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 US corporations steadily declined from the 1960s to the early 1980s, and has since steadily increased. Our empirical analysis shows that inflation can account for roughly the entire decline and one-third of the increase in the average firm-level cash ratio. Additionally, to provide an explanation for the negative relationship between inflation and the cash ratio, we show that these liquid asset holdings are imperfectly hedged against inflation. As a result, changes in inflation alter the real value of a firm’s liquid asset portfolio causing them to readjust their liquid asset balances. We construct a theoretical framework to formalize this explanation.

JEL Classification: G32; E31; E41; E44.

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

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1 Introduction

Liquid asset holdings as a share of total US non-financial assets – the so-called ‘cash ratio’ – have witnessed large changes since the early 1960s. Between the 1960s and early 1980s the US 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. As seen in Figure 1, 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. There is a negative relationship in the data between inflation and liquid asset holdings. In this paper we formally study this negative relationship.

We show that inflation is an important determinant of a firm’s liquid asset holdings. We find that changes in inflation can explain a significant portion of the long-run variation in the cash ratio over the past 50 years. We additionally build a theory to explain the mechanism through which inflation impacts a firm’s liquid asset holdings. With inflation at a 40-year low, the cash ratio on the rise, and the Great Recession highlighting the impact of liquidity on macroeconomic aggregates, it is important to understand the effect of macro-level inflation on firm-level liquidity.

Using firm-level data from the Compustat Industrial Database, our empirical 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

![Figure 1: Annual inflation and cash ratio of US non-financial corporations, 1960–2013](image)

*Notes: Cash ratio is calculated as the sum of checking deposits, saving deposits, foreign deposits, money market mutual funds, security repurchase agreements, commercial paper, US treasury securities, agency and GSE securities, municipal securities, and mutual funds as a share of total assets. Data is from the US 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 $\lambda = 1600$).*
inflation decreases the average cash ratio by 0.44 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-third of the increase thereafter.

To explain our results, we argue inflation impacts the cash ratio because liquid assets are imperfectly hedged against inflation. 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.

As a final empirical exercise we identify 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.

Our dynamic model provides a formal framework to explain the tradeoffs through which inflation exerts a negative effect on a firm’s liquid asset holdings. Firms in our model face a cash-flow mismatch problem that requires them to use liquid assets to fund the costs of inputs. This restriction gives firms an incentive to accumulate liquid assets, however such holdings come at a cost. Firm’s liquid assets are imperfectly hedged against inflation. Therefore, as inflation increases the real value of these assets falls. Thus, increases in inflation lead to a reduction in a firm’s liquid asset holdings.

Our model also sheds light on an important mechanism where changes in inflation, through inflation’s impact on firms’ liquid asset holdings, can have real effects. For example, average revenues are decreasing in inflation. Since firms need liquid assets to acquire inputs, a firm’s revenue is negatively related to the level of its liquid asset holdings. When inflation increases, firms reduce their liquid asset holdings. This in turn leads to a reduction in average revenue. This mechanism highlights the importance of understanding the relationship between inflation and the cash ratio for the real economy, and not just the nominal economy.

Our paper contributes to a growing literature that aims to explain why U.S. corporations hold liquid assets. Explanations in this literature include precautionary or tax reasons (Sànchez and Yurdagul, 2013). The precautionary motive is related to cash-flow uncertainty (Bates et al., 2009, Palazzo, 2012, and Zhao (2014), or uncertainty related with R&D (Brown and Petersen, 2011 and 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. We mainly focus on why the level of liquid asset holdings has changed over time. 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. Our paper focuses on a longer sample from the early 1960s to 2013 and shows that inflation is a main factor driving both the decline in corporate cash holding from the 1960s to the early 1980s.

1Our measure of liquid assets – the cash ratio – is standard in the finance literature and the “cash” component includes currency, deposits, treasuries, and other marketable securities.
and its rise thereafter.

Our paper also adds to the literature that studies the relationship between a firm’s liquid asset holdings and macroeconomic conditions. 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 US corporations from 2000 to 2007. To the best of our knowledge, we are the only paper that explicitly studies the role of macro-level inflation on the firm-level cash ratio.

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

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 that contains 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 a 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. For our analysis we only include firms that are incorporated in the US. 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.

Figure 2 presents the broad characteristics of the evolution of the cash ratio for our sample 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 the Flow of Funds and the correlation between the two is 0.877. 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 (SIC 2 digit codes 20-39) and non-manufacturing firms. Over the past 50 years the composition of firms in the sample 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 trend with the V-shape for manufacturing firms being more
Figure 2: Evolution of cash ratio by level, sector, assets size, and risk

Panel A shows the mean cash ratio by level, which has followed a general V-shape trend. Panel B presents the mean cash ratio by sector, with manufacturing firms generally holding more liquid assets than non-manufacturing firms. Panel C shows the mean cash ratio by total assets grouped in asset quintiles. Regardless of firms' size, the cash ratio's behavior 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.

