured at the first quarter of the year. We use this procedure to estimate the calculations of Harford et al. (2014) who use firms LTD that is due in the next one, two, and three years as a proxy for the maturity of firm's debt and their refinancing risk.
- *Macroeconomic productivity*: Nominal GDP scaled by prior-year total nonresidential fixed assets (Source: U.S. Bureau of Economic Analysis)
- *Real GDP growth*: Real GDP, percent change from year ago, quarterly, seasonally adjusted annual rate (chained 2012 $) (Source: FRED).
- *Sales/assets*: Net sales, receipts, and operating revenues [*SALES*] over total assets [*TOTASSET*].
- *Short-term leverage (STD/assets)*: Sum of short-term loans from banks with original maturity 1 year or less [*STBANK*], short-term commercial paper with original maturity 1 year or less [*COMPAPER*], other short-term loans with original maturity 1 year or less [*STDEBTOTH*] over total assets [*TOTASSET*].
- *Size-specific cost of carry*: The size-specific cost of carry is defined as [*L. CASHTIM/L. TOCASHSEC*] × *T-bill*, where [*CASHTIM/TOCASHSEC*] is a proxy for the fraction of liquid assets that is non-interest-bearing assets.
- *Total cash*: Sum of cash, U.S. Government and other securities [TOCASHSEC].
- *Total leverage*: Sum of short-term debt (*STD*) and long-term debt (*LTD*) over total assets [*TOTASSET*].
- *3-month T-bill rate*: 3-month Treasury-bill rate (Source: FRED).

Firm-level variables

All variables in brackets are Compustat data items.

- *Acquisition activity*: Acquisitions [*aqc*] scaled by total book assets [*at*].
- *Cash/assets*: Sum of cash and short-term investments [*che*] over total book assets [*at*].
- *Cash/net assets*: Sum of cash and short-term investments [*che*] over net assets, where net assets equal total book assets [*at*] minus cash holdings [*che*].
- *Cash flow/assets*: Operating income before depreciation [*oibdp*], after interest [*xint*], dividends [*dvc*], and taxes [*txt*] over total book assets [*at*].
- *Firm-level cost of carry*: Following Azar et al. (2016), it is defined as [*L. ch/L. che*] × *T-bill*, where [*ch/che*] is a proxy for the fraction of liquid assets that is non-interest-bearing assets.
- *Firm-level productivity*: We estimate firm-level TFP as the residual from the following Cobb-Douglas production function [$log(y_{i,\,t}) = \mu_i + \mu_t + \alpha_s^k \log(k_{i,\,t-1}) + \alpha_s^n \log(n_{i,\,t}) + \varepsilon_{i,\,t}$], where y is real sales, k is real book value of the capital stock [*ppegt*], n is employment [*emp*], μ_i is a firm fixed effect, and μ_t is a time fixed effect.

- *Industry sigma*: For each firm-year and two-digit SIC group, we calculate the standard deviation of *cash flow/assets* over the past 10 years. If fewer than 3 years of lagged data are available, the standard deviation is set to missing. Industry sigma for a two-digit SIC group is calculate as the average standard deviation of *cash flow/assets* across all firms in the group.
- *LTD maturity*: Long-term debt due in next three years [$dd1 + dd2 + dd3$] over total long-term debt [$dlc + dltt$].
- *Long-term leverage (LTD/assets)*: Long-term debt [*dltt*] over total book assets [*at*].
- *Market to book*: The market value of assets [$at + prcc\_f \times csho - ceq$] over total book assets [*at*].
- *NWC/assets*: Net working capital [*wcap-che*] over total book assets [*at*].
- *Real assets*: The book value of assets [*at*] in year 2012 real dollars.
- *R&D/sales*: R&D expenditures [*xrd*] over sales [*sale*]. R&D is set equal to zero when missing from Compustat.
- *Short-term leverage (STD/assets)*: Short-term debt [*dlc*] over total book assets [*at*].
- *Total leverage*: Sum of short-term debt [*dlc*] and long-term debt [*dltt*] over total book assets [*at*].

