Inflation and the Evolution of Firm-Level Liquid Assets*

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Abstract

This paper shows that inflation has been an important determinant of firm-level liquid asset holdings. Liquid assets as a share of total assets – the cash ratio – for U.S. corporations steadily declined from the 1960s to the early 1980s, and has since steadily increased. Our empirical analysis finds that inflation is a key factor accounting for these changes. We show that these liquid asset holdings are imperfectly hedged against inflation. Hence, changes in inflation alter the real value of a firm's liquid asset portfolio causing them to readjust these balances.

JEL Classification: G3; G32; E31.

Keywords: Cash Holding; Inflation; Liquidity; Liquid Assets; Cash Ratio.

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1 Introduction

Liquid asset holdings as a share of total U.S. non-financial assets – the so-called 'cash ratio' – have undergone large changes since the early 1960s. Between the 1960s and early 1980s the U.S. cash ratio shrunk by more than half, and from the 1980s on it has since steadily increased. At the end of 2013 the cash ratio stood at roughly 5.5%, with U.S. non-financial corporations holding $2 trillion in liquid assets. We show in Figure 1 that the trends in the cash ratio stand in stark contrast to those of inflation. Whereas the cash ratio fell between the 1960s to the 1980s and rose thereafter, inflation rose in the earlier time period and fell thereafter. While the literature has investigated the motives on *why* firms hold liquid assets, in this paper we explore the negative relationship between inflation and liquid asset holdings and quantify the impact of inflation on the *changes* in those holdings over time.

Our empirical results show that inflation is an important determinant of the level of a firm's liquid asset holdings and accounts for a significant portion of the long-run variation in the cash ratio over the past 50 years. With inflation at a 40-year low and a desire of the monetary authority to increase it, it is important to understand the effect of aggregate inflation on firm-level liquidity.

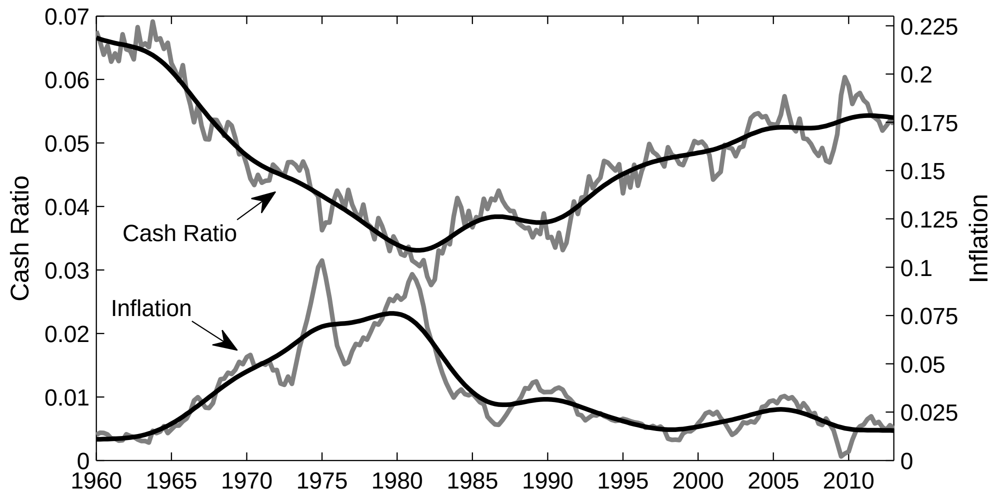

Figure 1: Quarterly Inflation at an annual rate and Cash Ratio of U.S. Non-Financial Corporations 1960Q1–2013Q4

Notes: Cash ratio is calculated as the sum of checking deposits, saving deposits, foreign deposits, money market mutual funds, security repurchase agreements, commercial paper, U.S. treasury securities, agency and GSE securities, municipal securities, and mutual funds as a share of total assets. Data is from the U.S. Flow of Funds. Inflation is the annual log change of the implicit GDP deflator. The dark lines are the Hodrick-Prescott filtered trends (smoothing parameter $\lambda = 1600$).

Using firm-level data from the Compustat Industrial Database, our analysis shows that inflation's negative impact on the firm-level cash ratio is robust even after controlling for size, industry, level of idiosyncratic risk faced, and other factors that have been known to influence a firm's liquid asset holdings. Our baseline results show that a 1 percentage point increase in aggregate inflation decreases the average cash ratio by 0.34 percentage points. In economic terms this result implies that inflation can account for as much as the entire fall of the cash ratio from the early 1960s to the early 1980s and roughly one-fifth of the increase thereafter.

To explain our results, we argue inflation impacts the cash ratio because liquid assets are imperfectly hedged against inflation. We empirically show that the nominal returns on the aggregate portfolio of liquid assets held by U.S. firms do not move one-for-one with inflation. In response to a 1% increase in inflation the returns on the portfolio of liquid assets only rises by 0.38%. As a result, the real value of liquid assets erodes in periods of high inflation prompting the firms to decrease its liquid asset holdings. Finally, we provide evidence of inflation's role in the dynamics of the cash ratio. We show that changes in inflation not only affect the *level* of a firm's cash ratio but also the dynamics: increases (decreases) in inflation slow (hasten) the accumulation of liquid assets.

While we provide conventional OLS estimates, our econometric approach departs from previous empirical studies that have focused on firm-level cash ratios. Since our primary dependent variable – the cash ratio – is bounded between 0 and 1, we use a fractional response model (Papke and Wooldridge, 1996) which restricts the predicted value of the cash ratio to be in this interval. We show that using ordinary least squares (OLS) leads to predicted values outside of this range making them inconsistent with the theoretical bounds of the cash ratio. Furthermore, we show that a firm's cash ratio adjustments to inflation are not linear in their holdings of liquid assets. This non-linear relationship, captured in the fractional response model, is missed in the OLS estimates.

Our paper contributes to the literature that aims to explain why U.S. corporations hold liquid assets. Explanations in this literature include precautionary or tax reasons (Sánchez and Yurdagul, 2013). The precautionary motive is related to cash-flow uncertainty (Bates et al., 2009; Palazzo, 2012; Zhao, 2014), or uncertainty related with R&D (Brown and Petersen, 2011; Pinkowitz et al., 2012). Our paper differentiates from these in that it focuses more on the costs of holding liquid assets and does not aim to explain the benefit of, and the reasons as to why, firms hold these assets. Other papers that study the evolution of the cash ratio over time include Falato et al. (2013). They find that the rise in firm-level intangible capital, rather than tangible capital that can be easily used as collateral, is the main factor driving the rise in corporate cash holding growth since the 1970s. We focus on a longer sample from the early 1960s to 2013 and show that inflation is a main factor driving both the decline in corporate cash holding from the 1960s to the early 1980s and its rise thereafter.

Our paper is also related to Azar et al. (2016). These authors focus on the cost of carry for explaining changes in the cash ratio. They measure the cost of carry as the nominal returns (T-bill rate) on the 10 year lagged average share of non-interest bearing liquid assets. We think of inflation as a more broad measure of the opportunity cost faced by firms. In our baseline model, we decompose the nominal interest rate into its real and inflation components and show that the economic significance from variation in inflation is much larger than the real interest rate in explaining the behavior of liquid asset holdings. Further, the underlying identification in our paper – by which each firm takes inflation as given – allows us to quantify the contemporaneous changes of the liquid asset portfolio composition from changes in the opportunity cost of holding these assets.

Specifically, we find that in response to inflation, firms contemporaneously adjust the composition of their liquid asset portfolio towards types of *liquid assets* that are most protected against inflation. Finally, our methodological contribution allows us to factor in both the non-linearities and the bounds inherent to the cash ratio which is absent using OLS.

We also add to the literature focusing on the relationships between macroeconomic aggregates and firm-level liquid asset holdings. Baum et al. (2006) show that macroeconomic volatility impacts the cross-sectional distribution of cash holdings across firms. More recently, Bacchetta et al. (2014) argue that, when wages are paid before production, falling employment can account for the negative comovement between employees and the cash ratio. Armenter and Hnatkovska (2011) develop a structural model and show that the concern of being credit constrained has been an important force driving the demand for net saving of U.S. corporations from 2000 to 2007.

In the next section, we describe our data sample, our empirical strategy, and present our main results.

2 Empirical analysis

Our main empirical analysis explores the impact of inflation on a firm's liquid assets. This section presents our data sample, estimation strategy, and results.

2.1 Sample description

Our data is from the Annual Compustat Industrial Database which consists of an unbalanced sample of publicly traded firms from 1950–2013. The main variable of interest, the cash ratio, is measured as the ratio of liquid assets to total assets. This is the common measure of cash holding in the literature. Liquid assets includes actual cash, saving deposits, treasuries, short-term bonds, commercial paper, money market mutual funds, equities, and other marketable securities with less than 1 year to maturity (Compustat variable "`CHE`"). For our analysis we only include firms that are incorporated in the U.S.. Also, financial firms and utilities (SIC codes 6000–6999 and 4900–4999) are excluded because their liquid asset holdings may partially be the result of capital requirements or government regulations.