In panel D we present the average cash ratio by quintiles of a measure of firm-specific risk. Under the precautionary motive of cash holding, firms hold cash to mitigate adverse shocks and to take advantage of promising investment opportunities (Bates et al., 2009). We measure firm-specific risk as the backward looking 9-year rolling window of the standard deviation of real sales growth at the firm-level. Consistent with the precautionary motive, since the 1970s, firms that face the highest risk hold more liquid assets.

In sum, these figures show that the cash ratio has followed a general V-shaped trend 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 trend. Annual inflation rose from 2.3 percent in the 1950s.

\[ \text{Real Sales}_t = \frac{\text{Real Sales}_t - \text{Real Sales}_{t-1}}{(1/2)(\text{Real Sales}_t + \text{Real Sales}_{t-1})} \]

\[ \text{Real Sales}_t \text{ is the real sales value at time } t, \text{ and the GDP deflator is used to convert nominal to real sales.} \]
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 baseline regression 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. 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”). We measure inflation as the annual growth rate of the GDP Deflator.

We additionally control for a number of firm-specific characteristics shown to be important in previous studies (for example in Bates et al. (2009)). To account for any cash-flow effects on liquid asset holdings, we control for capital expenditures, dividend payments, and firms’ contemporaneous real sales growth. Capital expenditures are measured by the ratio of capital expenditures to total assets, \( \frac{\text{CapX}}{\text{Assets}} \). Dividends are represented by a dummy variable equal to 1 in years a firm pays dividends and 0 otherwise. Finally, real sales growth is defined as 

\[
\frac{\text{RealSales}_t - \text{RealSales}_{t-1}}{(1/2)(\text{RealSales}_t + \text{RealSales}_{t-1})}
\]

where nominal sales are deflated by the GDP Deflator to get real sales.

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 is measured by the backward looking 9-year rolling window of the standard deviation of real sales growth, \( \sigma \text{ Sales Growth} \). Our results are not sensitive to alternative window sizes and we experiment with an alternative industry measure of risk in Section 2.4.2. In addition, firms with growth opportunities may hold liquid assets to have the necessary funding when those opportunities arise. We include the market-to-book ratio to capture future growth opportunities as measured through a firm’s market value. 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.

The remaining two control variables include 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 holdings.

Table 1 shows descriptive statistics for the firm-level variables constructed from the Compustat data. The final variable, inflation, is measured at the aggregate level with a mean of 0.035 and a standard deviation of 0.023. The restrictions on some of the variables limit our sample size. Our measure of firm-level risk, \( \sigma \text{ Sales Growth} \), requires firms to be in the sample for 10 consecutive years. The availability of our market-to-book ratio measure limits the beginning of usable observations to 1962. We additionally drop outliers of firm-year observations at the 1% level of \( \frac{\text{CapX}}{\text{Assets}} \) and the top 1% of Leverage and Market-to-Book.\(^3\) We also restrict observations to have positive sales in the year. Our sample contains 11,186 firms for 119,394 firm-year observations from 1962-2013.

\(^3\)Also using the annual Compustat Industrial Database, Bates et al. (2009) deal with outliers of these variables by winsorizing the top 1% of Market-to-Book, winsorizing leverage to be between 0 and 1, and winsorizing capital \( \frac{\text{CapX}}{\text{Assets}} \) at the 1% level.
Table 1: Summary statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash Ratio</td>
<td>0.136</td>
<td>0.069</td>
<td>0.170</td>
<td>119,394</td>
</tr>
<tr>
<td>Sales Growth</td>
<td>0.032</td>
<td>0.040</td>
<td>0.306</td>
<td>119,394</td>
</tr>
<tr>
<td>σ Sales Growth</td>
<td>0.232</td>
<td>0.165</td>
<td>0.213</td>
<td>119,394</td>
</tr>
<tr>
<td>Log Assets</td>
<td>5.438</td>
<td>5.414</td>
<td>2.176</td>
<td>119,394</td>
</tr>
<tr>
<td>Market-to-Book</td>
<td>1.759</td>
<td>1.253</td>
<td>2.062</td>
<td>119,394</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.257</td>
<td>0.220</td>
<td>0.252</td>
<td>119,394</td>
</tr>
<tr>
<td>CapX/Assets</td>
<td>0.062</td>
<td>0.045</td>
<td>0.062</td>
<td>119,394</td>
</tr>
<tr>
<td>Dividend Dummy</td>
<td>0.470</td>
<td>0.000</td>
<td>0.499</td>
<td>119,394</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.035</td>
<td>0.028</td>
<td>0.023</td>
<td></td>
</tr>
</tbody>
</table>

2.3 Estimation strategy

Our empirical strategy uses a fractional response model to identify the effect of inflation, and other firm-level characteristics, on the firm’s 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, it is likely that the response to the covariates may vary widely between firms with high and low cash ratios. Allowing for non-linearities may lead to a better estimate of the effects of these covariates on the cash ratio.