References

Acharya, V., Davydenko, S.A., Strebulaev, I.A., 2012. Cash holdings and credit risk. Rev. Financ. Stud. 25 (12), 3572–3609.
Almeida, H., Campello, M., Weisbach, M.S., 2004. The cash flow sensitivity of cash. J. Financ. 59 (4), 1777–1804.
Almeida, H., Campello, M., Weisbach, M.S., 2011. Corporate financial and investment policies when future financing is not frictionless. J. Corp. Finan. 17 (3), 675–693.
Almeida, H., Campello, M., Weisbach, M.S., 2021. The Cash Flow Sensitivity of Cash: Replication, Extension, and Robustness. Fisher College of Business Working Paper (2021−03), 002.
Autor, D., Dorn, D., Katz, L.F., Patterson, C., Van Reenen, J., 2017. Concentrating on the fall of the labor share. Am. Econ. Rev. 107 (5), 180–185.
Autor, D., Dorn, D., Katz, L.F., Patterson, C., Van Reenen, J., 2020. The fall of the labor share and the rise of superstar firms. Q. J. Econ. 135 (2), 645–709.
Azar, J.A., Kagy, J.-F., Schmalz, M.C., 2016. Can changes in the cost of carry explain the dynamics of corporate "cash" holdings? Rev. Financ. Stud. 29 (8), 2194–2240.
Baker, S.R., Bloom, N., Davis, S.J., 2016. Measuring economic policy uncertainty. Q. J. Econ. 131 (4), 1593–1636.
Bates, T.W., Kahle, K.M., Stulz, R.M., 2009. Why do us firms hold so much more cash than they used to? J. Financ. 64 (5), 1985–2021.
Bates, T.W., Chang, C.-H., Chi, J.D., 2018. Why has the value of cash increased over time? J. Financ. Quant. Anal. 53 (2), 749–787.
Baum, C.F., Caglayan, M., Ozkan, N., Talavera, O., 2006. The impact of macroeconomic uncertainty on non-financial firms' demand for liquidity. Rev. Financ. Econ. 15 (4), 289–304.
Bhamra, H.S., Kuehn, L.-A., Strebulaev, I.A., 2010. The aggregate dynamics of capital structure and macroeconomic risk. Rev. Financ. Stud. 23 (12), 4187–4241.
Boileau, M., Moyen, N., 2016. Corporate cash holdings and credit line usage. Int. Econ. Rev. 57 (4), 1481–1506.
Covas, F., Den Haan, W.J., 2011. The cyclical behavior of debt and equity finance. Am. Econ. Rev. 101 (2), 877–899.
Crouzet, N., Mehrotra, N.R., 2020. Small and large firms over the business cycle. Am. Econ. Rev. 110 (11), 3549–3601.
Curtis, C.C., Garin, J., Mehkari, M.S., 2017. Inflation and the evolution of firm-level liquid assets. J. Bank. Financ. 81, 24–35.
Denis, D.J., 2011. Financial flexibility and corporate liquidity. J. Corp. Finan. 17 (3), 667–674.
Denis, D.J., Sibilkov, V., 2010. Financial constraints, investment, and the value of cash holdings. Rev. Financ. Stud. 23 (1), 247–269.
Eckbo, B.E., Masulis, R.W., Norli, Ø., 2000. Seasoned public offerings: resolution of the "new issues puzzle". J. Financ. Econ. 56 (2), 251–291.
Erel, I., Julio, B., Kim, W., Weisbach, M.S., 2011. Macroeconomic conditions and capital raising. Rev. Financ. Stud. 25 (2), 341–376.
Eskandari, R., Zamanian, M., 2021. Heterogeneous responses to corporate marginal tax rates: Evidence from small and large firms. In: Working Paper. https://doi.org/10.2139/ssrn.3392479. Available at SSRN. https://ssrn.com/abstract=3392479.
Fama, E.F., French, K.R., 1989. Business conditions and expected returns on stocks and bonds. J. Financ. Econ. 25 (1), 23–49.
Farre-Mensa, J., Ljungqvist, A., 2016. Do measures of financial constraints measure financial constraints? Rev. Financ. Stud. 29 (2), 271–308.
Faulkender, M., Wang, R., 2006. Corporate financial policy and the value of cash. J. Financ. 61 (4), 1957–1990.