To give a broad overview of the evolution of the cash ratio in our sample, Figure 2 presents the cash ratio in our data under various decompositions. Panel A shows the cash ratio at the mean, median, and at the aggregate for each year. Since the Compustat data is only for publicly traded firms, the observations are a subset of the Flow of Funds data shown in Figure 1. From 1955–2013, the aggregate Compustat cash ratio series is, on average, 0.033 percentage points higher than in the Flow of Funds and the correlation between the two is 0.872. Consistent with the Flow of Funds data, each series shows a V-shape pattern with the cash ratio declining through the 1970s/early 1980s and increasing thereafter.

Panel B splits the sample into the average cash ratio for manufacturing (2 digit SIC codes 20–39) and non-manufacturing firms. Over the past 50 years the composition of firms in the sample

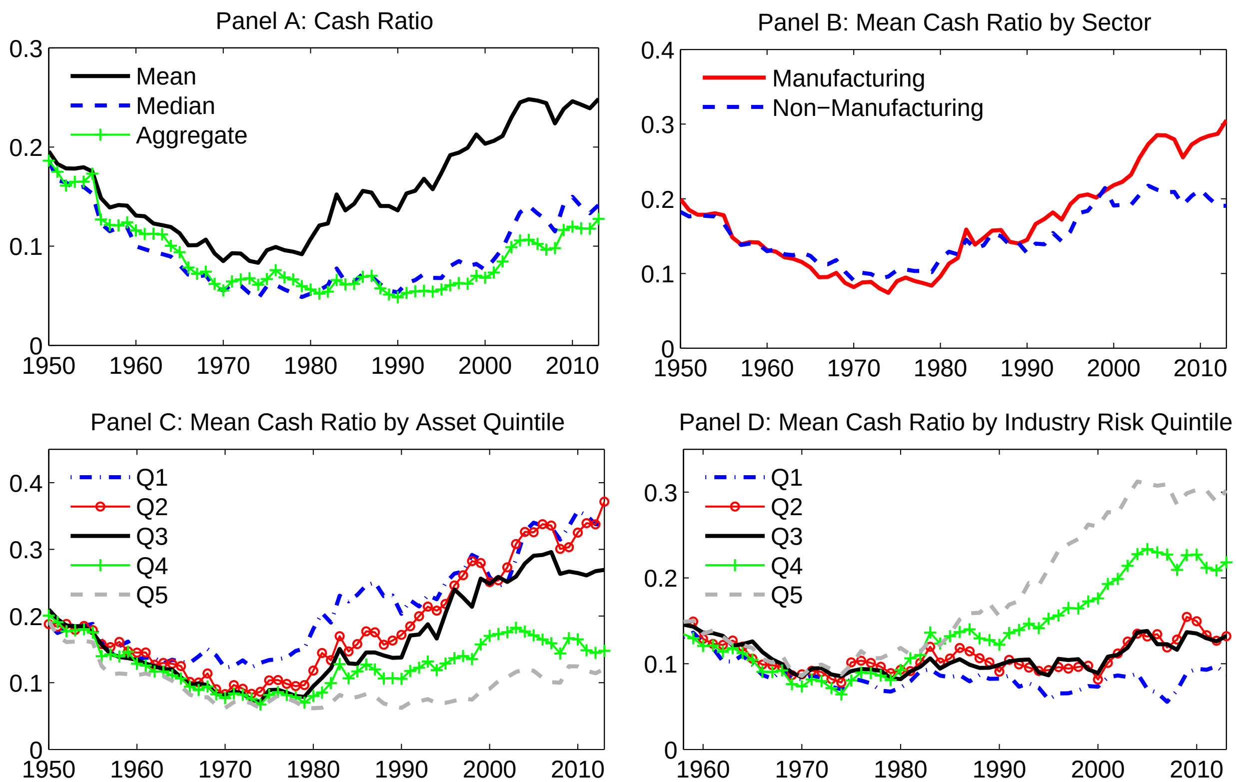

Figure 2: Evolution of cash ratio by level, sector, assets size, and industry risk

has moved from predominantly manufacturing towards non-manufacturing. In 1950, 77 percent of the observations were manufacturing firms and this declined to 49 percent by 2013. The cash ratio for both sectors follow a V-shaped pattern with this V-shape for manufacturing firms being more pronounced. Panel C shows the mean cash ratio by total assets grouped in asset quintiles. Regardless of firms' size, the cash ratio has followed the same, general V-shape trend. Media attention has focused on liquid asset holdings of large firms such as Apple, Pfizer, and General Motors. Relative to their size, however, smaller firms have increased their liquid asset holdings most dramatically since the 1980s.

Finally, Panel D presents the average cash ratio by quintiles of cash flow risk. Under the precautionary motive of cash holding, firms hold cash to mitigate adverse shocks and to take advantage of promising investment opportunities. Following Bates et al. (2009), cash flow risk is defined as the average annual firm-level standard deviation of cash flow to assets by 2 digit SIC industry. To calculate this, for each firm-year observation we first measure the 10 year backward-looking standard deviation of cash flow to assets, requiring a minimum of 3 observations. We then average the annual observations by industry. Consistent with the precautionary motive, since the 1970s firms in industries that face the highest cash flow volatility hold more liquid assets.

In sum, these figures show that the cash ratio has followed a general V-shaped pattern irrespective of industry, size, or risk faced. As shown in Figure 1, this is in contrast to the time series for inflation which has followed an opposite path: annual inflation rose from 2.3 percent in the 1950s and 1960s to as high as 9.3 percent in 1981 before falling to an average of 2.3 percent in the 2000s.

2.2 Variable description

Our empirical analysis studies the effect of aggregate inflation on the firm-level cash ratio. The cash ratio is defined as the ratio of liquid assets to total assets and inflation is measured as the annual growth rate of the GDP Deflator. We additionally account for firm-level and aggregate factors which may also impact liquid asset holding.

The firm-level variables we account for are common in the empirical literature on liquid asset holding, for example in Bates et al. (2009). To account for cash flow effects, *Cash Flow/Assets* is earnings before depreciation less interest, dividends, and taxes divided by total assets. We also include capital expenditures and dividend payments to capture uses of internal funds other than liquid asset holdings. Capital expenditures are the ratio of capital expenditures to total assets, *CapX/Assets*, and dividends are given as an indicator variable that equals 1 in years a firm pays dividends and 0 otherwise.

Next, to capture the precautionary motive of liquid asset holdings, we control for cash flow risk and uncertainty of future growth opportunities. Cash flow risk, *Industry* σ, is measured as in Section 2.1, which is the average annual firm-level standard deviation of cash flow to assets by 2 digit SIC industry. Additionally, firms with growth opportunities may hold liquid assets to have the necessary funding when those opportunities arise. We include the market-to-book ratio and R&D expenses to capture potential future growth opportunities. We follow Bates et al. (2009) in defining the market-to-book ratio as the book value of assets plus the market value of equity less the book value of equity all divided by the book value of assets, and R&D as R&D expenditures divided by assets. *R&D/Assets* is set to 0 for missing R&D expenditures as in Bates et al. (2009).

The remaining two firm-level variables are the logarithm of real assets to account for size effects, and leverage, defined as the ratio of total debt to total assets, to capture effects of debt on liquid asset holding.

At the aggregate level, we include factors that may also affect the costs and benefits of holding liquid assets across all firms. As a signal of current and future business conditions, we use the real GDP growth rate and the real T-bill rate. The real T-bill rate is given as the difference between the nominal T-bill rate and inflation. The real T-bill rate captures a number of macroeconomic factors. First, it proxies for general real returns to production. In this case, it captures the real opportunity cost of holding liquid assets. Second, to the extent liquid assets earn a real return (some do as we discuss in Section 2.5) holding these assets may be attractive if firm-level production activities are not promising. Third, the real T-bill rate also proxies for the real short-term borrowing costs absent risk.

In times of aggregate uncertainty, firms may wait to use liquid assets until market conditions are clear, the so-called "wait-and-see" effect. Our measure of aggregate uncertainty, σ *GDP Growth*, is the annual average of the five-year backward-looking standard deviation of quarterly real GDP

Table 1: Summary statistics

Firm-level Variables				Aggregate Variables			
Variable	Mean	Median	SD	Variable	Mean	Median	SD
Cash Ratio	0.163	0.081	0.202	Inflation	0.035	0.028	0.023
Cash Flow/Assets	0.016	0.064	0.220	Real T-bill	0.010	0.013	0.022
Industry σ	0.102	0.058	0.159	Real GDP Growth	0.031	0.032	0.020
Market-to-Book	1.839	1.281	1.890	Top Marg. Tax	0.413	0.375	0.069
Leverage	0.225	0.201	0.195	σ GDP Growth	0.020	0.019	0.008
CapX/Assets	0.063	0.045	0.063	Real R&D Growth	0.031	0.036	0.033
Log Real Assets	5.129	5.067	2.043				
R&D/Assets	0.043	0.000	0.105				
Dividend Dummy	0.416	0.000	0.493				

growth.[1] We include this to identify any real option effects of liquid asset holdings caused by aggregate uncertainty.