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, is given by

\[
E(\text{Cash Ratio}_{i,t}|\pi_t, X_{i,t}, \gamma_{i,t}) = g^{-1}(\beta_0 + \beta_1 \pi_t + \sum_{n=1}^{J} \phi_n X_{n,i,t} + \gamma_{i,t}) + \epsilon_{i,t}
\]  

(1)

where \(\pi_t\) is inflation at year \(t\), the \(X_i\) are the set of firm-level control variables described in Section 2.2, and the \(\gamma_i\) are SIC 2 digit 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.

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

Table 2 presents our estimates for the impact of inflation on firm-level cash ratios. For our baseline estimates, in column (i), we use the fractional response model given by equation (1). This
Table 2: The impact of inflation on the average firm-level cash ratio

<table>
<thead>
<tr>
<th></th>
<th>Fractional Response</th>
<th>OLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i)</td>
<td>(ii)</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.442***</td>
<td>-0.393***</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.083)</td>
</tr>
<tr>
<td>σ Sales Growth</td>
<td>0.118***</td>
<td>0.179***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Log Assets</td>
<td>-0.002***</td>
<td>-0.003***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Sales Growth</td>
<td>-0.015***</td>
<td>-0.026***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Market-to-Book</td>
<td>0.008***</td>
<td>0.014***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Leverage</td>
<td>-0.239***</td>
<td>-0.216***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>CapX/Assets</td>
<td>-0.362***</td>
<td>-0.318***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.020)</td>
</tr>
<tr>
<td>Dividend Dummy</td>
<td>-0.019***</td>
<td>-0.019***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.172***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>119,394</td>
<td>119,394</td>
</tr>
<tr>
<td>adj. $R^2$</td>
<td></td>
<td>0.314</td>
</tr>
</tbody>
</table>

The dependent variable is the cash ratio. Column (i) present estimates from the fractional response model. The estimates shown are the marginal effects at their means. Column (ii) present estimates using Ordinary Least Squares. All estimates use robust standard errors. Standard errors in parenthesis. Stars denote significance at the 1% (***)”, 5% (**), and 10% (*) levels.

Our main variable of interest is inflation. As seen in column (i) of Table 2 inflation 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 0.44 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 3.6 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 3.5 percentage points, or approximately 30 percent of the observed change in the average cash ratio over that same time period. Together, these two results from our baseline regression indicate that the impact of inflation on the cash ratio is both statistically and economically significant.

For comparison with the fractional response model, in column (ii) of Table 2 we present the
coefficients from a standard OLS regression. The OLS estimates are similar, albeit the magnitude of the point estimate for the effect of inflation is a little lower. The similarity of the coefficients between the two methods further validate our baseline estimates. We prefer the estimates from the fractional response model because it correctly bounds our dependent variable between 0 and 1. When using the OLS regression results from column (ii) we find that 3.3 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.

In addition to inflation, our baseline estimates also include a number of other firm-level variables as controls. In order, these are the standard deviation of sales growth, log assets, sales growth, the market-to-book ratio, leverage, the ratio of capital expenditures to assets, and whether or not the firm paid a dividend. As discussed in Section 2.2 these variables have previously been shown to be important determinants of the cash ratio. Our results, consistent with these previous studies, find these variables to have a statistically significant effect on the cash ratio in the directions predicted by these other studies.

Next, to better understand the relative importance of inflation as compared with the other control variables, Table 3 presents the estimated contribution of inflation and the control variables to the changes in the cash ratio over the two sub-periods: 1962 to 1981 and 1981 to 2013. The estimated contributions of each variable are calculated by multiplying the mean changes in each variable over each interval 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.

As seen in Table 3 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 30 percent of the observed increase in the cash ratio. Changes in Leverage between 1962 to 1981 and CapX/Assets and Market-to-Book 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.

Having shown that inflation is an important determined of 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, \( \omega_j \) 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
Table 3: Estimated contribution to changes in
the average cash ratio

<table>
<thead>
<tr>
<th></th>
<th>1962 to 1981</th>
<th>1981 to 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash Ratio Data</td>
<td>-0.036</td>
<td>0.119</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.036</td>
<td>0.035</td>
</tr>
<tr>
<td>σ Sales Growth</td>
<td>0.005</td>
<td>0.009</td>
</tr>
<tr>
<td>Sales Growth</td>
<td>0.001</td>
<td>0.000</td>
</tr>
<tr>
<td>Log Assets</td>
<td>0.002</td>
<td>-0.001</td>
</tr>
<tr>
<td>Market-to-Book</td>
<td>-0.003</td>
<td>0.011</td>
</tr>
<tr>
<td>Leverage</td>
<td>-0.023</td>
<td>0.005</td>
</tr>
<tr>
<td>CapX/Assets</td>
<td>-0.005</td>
<td>0.014</td>
</tr>
<tr>
<td>Dividend Dummy</td>
<td>0.004</td>
<td>0.006</td>
</tr>
</tbody>
</table>