Foley, C.F., Hartzell, J.C., Titman, S., Twite, G., 2007. Why do firms hold so much cash? A tax-based explanation. J. Financ. Econ. 86 (3), 579–607.
Gao, H., Harford, J., Li, K., 2013. Determinants of corporate cash policy: insights from private firms. J. Financ. Econ. 109 (3), 623–639.
Gao, X., Whited, T.M., Zhang, N., 2021. Corporate money demand. Rev. Financ. Stud. 34 (4), 1834–1866.
Gertler, M., Gilchrist, S., 1994. Monetary policy, business cycles, and the behavior of small manufacturing firms. Q. J. Econ. 109 (2), 309–340.
Gilchrist, S., Zakrajšek, E., 2012. Credit spreads and business cycle fluctuations. Am. Econ. Rev. 102 (4), 1692–1720.
Graham, J.R., Leary, M.T., 2015. The evolution of corporate cash. In: Working Paper. Available online. https://www.aeaweb.org/conference/2016/retrieve.php?pdfid=20691&tk=d4GE4GrE.
Graham, J.R., Leary, M.T., 2018. The evolution of corporate cash. Rev. Financ. Stud. 31 (11), 4288–4344.
Hackbarth, D., Miao, J., Morellec, E., 2006. Capital structure, credit risk, and macroeconomic conditions. J. Financ. Econ. 82 (3), 519–550.
Hadlock, C.J., Pierce, J.R., 2010. New evidence on measuring financial constraints: moving beyond the kz index. Rev. Financ. Stud. 23 (5), 1909–1940.
Harford, J., 1999. Corporate cash reserves and acquisitions. J. Financ. 54 (6), 1969–1997.
Harford, J., Klasa, S., Maxwell, W.F., 2014. Refinancing risk and cash holdings. J. Financ. 69 (3), 975–1012.
Harrison, S.G., Weder, M., 2006. Did sunspot forces cause the great depression? J. Monet. Econ. 53 (7), 1327–1339.
Kaplan, S.N., Zingales, L., 1997. Do investment-cash flow sensitivities provide useful measures of financing constraints? Q. J. Econ. 112 (1), 169–215.
Kim, C.-S., Mauer, D.C., Sherman, A.E., 1998. The determinants of corporate liquidity: theory and evidence. J. Financ. Quant. Anal. 33 (3), 335–359.
Korajczyk, R.A., Levy, A., 2003. Capital structure choice: macroeconomic conditions and financial constraints. J. Financ. Econ. 68 (1), 75–109.
Levy, A., Hennessy, C., 2007. Why does capital structure choice vary with macroeconomic conditions? J. Monet. Econ. 54 (6), 1545–1564.
Newey, W.K., West, K.D., 1987. A simple positive semi-definite heteroskedasticity and autocorrelation consistent covariance matrix.
Opler, T., Pinkowitz, L., Stulz, R., Williamson, R., 1999. The determinants and implications of corporate cash holdings. J. Financ. Econ. 52 (1), 3–46.
Ottonello, P., Winberry, T., 2020. Financial heterogeneity and the investment channel of monetary policy. Econometrica 88 (6), 2473–2502.
Pinkowitz, L., Williamson, R., 2002. What is a dollar worth? The market value of cash holdings. In: The Market Value of Cash Holdings (October 2002).
Riddick, L.A., Whited, T.M., 2009. The corporate propensity to save. J. Financ. 64 (4), 1729–1766.
Stein, J.C., 2003. Agency, information and corporate investment. In: Handbook of the Economics of Finance, 1. Elsevier, pp. 111–165.
Stone, A.-L., Gup, B.E., Lee, J., 2018. New insights about the relationship between corporate cash holdings and interest rates. J. Econ. Financ. 42 (1), 33–65.
Titman, S., Wessels, R., 1988. The determinants of capital structure choice. J. Financ. 43 (1), 1–19.
Van Reenen, J., 2018. Increasing Differences between Firms: Market Power and the Macro-Economy.
Whited, T.M., Wu, G., 2006. Financial constraints risk. Rev. Financ. Stud. 19 (2), 531–559.