To gauge the impact of liquid asset holdings from changes in tax policy, we include the top corporate marginal tax rate. Although firms may not actually face this rate, changes in the top rate are indicative of broader tax policy changes. For example, in our sample time frame the marginal tax rate peaked at 0.528 in 1968–1969 and fell to 0.35 where it has been since 1993. Finally, we also include real aggregate R&D growth as a measure overall innovative activity. As opposed to our firm-level measure of R&D, this captures current and expected technological improvements at the aggregate level.

Table 1 presents the descriptive statistics for the firm-level variables constructed from the Compustat data in the left panel and the aggregate variables to the right. Data requirements limit the time-frame of our study. The availability of the market-to-book ratio limits the beginning of usable observations to 1962. We additionally follow Bates et al. (2009) by winsorizing firm-year outliers. *Leverage* is winsorized to be between 0 and 1. *R&D/Assets*, *Industry* σ, and *CapX/Assets* are winsorized at the 1% level. We also winsorize the top 1% of *Market-to-Book* and the bottom 1% of *Cash Flow/Assets*. Our final sample contains 14,702 firms for 142,682 firm-year observations.

2.3 Estimation strategy

Our empirical strategy uses a fractional response model to identify the effect of inflation, and other firm-level characteristics and aggregates, on the cash ratio. This method was first introduced by Papke and Wooldridge (1996) to estimate 401(K) Plan participation rates. Since our primary dependent variable, the cash ratio, is bounded between 0 and 1, we use this method because it restricts the predicted values of the cash ratio to be in this interval. Additionally, the fractional response model allows for non-linearities in response to the dependent variables. Given the heterogeneity in the cash ratio across firms in our data, the response of the cash ratio to the covariates may vary between firms with high and low cash ratios. Allowing for non-linearities may lead to more accurate estimates of the effects of these variables on the cash ratio.

[1] We experimented with alternative window sizes but our results are not sensitive to these modifications.

Formally, the fractional response model for the relationship between the cash ratio for firm i at time t and inflation, controlling for firm-level characteristics and other aggregate factors, is given by

$$\mathbb{E}(\text{Cash Ratio}_{i,t}|\pi_t, X_{i,t}, \gamma_i) = g^{-1}\left(\beta_0 + \beta_1\pi_t + \sum_{n=1}^{N}\phi_n X_{n,i,t} + \sum_{m=1}^{M}\theta_m Z_{m,t} + \gamma_i + \epsilon_{i,t}\right) \quad (1)$$

where π_t is inflation at year t, the X are the set of firm-level control variables, the Z are the aggregate covariates, and the γ_i are 2 digit SIC industry dummy variables that control for differences in cash holding across industries. The inverse link function, $g^{-1}(\cdot)$, transforms the linear argument of this function to an expected response. We estimate this equation with a quasi-maximum likelihood estimator and a logistic link function. The distribution of the response is binomial to ensure the predicted cash ratio is in the interval $[0, 1]$. Since the model is non-linear, the estimates presented in the following sections represent the average marginal response of the cash ratio to changes in the independent variables (unless explicitly stated otherwise).

2.4 The Impact of inflation on firm-level liquid asset holdings

Table 2 presents our estimates for the impact of inflation on the firm-level cash ratio. The baseline estimates are given in column (i) where we use the fractional response model given by Equation (1). This model allows for non-linearites and thus the estimates presented here are the average marginal effects of the independent variables on the cash ratio. Our main variable of interest is inflation which has a statistically significant negative impact on cash holdings. For a 1 percentage point increase in inflation, the cash ratio at the firm level on average falls by 0.336 percentage points. Our regression results predict that an 8.2 percentage point increase in inflation – the observed change between 1962 and 1981– decreases the average cash ratio by 2.7 percentage points. This is roughly the same amount the average cash ratio in the data fell by from 1962 to 1981. Further, the regression predicts that an 8 percentage point decrease in inflation, such as the one that occurred between 1981 and 2013, increases the cash ratio by 2.7 percentage points, or approximately 20 percent of the observed change in the average cash ratio over that same time period. Together, these two results from our baseline estimation indicate that the impact of inflation on the cash ratio is both statistically and economically significant.

For comparison with the fractional response model, column (ii) of Table 2 shows the coefficient estimates from a standard OLS regression. The OLS estimates are not statistically different from the fractional response coefficient on inflation, however the point estimate on the OLS coefficient of inflation is slightly smaller.

The fractional response specification of Equation (1) does not allow us to include firm-level fixed effects. Papke and Wooldridge (2008) note that fractional response models with large numbers of cross-sectional observations have a retransformation problem when including a large number of time-invariant controls. In our sample, including firm-level fixed effects leads to inconsistencies estimating the magnitude of the response variables. They propose an alternative estimation strategy; however, this requires a balanced panel, which is not the case in our sample. A balanced panel for

Table 2: The impact of inflation on the firm-level cash ratio

	Fractional Response	OLS	
	(*i*)	(*ii*)	(*iii*)
Inflation	-0.336***	-0.267***	-0.200***
	(0.075)	(0.067)	(0.050)
Cash Flow/Assets	-0.073***	-0.129***	-0.075***
	(0.006)	(0.009)	(0.006)
Industry σ	0.038***	0.080***	0.020***
	(0.009)	(0.017)	(0.005)
Market-to-Book	0.009***	0.015***	0.009***
	(0.001)	(0.001)	(0.001)
Leverage	-0.306***	-0.294***	-0.202***
	(0.010)	(0.007)	(0.005)
CapX/Assets	-0.330***	-0.317***	-0.283***
	(0.017)	(0.022)	(0.015)
Log Real Assets	-0.004***	-0.005***	-0.010***
	(0.001)	(0.001)	(0.001)
R&D/Sales	0.205***	0.374***	-0.185***
	(0.016)	(0.022)	(0.015)
Dividend Dummy	-0.035***	-0.036***	0.006***
	(0.003)	(0.004)	(0.001)
Real T-bill	-0.317***	-0.310***	-0.077*
	(0.088)	(0.090)	(0.043)
Real GDP Growth	-0.189**	-0.164	-0.148***
	(0.092)	(0.102)	(0.049)
Top Marg. Tax	-0.142***	-0.100***	-0.034
	(0.037)	(0.033)	(0.022)
σ GDP Growth	0.529***	0.391**	0.551***
	(0.184)	(0.194)	(0.102)
Real R&D Growth	0.275***	0.205***	0.106***
	(0.061)	(0.068)	(0.033)
Intercept		0.273***	0.278***
		(0.014)	(0.012)
SIC 2 Digit Dummy	Yes	Yes	No
Firm-Level Dummy	No	No	Yes
N	142,682	142,682	142,682
adj. R^2		0.442	0.774

Notes: The dependent variable is the cash ratio. Column (*i*) present estimates from the fractional response model. The estimates shown are the average marginal effects. Column (*ii*) present estimates using Ordinary Least Squares. Standard errors are in parenthesis and are clustered by year. Stars denote significance at the 1% (***), 5% (**), and 10% (*) levels.

our data reduced the sample from 14,702 to only 16 firms. Instead, in column (*iii*) we incorporate firm-level fixed effects using OLS. This includes firm-level dummy variables into the OLS specification less the 2 digit SIC industry dummies. This reduces the point estimate on inflation, however it is not significantly different from the estimate in column (*ii*). Unsurprisingly, the magnitude of almost all of the coefficients are dampened in this specification, the exceptions being *Log Real Assets* and σ *GDP Growth*.

We prefer the estimates from the fractional response model for two reasons. First, it correctly bounds our dependent variable between 0 and 1. When using the OLS regression results from column (*ii*), 4.1 percent of the predicted cash ratio values fall outside of the 0 to 1 interval making them inconsistent with the true theoretical bounds on the cash ratio. Second, OLS misses the non-linear responses of inflation and the other covariates, particularly when cash ratio observations are close to 0. In our sample, 37% of all cash ratio observations are less than 0.05. To illustrate how heterogeneity in the level of a firm's cash ratio may lead to non-linear responses from inflation, consider a firm with a low cash ratio (close to 0). Since the cash ratio is bounded below by 0, the response of the cash ratio from an increase in inflation for such a firm is constrained in their cash ratio adjustment. On the other hand, a firm with a larger cash ratio may be able to respond more aggressively to inflationary changes. To quantify this point, we estimate the average marginal response of inflation evaluated for each cash ratio decile from our baseline fractional response model. Table 3 reports these estimates. The responses range from -0.25 for observations in the lowest decile of the cash ratio up to -0.57 for those with the highest cash ratios. In contrast, the estimates on inflation using OLS are constant across the distribution, which is clearly not the case with our bounded dependent variable.