The table presents the predicted contribution to changes in
the cash ratio from mean changes in each conditioning vari-
able. 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).

from being positive and perfectly correlated with inflation, to assets such as cash that pay a zero
percent nominal return and whose value is independent of inflation. We expand the cumulative
returns given above to account for this inflation effect

\[
i = \sum_{j \in J} \omega_j \tilde{i}_j
= \sum_{j \in J} \omega_j (a_j + b_j \pi)
= \sum_{j \in J} \omega_j a_j + \left( \sum_{j \in J} \omega_j b_j \right) \pi
= a + b\pi
\]

where \(a_j\) is a constant and \(b_j\) gives the responsiveness of asset \(j\)’s returns to changes in inflation, \(\pi\). 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, \(r = i - \pi\), on the portfolio of liquid assets can be written as

\[r = a + (b - 1)\pi.\]

If \(b < 1\), then as 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
Table 4: Inflation and the return to the liquid asset portfolio

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quarterly</td>
<td>Annual</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(i)</td>
<td>(ii)</td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>0.376***</td>
<td>0.385***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.038)</td>
<td>(0.077)</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>0.021***</td>
<td>0.021***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.004)</td>
<td></td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td>0.326</td>
<td>0.326</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>204</td>
<td>51</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Standard errors are in parentheses. Stars denote significance at the 1% (***) and 5% (**), and 10% (*) levels.

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, $r_j$, 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 component in the Flow of Funds data.

Table 4 gives the OLS regression of the annualized nominal return, $i$, constructed above, on inflation for both the quarterly and annual frequency. The coefficient on inflation in these regressions gives an estimate of $b$. $b$ is between 0 and 1, statistically significant at the 1% level. When inflation increases the real returns on the liquid asset portfolio fall, causing the marginal cost of holding this portfolio to rise. This, in turn, incentives firms to cut back on their liquid asset holdings.

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

---

This estimation is similar to Fama and Schwert (1977)’s analysis of ‘inflation betas’ – the relationship between asset returns and inflation.
Table 5: The impact of the T-bill rate and inflation on the average firm-level cash ratio

<table>
<thead>
<tr>
<th></th>
<th>Baseline (i)</th>
<th>(ii)</th>
<th>(iii)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inflation</strong></td>
<td>-0.442***</td>
<td>-0.418***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.018)</td>
<td></td>
</tr>
<tr>
<td><strong>T-bill</strong></td>
<td>-0.449***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Real T-bill</strong></td>
<td>-0.455***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>σ Sales Growth</strong></td>
<td>0.118***</td>
<td>0.115***</td>
<td>0.116***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td><strong>Log Assets</strong></td>
<td>-0.002***</td>
<td>-0.003***</td>
<td>-0.003***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td><strong>Sales Growth</strong></td>
<td>-0.015***</td>
<td>-0.015***</td>
<td>-0.014***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td><strong>Market-to-Book</strong></td>
<td>0.008***</td>
<td>0.008***</td>
<td>0.008***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td><strong>Leverage</strong></td>
<td>-0.239***</td>
<td>-0.235***</td>
<td>-0.235***</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.004)</td>
</tr>
<tr>
<td><strong>CapX/Assets</strong></td>
<td>-0.362***</td>
<td>-0.334***</td>
<td>-0.336***</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.009)</td>
</tr>
<tr>
<td><strong>Dividend Dummy</strong></td>
<td>-0.019***</td>
<td>-0.017***</td>
<td>-0.018***</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td><strong>Intercept</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>119,394</td>
<td>119,394</td>
<td>119,394</td>
</tr>
</tbody>
</table>

The dependent variable is the cash ratio. All columns show coefficients of the marginal effects at their means from the fractional response model. Column (i) replicates the baseline estimates from Table 2. All estimates use robust standard errors. Standard errors in parenthesis. Stars denote significance at the 1% (***) 5% (**), and 10% (*) levels.

portfolio. The opportunity cost where \( i^T \) is the T-bill rate is given as

\[
Opp.\text{Cost} = i^T - i
= i^T - (a + b\pi).
\]

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

\[
Opp.\text{Cost} = r^T + \pi - (a + b\pi)
= r^T - a + (1 - b)\pi.
\]

If \( b < 1 \), then as inflation increases the opportunity cost of holding liquid assets increases, causing the firm to cut back on its liquid asset holdings. We have already shown above that \( b < 1 \).

The opportunity cost interpretation of why firm’s hold on to cash is similar to a paper by Azar.
et al. (2014). As the T-Bill rate rises the opportunity cost of holding liquid assets rises causing the cash ratio to fall. The T-bill rate is comprised of two components, the real interest rate and inflation. In column (ii) of Table 5 we first alter our baseline regression to include the annual T-bill rate in place of inflation. We next include both components of the T-bill rate in column (iii). The real T-bill rate is calculated as the log difference between the nominal T-bill rate and inflation. Column (ii) shows that the T-bill rate is indeed a determinant of liquid asset holdings, however, column (iii) further indicates that both 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 predict that changes in the real interest rate increase the average cash ratio by 0.6 percentage points from 1962 to 1981 and by 1.1 percentage points from 1981 to 2013. In comparison, the estimates from column (iii) predict changes in inflation decrease the average cash ratio by 3.4 percentage points from 1962 to 1981 and increase it by 3.3 percentage points from 1981 to 2013. We do not discount the real T-bill rate as being unimportant in explaining changes in firm-level cash holding. Rather, these estimates show that inflation is substantially more important than the real T-bill in accounting for the salient features of the evolution of the cash ratio.

2.4.1 Alternative measures of liquid assets and inflation

In our baseline regression we use the GDP Deflator as our measure of inflation and, consistent with the literature, the cash ratio as our measure of liquid asset holdings. In this section we consider alternative measures of inflation and liquid assets.

Alternative Measures of Liquid Assets. The first alternative measure of liquid assets that we consider is the M1 Ratio. The M1 Ratio has been argued to follow M1-type holdings (Mulligan, 1997) and is calculated by dividing a subset of the liquid assets, Compustat variable “CH”, by total assets. This variable includes currency, bank drafts, bankers acceptances, certificates of deposits included in cash by the company, checks, demand certificates of deposits, letters of credit, and money orders. This is in contrast to the set of liquid assets used to construct the cash ratio, which also includes commercial paper, government securities, marketable securities, and short-term investments. The main economic difference between the cash ratio from our baseline regressions and the M1 Ratio is that the subset of the assets in the latter are the least protected against inflation. It should be noted that the assets included in the M1 Ratio are not a trivial portion of a firm’s liquid asset portfolio – these assets on average make up 80 percent of all liquid asset holdings.

As seen in column (ii) of Table 6, inflation has a much stronger average effect on the M1 Ratio measure of liquid asset holdings as compared to the cash ratio measure. This result is consistent with our explanation of how increases in inflation lower the real returns on liquid asset holdings. Given that the M1 Ratio contains assets that are the least protected against inflation, the real returns on a portfolio of these assets is more likely to be effected by a change in inflation.
Following Opler et al. (1999), we next consider the natural logarithm of liquid to net assets, ln Net Cash Ratio, as an alternative measure of liquid assets. Net assets are measured as total assets less liquid assets. One benefit of using ln Net Cash Ratio as a measure of liquidity is that changes in this ratio more directly measure changes in the liquid asset holdings.\textsuperscript{5} The reason is that for this measure changes in liquid assets only affect the numerator, whereas for our standard cash ratio measure changes in liquid asset holdings affect both the numerator and denominator. In column (iii) of Table 6 we present our OLS results with ln Net Cash Ratio. We use OLS estimation because, unlike the cash ratio, the value of liquid assets to net assets can lie outside of the 0 and 1 interval. The coefficient on inflation for this alternative measure of liquid asset holdings remains negative and statistically significant at the 1 percent level. For completeness, in column (iv) we further estimate the regression using the non-logged value of the Net Cash Ratio and obtain a coefficient on inflation of -0.852, also significant at the 1 percent level. The more negative coefficient, as compared to the baseline, provides further evidence that changes in inflation directly affects a firm’s liquid asset holding.

**Alternative Measures of Inflation.** A potential concern is that our results may be driven by the most volatile components of inflation (i.e. energy). To investigate this, 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. Column (ii) uses the Producer Price Index (PPI) intermediate energy price inflation. The availability of this price index limits our sample to 1974 to 2013. The coefficient on PPI energy inflation is positive and statistically significant, but its economic significance is small. For instance, a large decrease of 20 percentage points in energy prices is predicted to decrease the cash ratio by only one-quarter 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 -0.318. For completeness, we also use

\textsuperscript{5}On the other hand, as Bates et al. (2009) point out, the liquid to net asset ratio generates extreme outliers, particularly for those with a substantial portion of their assets in liquid assets. To control for this, we trim the top and bottom one percent of Net Cash Ratio and In Net Cash Ratio observations.
Table 7: Alternative measures of inflation

<table>
<thead>
<tr>
<th>Inflation Measure</th>
<th>Baseline (i)</th>
<th>(ii)</th>
<th>(iii)</th>
<th>(iv)</th>
<th>(v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation (GDP Deflator)</td>
<td>-0.442***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPI Intermediate Energy</td>
<td>0.013***</td>
<td>0.039***</td>
<td></td>
<td>0.040***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.005)</td>
<td></td>
<td>(0.006)</td>
<td></td>
</tr>
<tr>
<td>PPI Final less Energy</td>
<td>-0.318***</td>
<td></td>
<td>-0.399***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td></td>
<td>(0.026)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPI Energy</td>
<td></td>
<td></td>
<td>0.053***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPI Core</td>
<td></td>
<td></td>
<td>-0.589***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.020)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample</td>
<td>Full</td>
<td>Full</td>
<td>Full</td>
<td>Full</td>
<td>Manuf. Only</td>
</tr>
<tr>
<td>N</td>
<td>119,394</td>
<td>104,646</td>
<td>104,646</td>
<td>119,394</td>
<td>59,536</td>
</tr>
</tbody>
</table>

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 marginal effects at their means from the fractional response model. All estimations use the full sample in the baseline specification except column (v) which only uses manufacturing firms. All estimates use robust standard errors. Standard errors in parenthesis. Stars denote significance at the 1% (***), 5% (**), and 10% (*) levels.