Table 3: The impact of inflation on the firm-level cash ratio by cash ratio decile

	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}	8^{th}	9^{th}	10^{th}
Inflation	-0.25***	-0.24***	-0.24***	-0.25***	-0.27***	-0.31***	-0.35***	-0.40***	-0.48***	-0.57***
(standard error)	(0.055)	(0.053)	(0.054)	(0.056)	(0.061)	(0.068)	(0.077)	(0.090)	(0.106)	(0.128)

Notes: The dependent variable is the cash ratio. The estimates are the average marginal effects of inflation for each decile of the cash ratio given by the estimate of Equation (1). Standard errors in parenthesis. Stars denote significance at the 1% (***), 5% (**), and 10% (*) levels.

The relationships between the cash ratio and the firm-level variables given in Table 2 all have statistically significant effects in the directions found in previous studies. Firms in industries with higher cash flow volatility hold more liquid assets, consistent with the precautionary motive. Firms with higher growth opportunities, captured by *Market-to-Book*, hold liquid assets for when these occasions arise. The negative signs on *CapX/Assets* and *Dividend Dummy* indicate alternative uses of funds other than liquid asset holdings. The positive sign on *R&D/Assets* relates to Brown and Petersen (2011) who find that firms hold liquid assets to smooth R&D expenditures in response to negative financing shocks, particularly if they face financial frictions.

As for the aggregate variables, the negative sign on *Real T-bill* is consistent with the opportunity

Table 4: Estimated contribution to changes in the average cash ratio

	1962 to 1981 (*i*)	1981 to 2013 (*ii*)
Cash Ratio Data	-0.022	0.147
Inflation	-0.027	0.027
Cash Flow/Assets	0.002	0.007
Industry σ	0.000	0.005
Market-to-Book	-0.002	0.013
Leverage	-0.024	0.012
CapX/Assets	-0.006	0.015
Log Real Assets	0.007	-0.005
R&D/Assets	0.002	0.011
Dividend Dummy	0.010	0.009
Real T-bill	0.004	0.008
Real GDP Growth	0.006	0.002
Top Marg. Tax	0.009	0.016
σ GDP Growth	-0.003	-0.001
Real R&D Growth	-0.012	-0.007

Notes: The table presents the predicted contribution to changes in the cash ratio from mean changes in each conditioning variable. The time intervals presented are 1962 to 1981 and 1981 to 2013. The Row 1 reports the mean cash ratio changes in the data. These show predicted changes from the baseline estimates given in Table 2 column (*i*).

cost of holding liquid assets. The coefficient on *Real GDP Growth* is negative whereas σ *GDP Growth* is positive. The former may be a reflection of current growth opportunities while the latter captures the "wait-and-see" effect of aggregate uncertainty. The cash ratio is additionally decreasing in the top federal marginal corporate income tax rate. This rate was highest in our sample period in 1968–1969 and fell to its current level of 0.35 by 1993, which, according to our estimates, leads to an increase in the cash ratio.[2] Additionally, aggregate real R&D growth is predicted to increase liquid asset holdings. If this captures a potential for future aggregate technology change, firms may increase their cash ratio to have the necessary liquidity for technology adoption.

Next, to better understand the relative importance of inflation and the other control variables, Table 4 presents the estimated contribution of inflation and the control variables to the changes in the cash ratio over two sub-periods: 1962 to 1981 and 1981 to 2013. The estimated contributions of each variable are calculated by multiplying the mean changes in the variables over each interval

[2]However, since the 2000s corporate income tax rates in many OECD countries have fallen relative to the U.S.. U.S. firms operating in these countries face a repatriation tax – broadly the difference between the foreign and U.S. corporate tax rate on overseas profits – when transferring overseas profits to the U.S. parent company. Fritz Foley et al. (2007) show tax rates play a role in firm-level liquid asset holdings as firms attempt to defray dividends, particularly if the liquid assets are held abroad.

by the coefficients in our baseline fractional response model. We choose these sub-periods because they capture the largest time-series variation in inflation and the average cash ratio. Inflation rose from the beginning of the sample in 1962 to its peak in 1981 before falling thereafter. The timing approximately lines up with the V-shape in the cash ratio series.

Table 4 shows that during the 1962 to 1981 period, inflation alone can account for approximately the entire decline in the cash ratio. For the 1981 to 2013 period, inflation has the most explanatory power capturing nearly 20 percent of the observed increase in the cash ratio. Changes in *Leverage* in both sub-periods and *CapX/Assets*, *Market-to-Book*, and *Top Marg. Tax* between 1981 and 2013 also have significant explanatory power, although lower than that of inflation. In sum, whereas each of our additional controls has a statistically significant effect on cash holdings, in terms of economic significance inflation is the most important variable influencing changes in firm-level liquid asset holding.[3]

2.5 Causes of inflation's role on liquid asset holdings

Having shown the relationship between inflation and firm-level liquid asset holdings, we now explore why this is the case. A firm's liquid assets comprise of a number of different assets including cash. Many of these liquid assets pay a positive nominal return. Thus, the cumulative nominal returns, i, on the portfolio of these assets can be written as

$$i = \sum_{j \in J} \omega_j \tilde{i}_j$$

where J gives the set of different liquid assets in the portfolio, ω_j gives the share of asset j in the portfolio, and $\tilde{i}_j$ gives the corresponding return on asset j. The returns on the liquid assets, $\tilde{i}_j$, vary from being positive and perfectly correlated with inflation, to assets such as actual cash that do not earn interest and thus whose returns are independent of inflation. We expand the cumulative returns given above to account for this inflation effect

$$\begin{aligned} i &= \sum_{j \in J} \omega_j \tilde{i}_j \\ &= \sum_{j \in J} \omega_j \left(a_j + b_j \mathbb{E}[\pi] \right) \\ &= \sum_{j \in J} \omega_j a_j + \left(\sum_{j \in J} \omega_j b_j \right) \mathbb{E}[\pi] \\ &= a + b \mathbb{E}[\pi] \end{aligned}$$

[3] We further investigate the contribution of inflation by sub-period by including an interaction with inflation and an indicator variable for years prior to 1981. The response to a 1 percentage point increase in inflation is -0.401 pre-1981 (main and interaction effects) and -0.204 at and after 1981. In terms of economic significance, compared to the remaining firm-level and aggregate variables inflation still has the largest impact on the changes in the cash ratio over each sub-period.

Table 5: Inflation and the return to the liquid asset portfolio

	Frequency	
	Quarterly	Annual
	(*i*)	(*ii*)
Inflation	0.376***	0.385***
	(0.038)	(0.077)
Intercept	0.021***	0.021***
	(0.002)	(0.004)
Adj. R^2	0.326	0.326
N	204	51

Notes: The dependent variable is the annual nominal returns i from the constructed portfolio in the Flow of Funds data. Standard errors are in parentheses. Stars denote significance at the 1% (***), 5% (**), and 10% (*) levels.

where a_j is a constant and b_j gives the responsiveness of asset j's returns to changes in expected inflation, $\mathbb{E}[\pi]$. Aggregating up, we then have a as a constant and b gives the responsiveness of a firm's portfolio returns to inflation.

The real returns, $r = i - \mathbb{E}[\pi]$, on the portfolio of liquid assets can be written as

$$r = a + (b - 1)\mathbb{E}[\pi].$$

If $b < 1$, then as expected inflation increases the real returns on the portfolio fall causing the marginal cost of holding liquid assets to rise and the firm to cut back on its holdings. We conjecture that this is the channel through which inflation affects liquid asset holdings. To provide evidence for this channel we estimate the value of b in the data.

Our firm-level data from Compustat only reports the sum of liquid assets in broad categories and thus does not allow us to do a proper firm-level disaggregation of the various assets that comprise the firm-level liquid asset portfolio. As a result, we use aggregate data from the Flow of Funds to construct an aggregate portfolio of liquid assets and calculate i and thus estimate b. We include the following 10 assets in our liquid asset portfolio: 1) currency and checkable deposits, 2) time and saving deposits, 3) commercial paper, 4) security repurchase agreements, 5) agency securities, 6) municipal securities, 7) mutual fund shares, 8) money market mutual funds, 9) foreign deposits, and 10) treasury securities. We then calculate the annualized nominal returns, i_j, for each of these as follows. We assign a nominal interest rate of 0 for currency and checkable deposits, and the nominal interest rate on saving deposits is the effective federal funds rate. AAA corporate bond rates are a proxy for components 3–7 and the secondary market T-bill rate is assigned for components 8–10. Finally, we set the individual weights, $\omega_j = \frac{s_j}{\sum_{j \in J} s_j}$, where s_j is the aggregate shares of each components in the Flow of Funds data.

Table 5 gives OLS regression results of the annualized nominal return, i, on expected inflation at both quarterly and annual frequencies. These estimates are a simple 'inflation beta' analysis on the firms' liquid asset portfolio. For the expected inflation measure, we assume a random walk by using current inflation to predict future inflation. This measure follows Atkeson and Ohanian (2001) who find that inflation predictions using a variety of out-of-sample forecasts perform no better than assuming a random walk. The coefficients on inflation in Table 5 gives an estimate of b – which is between 0 and 1 and is statistically significant at the 1% level. When inflation increases, the real returns on the liquid asset portfolio fall, which causes the marginal cost of holding this portfolio to rise. This incentivizes firms to cut back on their liquid asset holdings.

We note that the estimation of the nominal returns from inflation, b, is partially determined by the composition of assets within the portfolio (i.e. assets such as cash are non-interest bearing). Whereas our results suggest a reallocation of liquid assets in response to inflation on the *extensive* margin, firms may reallocate their liquid asset portfolio in the *intensive* margin towards more interest-bearing assets. Even so, the holding of interest bearing assets does not necessitate a complete hedging against inflation – for instance, Bekaert and Wang (2010) find the inflation beta on T-bills to be less than 1.

Alternatively, instead of calculating the real returns and hence the direct marginal cost of holding liquid assets, we could instead calculate the opportunity cost of holding liquid assets. If we assume that the T-bill rate proxies for the returns on production, the opportunity cost of holding these assets can be calculated as the difference between the T-bill rate and the returns on the liquid portfolio. The opportunity cost, where i^T is the T-bill rate, is given as

$$\begin{aligned} Opp.Cost &= i^T - i \\ &= i^T - (a + b\mathbb{E}[\pi]) \,. \end{aligned}$$

Applying the Fisher equation with r^T as the real T-bill interest rate, we can simplify this further to

$$\begin{aligned} Opp.Cost &= r^T + \pi - (a + b\mathbb{E}[\pi]) \\ &= r^T - a + (1 - b)\,\mathbb{E}[\pi]. \end{aligned}$$

If $b < 1$, then a rise in expected inflation increases the opportunity cost of holding liquid assets, causing the firm to cut back on its liquid asset holdings. We have already shown above that $b < 1$.

The opportunity cost interpretation of cash holding is related Azar et al. (2016). In their paper, a rise in the T-bill rate on the share of non-interest bearing liquid assets, capturing an increase in the cost of carry, causes the cash ratio to fall. The T-bill rate, however, is comprised of two components: the real interest rate and inflation. We reestimate our baseline specification but instead replace inflation with the nominal T-bill rate. The coefficient on the nominal T-bill rate is -0.32 (results not shown). However, our baseline model indicates that both the inflation and real components of the T-bill rate are individually important. This decomposition of the T-bill rate is important because it shows that inflation is a primary driving force behind the opportunity cost interpretation.

The estimates on the real T-bill rate from our baseline specification predict that changes in the real interest rate increase the average cash ratio by 0.4 percentage points from 1962 to 1981 and by 0.8 percentage points from 1981 to 2013 (see Table 4). In comparison, inflation decreases the average cash ratio by 2.7 percentage points from 1962 to 1981 and increases it by 2.7 percentage points from 1981 to 2013. We do not discount the real T-bill rate as being important in explaining changes in firm-level liquid asset holdings. Rather, these estimates show that inflation is substantially more important than the real T-bill rate in accounting for the salient features of the evolution of the cash ratio.

2.6 Dissecting the importance of aggregate factors

We next examine the influence of inflation versus all aggregate factors that impact the firm-level cash ratio. To do this, we first consider an OLS specification that includes the firm-level covariates from our sample but uses annual dummy variables in place of the aggregate variables used in the baseline. The annual dummy variables capture the cumulative impact of all aggregate factors, including inflation, that uniformly influence the cash ratio of all firms. Our specification is given as

$$Cash\ Ratio_{i,t} = \alpha + \sum_{n=1}^{N} \phi_n X_{n,i,t} + \eta_i + \delta_t + \epsilon_{i,t} \tag{2}$$

where α is a constant, the X are the firm-specific variables used in our baseline specification, the η are firm-level dummy variables, and the δ are annual dummy variables.

We estimate Equation (2) and retrieve the coefficient estimates on the time dummy variables. We then investigate the relationship between these dummy coefficients and inflation. The correlation between the two series is -0.55. To further examine this relationship, in column (*i*) of Table 6 we regress these dummy coefficients on an intercept and inflation from 1962–2013.[4] The slope coefficient on inflation of -0.22 is highly significant. Since the annual dummy coefficients encapsulate the sum of all aggregate factors that impact liquid asset holding, this results further suggests that inflation is an important component in accounting for changes in the firm-level cash ratio.

In column (*ii*), we then use inflation and the remaining aggregate variables used in our baseline specification as covariates. Several of the remaining factors are independently and significantly related to the annual time dummy coefficients, but the estimate on inflation is basically unchanged. We reestimate the regression but exclude inflation in column (*iii*). The adjusted R^2 falls from 0.514 from column (*ii*) to 0.382 when inflation is removed. In comparison, we do a similar exercise removing each variable one-by-one but retain the other aggregates (results not shown). The largest reduction in the adjusted R^2 from these remaining variables is from the removal of *Real R&D Growth* where it falls to 0.417 (versus an even larger fall with inflation to 0.382). Overall, these exercises illustrate that of all factors that uniformly impact the cash ratio of all firms, inflation is a significant component.

[4] All estimates in Table 6 are weighted by the number of annual observations used to estimate Equation (2). Using an unweighted regression gives larger (in magnitude) coefficient estimate on inflation, but the results are still quantitatively similar.

Table 6: Relationship of aggregate variables and time dummy coefficients

	(i)	*(ii)*	*(iii)*
Inflation	-0.223***	-0.243***	
	(0.059)	(0.066)	
Real T-bill		-0.132**	-0.133*
		(0.065)	(0.073)
Real GDP Growth		-0.195**	-0.133
		(0.074)	(0.081)
Top Marg. Tax		-0.056*	-0.119***
		(0.029)	(0.026)
σ GDP Growth		0.564***	0.544***
		(0.177)	(0.199)
Real R&D Growth		0.146***	0.153***
		(0.048)	(0.054)
Intercept	-0.004	0.011	0.026***
	(0.002)	(0.008)	(0.008)
N	52	52	52
Adj. R^2	0.209	0.514	0.382

Notes: The dependent variable is the time dummy variable coefficient estimated from Equation (2). Regressions are weighted by the number of annual observations used in the estimate of Equation (2). Standard errors in parenthesis. Stars denote significance at the 1% (***), 5% (**), and 10% (*) levels.

2.7 Sources of inflation

The evidence suggests that inflation is an important component for understanding firm-level liquid asset holdings. We next explore the sources of inflation behind this finding. Is this being driven by the most volatile element of inflation, energy, or from core components? In columns (*ii*)–(*v*) of Table 7, we separately identify the impact of the core and energy components of inflation on firms' liquid asset holdings. In these estimates, the firm-level and aggregate variables are the same as in the baseline fractional response model, but we utilize alternative measures of inflation. Column (*ii*) uses the Producer Price Index (PPI) intermediate energy price inflation as an explanatory variable. The availability of this price index limits our sample from 1974 to 2013. To make this estimates comparable to the baseline, the coefficient on inflation of the baseline with the same sample period is -0.264 and significant at the 5% level. The coefficient on PPI energy inflation is negative but not statistically significant. For instance, a large decrease of 20 percentage points in energy prices is predicted to decrease the cash ratio by only one-third of one percentage point. Column (*iii*) includes both a core inflation measure based on the PPI final goods less energy and PPI energy inflation. The average marginal response of the cash ratio to final goods inflation is -0.438 and 0.027 for energy inflation. To compare the economic significance of these variables, the estimates predict that a one standard deviation increase in energy and final goods inflation, respectively, leads to a 0.003 increase and -0.012 decrease in the cash ratio. Using additional inflation measures, column (*iv*) includes the

Table 7: Alternative measures of inflation

Inflation Measure	Baseline (*i*)	(*ii*)	(*iii*)	(*iv*)	(*v*)
Inflation (GDP Deflator)	-0.336*** (0.075)				
PPI Intermediate Energy		-0.016 (0.014)	0.027* (0.0152)		0.027** (0.014)
PPI Final less Energy			-0.438*** (0.107)		-0.439*** (0.095)
CPI Energy				0.025* (0.014)	
CPI Core				-0.457*** (0.069)	
Sample	Full	Full	Full	Full	Manuf. Only
Firm-level controls	Yes	Yes	Yes	Yes	Yes
N	142,682	122,737	122,737	142,682	71,901

Notes: The dependent variable is the cash ratio. All estimations include the conditioning variables used in the baseline specification. Column (*i*) replicates the baseline estimates from Table 2. All columns show the coefficients of the average marginal effects from the fractional response model. All estimations use the full sample in the baseline specification except column (*v*) which only uses manufacturing firms. Standard errors are in parenthesis and are clustered by year. Stars denote significance at the 1% (***), 5% (**), and 10% (*) levels.

Consumer Price Index (CPI) based energy and core CPI inflation rates. Our results with the CPI measure show a similar pattern to those with the PPI measure: core inflation is more important than the energy component in capturing inflation's impact on firm-level liquid asset holdings.

In column (*v*) we focus on the effects of core and energy inflation solely on manufacturing firms, as these firms tend to be the most energy intensive. If it is costly to alter energy use, firms may use their liquid assets to smooth out energy inputs when these prices fluctuate. The results in this column show that the effects of PPI energy and the PPI less energy inflation for firms in the manufacturing sector are similar to the entire population of firms. There is no evidence that manufacturing firms respond differently in their preference for liquid assets following changes in the price level.