The 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 them 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 classification. 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 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. The estimates show no clear pattern of the effects of the

---

6The energy use data is from the 1998 Manufacturing Energy Consumption Survey (MECS) conducted by the US Energy Information Administration and it draws from a nationally representative sample that includes firms
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.

inflation measures on liquid asset holdings by energy intensity. Other than the outlier, SIC industry 28 Chemicals and Allied Products, all the other industries show a negative response of core inflation to liquid asset holdings.

2.4.2 Additional determinants of the firm-level cash ratio

For our baseline regression we included a standard set of covariates. In this section, we expand on these and consider other determinants of firm-level liquid asset holding that some previous studies have shown to be potentially influential in explaining the relative preference for liquidity. We first analyze additional firm-specific factors and then look at broader macroeconomic factors. We find that although some of these components are important, the measured impact of inflation on firms’ liquid asset holdings remains robust.

Firm-level determinants. We consider additional firm-level characteristics as determinants of liquid asset holdings in Table 8. Each column shows the estimated coefficients from our fractional response model and includes the variables indicated as an additional covariate. In each estimation, the remaining conditioning variables from our baseline estimation are included but not reported for brevity. To provide a measure of the economic significance of each covariate, the last row gives its contribution to the cash ratio in response to a one standard deviation increase in the variable.

Column (ii) provides an alternative industry-level measure of uncertainty: the standard deviation of industry cash flow to assets.\(^7\) Cash flow to assets is constructed by adding operating income representing over 97 percent of manufacturing payroll.

\(^7\)This measure was also used by Bates et al. (2009), Liu and Mauer (2011), and others.
Table 8: Additional firm-level determinants of the average firm-level cash ratio

<table>
<thead>
<tr>
<th></th>
<th>Baseline (i)</th>
<th>Industry σ (ii)</th>
<th>Acquisitions/ Assets (iii)</th>
<th>R&amp;D/ Assets (iv)</th>
<th>Earnings - T-bill (v)</th>
<th>Implied Marginal Tax (vi)</th>
<th>Asset Tangibility (vii)</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>0.104***</td>
<td>-0.232***</td>
<td>0.231***</td>
<td>-0.023***</td>
<td>-0.045***</td>
<td>-0.247***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.011)</td>
<td>(0.008)</td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.010)</td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.442***</td>
<td>-0.504***</td>
<td>-0.461***</td>
<td>-0.568***</td>
<td>-0.399***</td>
<td>-0.405***</td>
<td>-0.305***</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.017)</td>
<td>(0.020)</td>
<td>(0.027)</td>
<td>(0.018)</td>
<td>(0.019)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>N</td>
<td>119,394</td>
<td>164,271</td>
<td>107,525</td>
<td>65,769</td>
<td>117,935</td>
<td>119,265</td>
<td>117,437</td>
</tr>
<tr>
<td>Effect of 1 σ increase x</td>
<td>0.014</td>
<td>-0.014</td>
<td>0.026</td>
<td>-0.004</td>
<td>-0.006</td>
<td>-0.076</td>
<td></td>
</tr>
</tbody>
</table>

The dependent variable is the cash ratio. All estimates are conducted with the fractional response model. All estimations include the conditioning variables used in the baseline specification. Column (i) replicates the baseline estimates from Table 2. The estimates for the x variable are the marginal effects at their means for the column variable. All estimates use robust standard errors. Standard errors in parenthesis. Stars denote significance at the 1% (***) , 5% (**), and 10% (*) levels.

The standard deviation of industry cash flow to assets is then constructed as the average of the backward-looking standard deviation of cash flow to assets by 2-digit SIC industry. Firms with more than 3 observations are included, leading to a larger sample size than our main specification (which required at least 10 continuous observations). This measure of uncertainty is quantitatively significant in explaining the behavior of the firm-level cash ratio: a one standard deviation increase in uncertainty leads to a 1.4 percentage point increase in a firm’s cash ratio. In our baseline specification, we use a firm-specific rather than an industry-specific measure of risk. The reason for this choice is that when firms are deciding liquid asset holdings, their own uncertainty is more relevant than industry-wide volatility.

Columns (iii) and (iv) show the results for acquisitions as a share of assets and R&D expenditures divided by assets. The only reason these variables are excluded from our main specification is that the acquisition data shortens the sample by 9 years and the R&D data cuts the sample by over 40 percent. Although these variables have considerable explanatory power, the impact of inflation on the cash ratio is not diminished.