Within the manufacturing sector, energy usage varies among the different industries. We next estimate the model using PPI energy and PPI final goods less energy inflation, but additionally include interaction terms between these inflation measures and the SIC industry to capture any additional heterogeneity in the responses. In Figure 3 we evaluate the model separately for manufacturing firms by 2 digit SIC industries. The estimates in this figure are the average marginal effects of inflation for each industry (this includes the entirety of the main and interaction effects for each industry). We order the industries on the graph from left to right from the least energy

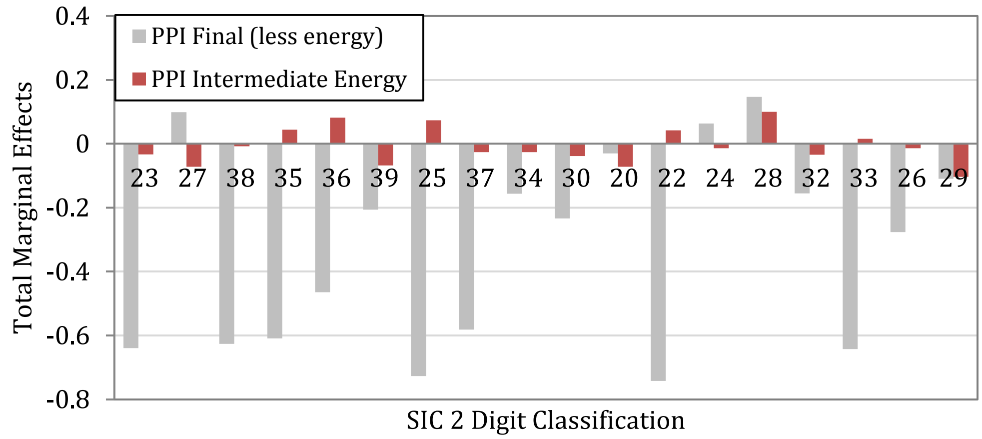

Figure 3: Effects of producer price index less energy and energy inflation on liquid asset holding by manufacturing industry

Notes: The estimates include the main effects of PPI less energy and PPI energy inflation and interaction terms between each inflation measure and industry at the SIC 2 digit level for manufacturing firms. The reported estimates are the sum of the main and interaction effects with each inflation measure. All estimations include the firm-level conditioning variables included in the baseline specification. SIC 2 digit industries are ordered from least to most energy intensive industries based on the BTU per dollar value added used.

intensive (Apparel and Textiles, 23) to most energy intensive (Petroleum and Coal, 29) based on amount of energy (British thermal unit, BTU) per dollar of value added.[5] The estimates show no clear pattern of the effects of the inflation measures on liquid asset holdings by energy intensity. We thus conclude that the responsiveness of liquid asset holdings to inflation is primarily driven by the core, rather than energy, components.

2.8 Asset portfolio adjustments from inflation

We conjecture that inflation alters the firm-level cash ratio by eroding the real value of liquid assets when these assets are imperfectly hedged against price-level changes. It follows that in times of high inflation, firms may adjust the composition of their asset portfolio towards those most protected against inflation. Our results show that inflation reduces the overall holdings of liquid assets. In this section, we first show that inflation is additionally associated with a reallocation of firms' liquid asset portfolios towards types of liquid assets most protected against inflation. Further, we find a positive relationship between inflation and a firm's holdings of non-cash substitutes.

The Compustat data reports a subset of our liquid asset measure, variable "CH". This measure is argued to be most similar to M1 types of assets (Mulligan, 1997). It includes currency, bank drafts, banker's acceptances, certificates of deposits included in cash by the company, checks, demand certificates of deposits, letters of credit, and money orders. In comparison, our broader measure of liquid assets we use to construct the cash ratio includes all of these assets plus commercial paper,

[5]The energy use data is from the 1998 Manufacturing Energy Consumption Survey (MECS) conducted by the U.S. Energy Information Administration and it draws from a nationally representative sample that includes firms representing over 97 percent of manufacturing payroll.

Table 8: Adjustments of liquid asset portfolio from inflation

	Dependent Variable		
	Cash Ratio (Baseline) (*i*)	M1 Ratio (*ii*)	M1/ Liquid Assets (*iii*)
Inflation	-0.336***	-0.298**	-0.589***
	(0.075)	(0.151)	(0.067)
Firm-level controls	Yes	Yes	Yes
Aggregate controls	Yes	Yes	Yes
SIC 2 Digit Dummy	Yes	Yes	Yes
N	142,682	126,713	125,979

Notes: All estimations include the conditioning variables used in the baseline specification. Column (*i*) replicates the baseline estimates from Table 2. All columns show the coefficients of the average marginal effects from the fractional response model. Standard errors are in parenthesis. Stars denote significance at the 1% (***), 5% (**), and 10% (*) levels.

government securities, marketable securities, and short-term investments. For our purposes, the main difference between the broader measure of liquid assets and these M1-type holdings is that the latter are arguably the least protected against inflation as the components earn little to no nominal returns. We define an alternative measure of liquid asset holdings, the *M1 Ratio*, as the M1-type assets divided by total assets. On average, the assets included in this measure make up 77% of a firms' total liquid assets.

Column (*ii*) of Table 8 uses the same covariates as our baseline specification but includes the *M1 Ratio* as the dependent variable in place of *Cash Ratio*. The coefficient on inflation of -0.298 is in line with our baseline results. To understand how firms adjust the composition of liquid assets in their portfolio in response to inflation, in column (*iii*) we use the ratio of M1-type assets to total liquid assets as our dependent variable. The negative sign on inflation suggests that firms hold relatively less M1-type assets in their liquid asset portfolio due to increases in inflation. This result is consistent with our hypothesis that inflation erodes the real value of liquid assets imperfectly inflation protected. That is, even as an increase in inflation leads to a reduction in liquid asset holdings, firms rebalance their liquid asset portfolios towards holding relatively more of those assets that are hedged against inflation.[6]

If inflation causes firms to deplete their liquid asset holdings, it may then alter a firm's margin between holding cash and substitutes for these liquid assets. For example, non-cash net working capital – working capital net of liabilities less liquid assets – can be such a substitute (Bates et al., 2009). Figure 4 plots the average net working capital as a share of assets (*NWC/Assets*), non-cash net working capital as a share of assets (*NCNWC/Assets*), and the cash ratio in our sample. Net working capital as a share of assets remains relatively steady while its cash and non-cash components

[6]This result relates to Azar et al. (2016). While they use the T-bill rate on the 10 year lagged average on the non-interest bearing shares of cash as a measure of the cost of carry, we note that underlying identification in our paper – by which each firm takes inflation as given – allows us to quantify the contemporaneous changes of the liquid asset portfolio composition from inflation.

mirror each other. As the cash ratio falls through the 1960s and 1970s, *NCNWC/Assets* remains relatively high. Beginning in the 1980s as the cash ratio rises, *NCNWC/Assets* steadily falls until the mid-2000s.[7] To the extent inflation causes a fall in the cash ratio, firms may substitute these assets for non-cash net working capital. We regress *NCNWC/Assets* on the firm-specific and aggregate variables used in our baseline estimation (results not shown) and the coefficient on inflation of 0.439 is statistically significant at the 1% level. If non-cash net working capital is substitutable with highly liquid assets *and* inflation decreases the cash ratio, then inflation may cause firms to interchange liquid assets with non-cash net working capital.[8]

Overall, the results here lend further support for our hypothesis that inflation erodes the real value of liquid asset holdings. Firms adjust their cash ratio in response to inflation which causes them to change the composition of their asset portfolio towards liquid assets that are most inflation protected and to other assets that are substitutes for cash.

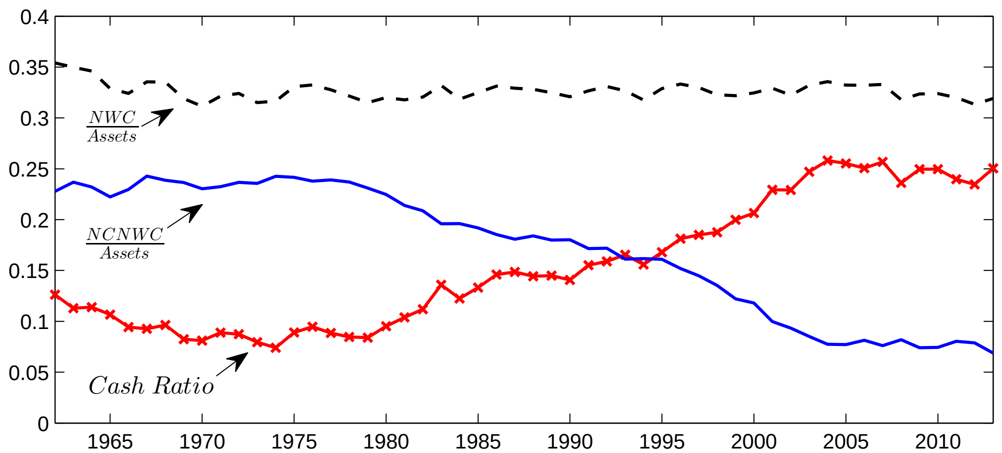

Figure 4: Mean net working capital as a share of assets (*NWC/Assets*), non-cash net working capital as a share of assets (*NCNWC/Assets*), and the cash ratio

2.9 The dynamics of liquid asset holding in response to inflation

We have established that inflation impacts the *level* of a firm's liquid asset holding. To provide further evidence of inflation's impact on these holdings, we next explore *how* inflation influences the adjustments to liquid asset holdings across time. We begin by outlining a hypothesis for the role of inflation on the dynamics of the liquid asset accumulation process. We then empirically confirm the qualitative predictions of our hypotheses. In summary, our results show that in response to changes in inflation, the change in a firm's liquid asset holdings is heterogeneous in their own *level* of these

[7]Some of the fall in *NCNWC/Assets* may be attributed to the rise in just-in-time inventory practices developed in the 1980s which allows firms to reduce inventory holdings.

[8]We do acknowledge that causality may also run the opposite direction, i.e. an increase in *NCNWC/Assets* leads to a fall in the cash ratio as firms accumulate these non-cash substitutes. It is likely that causality runs in both directions.

liquid asset holdings.

2.9.1 How inflation impacts cash ratio adjustments

We hypothesize that firms have a target cash ratio that is based on firm-level characteristics and inflation, and that they adjust their cash ratio to reach this target. While in the long run firms reach their target, in the short-run rigidities in the liquid asset adjustment process cause cash ratios to differ from their target. Frictional adjustments to liquid assets may originate from costs of converting non-liquid assets to liquid assets or from variations in the length of the cash conversion cycle. Below we illustrate how inflation impacts the dynamics of the cash ratio while allowing for the possibility that their cash ratio may be above or below their target.

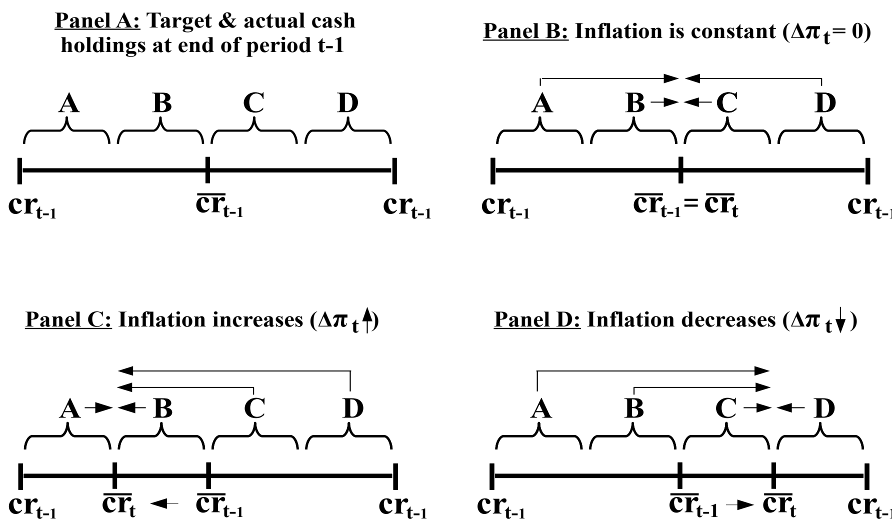

Figure 5: Inflation and the Dynamic Adjustment of Cash Ratio

In Panel A of Figure 5 we present four groups of firms based on the distance of their cash ratio from their target, $\overline{cr}_{t-1}$, in $t-1$. Segments A and B pool firms that are farthest and just below their target, respectively. The cash ratios of firms in segments C are just above the target, while those in segment D are far above. In the remaining panels we consider the dynamics of the liquid asset holdings of these firms in response to changes in inflation. For this figure, we assume that firm-level attributes are constant across the firms, and thus the target cash ratio is a function of inflation only.

Panel B shows the case where inflation is unchanged from periods $t-1$ to t. As inflation remains the same across periods, so does the target cash ratio, i.e. $\overline{cr}_{t-1} = \overline{cr}_t$. The arrows show the direction and magnitude of the cash ratio adjustments for each segment. Firms with liquid asset holdings below their target accumulate and those above their target reduce these assets. The distance from a firm's cash ratio to its target impacts the magnitude of the adjustment in its liquid asset holdings. As seen in segments A and D, the total adjustments are largest for those whose cash ratio at the end of period $t-1$ is farthest away from their target.

Panel C of Figure 5 shows the case when inflation increases between periods $t-1$ and t. As inflation increases, the target cash ratio decreases, depicted as $\overline{cr}_{t-1}$ moving left to $\overline{cr}_t$. The actual cash ratios of firms in segments C and D are now further away from their cash ratio target, and thus these firms aggressively adjust their liquid asset balances downward to reach the new target. Firms in segment B, whose liquid asset holdings in period $t-1$ where below their target, now in period t are above the target. These firms now start reducing their cash ratio. While firms in segment A, whose liquid asset holding were far below their target at the end of period $t-1$, still increase their liquid asset holding, however, less aggressively than before.

Panel D of Figure 5 shows the adjustments to a firm's cash ratio in response to a decrease in inflation. This case is opposite and symmetric to the increase in inflation presented in Panel C. Firms far below their target in segment A now even more aggressively accumulate liquid assets to reach their new target. Firms above their target in segment D still reduce their cash ratios, but the fall in inflation results in a smaller downward adjustment in liquid assets.

Overall, the magnitude of liquid asset adjustments in response to inflation is heterogeneous based on both how far the firm is away from its target and whether they are above or below this target. We next empirically test these predictions.

2.9.2 Empirical analysis of cash ratio adjustments and inflation

This section empirically tests our hypothesis of the dynamics of adjustments to the firm-level cash ratio outlined above. We show there is a time-varying target cash ratio that firms are adjusting their liquid asset balances towards. And in order, we establish four results about the target cash ratio: 1) The target cash ratio is firm-specific. 2) The size of adjustments toward the target cash ratio is determined by the distance of the firm's cash ratio from its target. 3) The firm-specific target cash ratio, in addition to being a function of a firm's individual characteristics, also depends on aggregate inflation. 4) If inflation increases, the accumulation of liquid assets for firms below their target decreases, and for firms above their target the magnitude of the reduction in their liquid assets increases.

We first estimate a firm's target cash ratio. Following Opler et al. (1999), we define the target cash ratio, $\overline{cr}_{i,t}$, as the predicted value for a firm i from a fractional response model of the cash ratio on firm-specific controls using only cross-sectional data from period t. We show next that firms are adjusting their liquid asset holdings towards these target cash ratios. This establishes that these targets are firm-specific (i.e. result 1). To understand how firms adjust their liquid asset holdings over time, we estimate the following regression for each firm:

$$\Delta cr_{i,t} = \alpha + \beta_i(cr_{i,t-1} - \overline{cr}_{i,t-1}) + \epsilon_{i,t} \tag{3}$$

where $\Delta cr_{i,t}$ is the change in the cash ratio for firm i and $cr_{i,t-1} - \overline{cr}_{i,t-1}$ is the difference between the cash ratio and the target cash ratio at the end of the previous year. Figure 6 shows the distribution of the β_i coefficients for all firms with at least ten continuous observations in the sample period. The area with the shaded columns represent the proportion of β_i coefficients that are statistically significant at the 5 percent level which overall accounts for 44% of the estimates. The mean coefficient is -0.43 and the median is -0.40. The negative coefficients indicate that firms adjust their liquid asset holdings to their target. For example, firms that at the end of the previous year were below their target increase their liquid asset holdings.

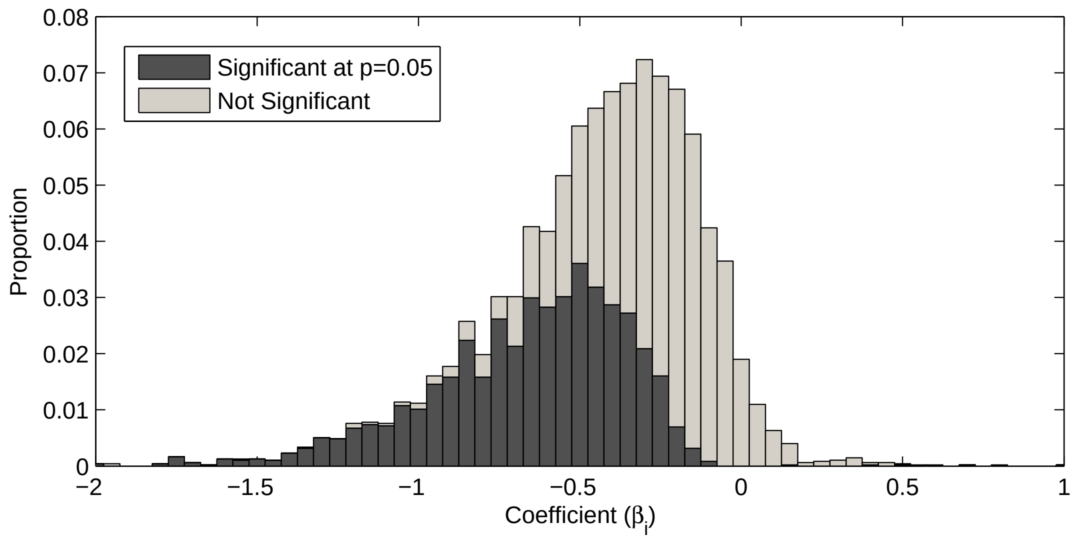

Figure 6: Distribution of firm-level β_i on the difference of actual cash ratio and target cash ratio at the end of $t-1$

Notes: This is the distribution of the β_i coefficients of firm-wise estimates of Equation (3). The height of the bar is the proportion of the β_i coefficients in that interval. The dark bars are the estimates that are statistically significant at the 5 percent level.