We next include a firm-level measure of the spread between returns to long and short term assets, earnings minus the T-bill rate, in Column (v). Earnings are operating income after depreciation as a share of assets which measures the return to fixed capital while the T-bill rate measures the return to short-run liquid assets. This is also an alternative measure of the opportunity cost of holding liquid assets. Since earnings capture returns from a firm’s fixed capital stock, as the returns to investing in long-term fixed assets rise relative to short-term returns, we would expect the level of liquid assets to fall. The coefficient confirms this but its economic significance is relatively small.

8Pinkowitz et al. (2012) and Brown and Petersen (2011) show that R&D expenditures have been positively associated with uncertainty.

9It standard in the literature to treat missing R&D observations in the Compustat data as observations with zero R&D expenses. We additionally follow this method and obtained similar results to the ones presented here.
Column (vi) includes the implied marginal tax rate in the previous year, before deductions or exceptions. Tax motives may affect liquid asset holdings. Again, while this variable is statistically significant, its economic significance is small.

The final column includes the liquidation value of firms’ assets, Asset Tangibility, as calculated in Berger et al. (1996). Asset Tangibility is equal to \(0.715 \times \text{Receivables} + 0.547 \times \text{Inventories} + 0.535 \times \text{FixedAssets}\) divided by total assets. If firms’ assets are reversible, they may be substitutes for liquid assets or may lessen credit constraints. Including Asset Tangibility slightly dampens the effects of inflation. This is expected given the correlation between liquid asset holdings and intangible assets. Falato et al. (2013) find that liquid asset holdings have risen along with the growth in intangible capital held by firms since the 1970s.

The coefficients on inflation in Table 8 show that the impact of inflation on cash holding is robust to an array of additional firm-level characteristics. We next investigate competing macroeconomic factors that may impact the cash ratio.

**Macroeconomic determinants.** In Table 9 we consider additional aggregate factors that may influence firms’ cash ratio. Each column presents separate estimates of the fractional response model and includes the aggregate covariate in the baseline model. As before, the first row shows the average marginal effect of the covariate on the cash ratio and the last row gives the impact on the cash ratio from a one standard deviation increase in the covariate.

In column (ii) we include real aggregate corporate profit growth which may signal current and future business conditions.\(^{10}\) The coefficient for corporate profit is small. For example, in 2010 corporate profits increased 21 percent; this change is predicted to increase the cash ratio by less than two-tenths of one percentage point.

For column (iii) we include an aggregate uncertainty measure. In times of high aggregate uncertainty, firms may wait to use their liquid assets until market conditions are clear, the so-called “wait and see” effect. We include this to identify any real option effects of liquid asset holdings caused by aggregate uncertainty. Our measure of uncertainty, \(\sigma \text{ GDP growth}\), is the annual average of the five year backward-looking standard deviation of quarterly GDP growth.\(^{11}\) The positive sign on the covariate is consistent with the wait-and-see effect. For our baseline estimation, we include firm-level uncertainty as a more appropriate measure of uncertainty faced by a firm.

We next turn to how variations in the term structure of interest rates may impact the cash ratio in column (iv). We use the yield curve – the difference of the 10 year T-Bond interest rate and the 3 month T-Bill rate – to capture differences between long and short term rates. The mean of the yield curve for the period is 0.015 and the standard deviation is 0.011. Given the relatively small size of the coefficient on the yield curve, changes in the observed term structure, while statistically significant, have a small impact on the cash ratio.

The final column identifies changes in tax policy on firms’ liquid asset holdings. We use the top

---

\(^{10}\)Data for corporate profits are compiled by the U.S. Bureau of Economic Analysis and adjust for inventory valuations and capital consumption. The GDP deflator is used to convert nominal into real profits.

\(^{11}\)Our results are robust to alternative window sizes.
Table 9: Additional aggregate determinants of the average firm-level cash ratio

<table>
<thead>
<tr>
<th></th>
<th>Baseline (i)</th>
<th>Corp. profit growth (ii)</th>
<th>σ GDP (iii)</th>
<th>Yield curve (iv)</th>
<th>Top marg. tax rate (v)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflation</td>
<td>-0.442***</td>
<td>-0.432***</td>
<td>-0.500***</td>
<td>-0.409***</td>
<td>-0.314***</td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.019)</td>
<td>(0.020)</td>
<td>(0.020)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>N</td>
<td>119,394</td>
<td>119,394</td>
<td>119,394</td>
<td>119,394</td>
<td>119,394</td>
</tr>
<tr>
<td>Effect of 1 σ increase x</td>
<td>0.001</td>
<td>0.003</td>
<td>0.002</td>
<td>-0.005</td>
<td></td>
</tr>
</tbody>
</table>