Further, the fact that many of the coefficients are non-zero implies that the further away a firm is from its target cash ratio the larger its adjustment (in magnitude) towards it. The size of the adjustment of a firm's liquid asset holdings is a function of how far away its cash ratio is from its target. That is result 2.

As robustness, we construct an alternate measure of the target cash ratio based on a regression of the full sample versus the repeated cross-section used above. The alternate target cash ratios are defined as the predicted values from a modified version of the baseline fractional response model. The only difference from the baseline specification is that we omit inflation and the other aggregate variables and instead include a set of annual dummy variables to capture all aggregate influences on liquid asset holdings. Using these estimates as the target cash ratio, we reestimate Equation (3) for each firm. The mean β_i coefficient from this regression is -0.42 and the median is -0.37 (in comparison to -0.43 and -0.40, respectively, for our first target cash ratio measure).

Next, consider inflation's influence on the target cash ratio. To examine this relationship, we regress the target cash ratio on inflation and an intercept term. The coefficient on inflation -1.89 and is significant at the 1 percent level using both measures of the target cash ratio. These results show that the target cash ratio is not only a function of firm-specific variables but also inflation.

That is result 3.

We next turn our attention to how inflation governs the dynamics of cash ratio adjustments in the following OLS regression:

$$\Delta cr_{i,t} = \alpha + \beta_1(cr_{i,t-1} - \overline{cr}_{t-1}) + \beta_2 \Delta\pi_t + \beta_3(cr_{i,t-1} - \overline{cr}_{t-1})^* \Delta\pi_t + \sum_{n=1}^{N} \phi_n X_{n,i,t} + \sum_{m=1}^{M} \theta_m Z_{m,t} + \epsilon_{i,t} \quad (4)$$

where the dependent variable $\Delta cr_{i,t}$ is the change in firm i's cash ratio. The explanatory variables include the interaction and main effects of the distance from the target cash ratio at the end of the previous year and the absolute change in inflation. We also include the first differences of the firm-specific and aggregate variables used in the baseline (the X and Z controls, respectively).[9] Table 9 summarizes the β coefficients estimated in Equation (4). The remaining firm-specific and aggregate coefficients are not reported for brevity.

Column (i) of Table 9 shows that adjustments in cash balances are inversely related to the distance to the target cash ratio at the end of period $t-1$. Column (ii) shows that as inflation increases the rate of liquid asset accumulation falls. Finally, column (iii) shows the interaction effect between a firms distance to their target at the end of period $t-1$ and changes in inflation.

The results in Table 9 are best understood graphically. Figure 7 shows the predicted change in the cash ratio ($\Delta cr_{i,t}$) due to changes in inflation ($\Delta\pi_t$). We plot out the predicted changes in the cash ratio for firms 10 and 1 percentage points below their target at the end of the previous year, and firms that are 10 and 1 percentage points above their target.

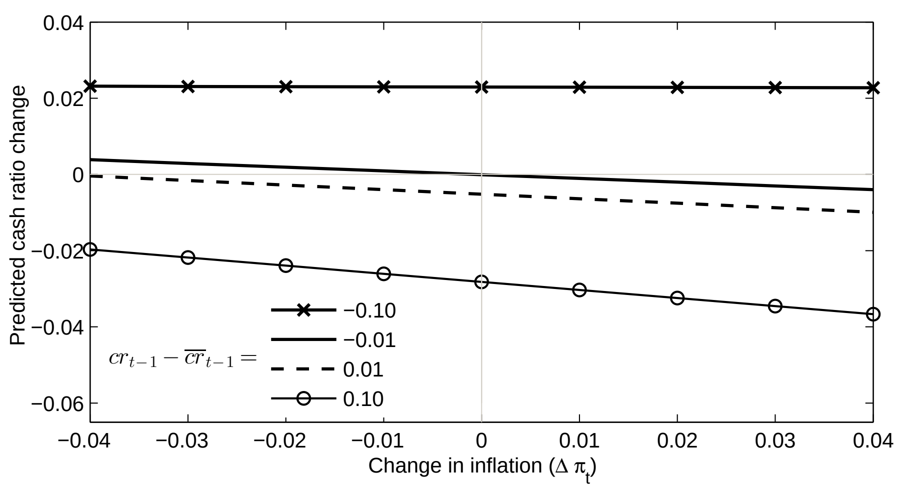

Figure 7: Percentage Point Change in Cash Ratio and Inflation.

Notes: The predictions are from the estimates of Equation (4) presented in Table (9). Each series shows changes in the predicted cash ratio from inflation holding the distance from the actual to target cash ratio in the previous year fixed. The target cash ratio is the predicted value of the cash ratio in the repeated cross section estimates of the cash ratio.

[9]The exceptions are the indicator variable *Dividend Dummy* and *Real GDP Growth* and *Real R&D Growth* which are already expressed as growth rates.

Table 9: Cash ratio adjustments and inflation.
Dependent variable: $\Delta cr_{i,t}$

	$\overline{cr}$ estimation method	
	Repeated Cross-Section	Full Sample
$(cr_{t-1} - \overline{cr}_{t-1})$	-0.253***	-0.250***
	(0.003)	(0.003)
$\Delta\pi_t$	-0.071***	-0.070***
	(0.019)	(0.019)
$(cr_{t-1} - \overline{cr}_{t-1})^{*}\Delta\pi_t$	-1.115***	-0.938***
	(0.361)	(0.350)
Firm-level controls	Yes	Yes
Aggregate controls	Yes	Yes
SIC 2 Digit Dummy	Yes	Yes
N	127,986	127,986
adj R^2	0.188	0.190

Notes: The dependent variable is the change is the cash ratio from time $t-1$ to time t. All estimates use Ordinary Least Squares. All estimates include the first difference of the firm-specific conditioning variables used in the baseline estimation model and the first difference of the aggregate variables. The exceptions are *Dividend Dummy* at the firm-level and aggregate variables *Real GDP Growth* and *Real R&D Growth* which are both already expressed as growth rates. Standard errors are in parenthesis. Stars denote significance at the 1% (***), 5% (**), and 10% (*) levels.

Let us first look at liquid asset adjustments for firms that are 10 percentage points below their target. Firms in this range are accumulating liquid asset irrespective of the size of the change in inflation.[10] Contrast this with firms at the other extreme whose cash ratio is 10 percentage points above their target. For any given change in inflation, these firms always reduce their liquid asset holdings. Additionally, as inflation increases, the magnitude of the downward adjustments in their cash ratio increases.

The comparison of these two series shows the absolute magnitudes of liquid asset adjustments in response to inflation are heterogeneous based on whether a firm's cash ratio is above or below their target. That is result 4. This observation is consistent with the response to the increase in inflation depicted in Panel C in Figure 5 and the reduction of inflation in Panel D of the same figure.

3 Conclusion

This paper makes three main contributions.

First, to the best of our knowledge, this is the first paper that explicitly shows that inflation is an important determinant in accounting for the evolution and the dynamics of liquid asset holdings experienced by U.S. corporations. At the individual firm level a 1 percentage point increase in

[10] The observed changes in inflation during our sample period never exceed 4% or fall below -4%.

aggregate inflation results in a statistically significant 0.34 percentage point decrease in a firm's cash ratio. Economically, this implies that inflation alone can fully account for the entire fall in the average U.S. cash ratio from the early 1960s to the early 1980s and roughly one-fifth of the increase thereafter.

Second, we put forward an explanation for how inflation can impact a firm's liquid asset holdings. We show that the portfolio of liquid assets held by U.S. firms is not fully hedged against inflation. This causes the real value of these assets to change as inflation changes, which induces the firm to alter their liquid assets holdings in response to inflation changes.

Third, our methodological contribution is the application of the fractional response model developed in Papke and Wooldridge (1996). Since our primary dependent variable – the cash ratio – is bounded between 0 and 1, our econometric method bounds the predicted values in this interval. We find that using OLS leads to predicted values outside of the theoretical bounds of the cash ratio. Moreover, we show that the response of the cash ratio to inflation is not constant across the distribution of firms' liquid asset holdings, providing further support of our method.

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