The dependent variable is the cash ratio. All estimates are conducted with the fractional response model. All estimations include the conditioning variables used in the baseline specification. The estimates for the x variable are the marginal effects at their means for the column variable. Column (i) replicates the baseline estimates from Table 2. All estimates use robust standard errors. Standard errors in parenthesis. Stars denote significance at the 1% (***) and 5% (**), and 10% (*) levels.

corporate marginal tax rate as a proxy for changes in tax policy. Although firms may not actually face this rate, changes in the top rate are indicative of broader tax policy changes. The top marginal tax rate fell from a high of 0.528 to 0.35 where it has been since 1993. Our estimations predict that this change in the marginal tax rate would result in a modest 1.3 percentage point increase in the cash ratio.\footnote{As Fritz Foley et al. (2007) show, tax rates may play a role in firm-level liquid asset holdings as firms attempt to defray dividend, particularly if the liquid assets are held abroad. However, Pinkowitz et al. (2012) argue that high R&D expenditures of multinational firms is the main factor why these firms have such high liquid assets holdings.}

As a whole, the economic significance of the aggregate variables are small in magnitude and the effects of inflation on firm-level liquid asset holding remain robust in all of these specifications.

2.5 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. In this section, we next explore how inflation influences the adjustments to liquid asset holdings across time. We begin by outlining 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 liquid asset holdings.

2.5.1 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.

In panel A of Figure 4 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 4 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 4 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.

### 2.5.2 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 firm’s 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:

\[
(cr_{i,t} - cr_{i,t-1}) = \alpha + \beta_i (cr_{i,t-1} - \overline{cr}_{i,t-1}) + \epsilon_{i,t}
\]

where \( cr_{i,t} - cr_{i,t-1} \) 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 5 shows the distribution of the \( \beta_i \) coefficients for all firms with at least ten continuous observations in the sample period. The area with the shaded columns represent the proportion of \( \beta_i \) coefficients that are statistically significant at the 5 percent level. The mean coefficient is -0.44 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.

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 instead include a set of annual dummy variables to capture all macroeconomic influences on liquid asset holdings. Using these estimates as the target cash ratio, we reestimate equation (2) for each firm. The mean coefficient for Figure 5 is -0.43 and the median is -0.38 (in comparison to -0.44 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 using a fractional response model. The average marginal effects of inflation are -1.53 and 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:

\[
(cr_{i,t} - cr_{i,t-1}) = \alpha + \beta_1 (cr_{i,t-1} - \overline{cr}_{t-1}) + \beta_2 \Delta \pi_t + \beta_3 (cr_{i,t-1} - \overline{cr}_{t-1})^* \Delta \pi_t + \sum_{n=1}^{I} \phi_n X_{n,i,t} + \epsilon_{i,t} \quad (3)
\]

where the dependent variable 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
Table 10: Cash ratio adjustments and inflation

<table>
<thead>
<tr>
<th></th>
<th>( (c_t - c_{t-1}) )</th>
<th>( \Delta \pi_t )</th>
<th>( (c_{t-1} - c_{t-1}) \Delta \pi_t )</th>
<th>N</th>
<th>adj ( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeated cross-section</td>
<td>-0.211***</td>
<td>-0.188***</td>
<td>-1.161***</td>
<td>106,734</td>
<td>0.122</td>
</tr>
<tr>
<td></td>
<td>-0.004</td>
<td>-0.0187</td>
<td>-0.371</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full sample</td>
<td>-0.208***</td>
<td>-0.186***</td>
<td>-1.091***</td>
<td>106,734</td>
<td>0.125</td>
</tr>
<tr>
<td></td>
<td>-0.003</td>
<td>-0.019</td>
<td>-0.345</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The dependent variable is the change in the cash ratio from time \( t-1 \) to time \( t \). All estimates use Ordinary Least Squares. The first row shows regressions using the repeated cross-section estimates of the target cash ratio. The second row shows regressions using the full sample fractional response estimates of the target cash ratio. All estimates include the full list for firm-specific conditioning variables used in the baseline estimation model. Standard errors are in parenthesis. Stars denote significance at the 1% (***) , 5% (**), and 10% (*) levels.

The results in Table 10 are best understood graphically. Figure 6 shows the predicted change in the cash ratio \( c_t - c_{t-1} \) 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.\(^{13}\)

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.\(^{14}\) The downward slope of the cash ratio changes indicates that as inflation increases liquid asset accumulation decreases.

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 4 and the reduction of inflation in panel D of the same figure.

\(^{13}\)During our sample period, 73 percent of the observations are between -0.1 and 0.1 from their target.

\(^{14}\)The observed changes in inflation during our sample period never exceed 4% or fall below -4%.
3 A dynamic model of liquid asset holding

In this section we develop a dynamic model that provides theoretical underpinnings for our empirical analysis.\textsuperscript{15} Our model also provides insights into how inflation can effect real variables through its affect on liquid asset holdings.

3.1 Model

Our model firm produces goods each period using inputs, $I$, and faces a demand shock, $A$, according to the revenue function

$$ A f(I) = AI^\alpha $$

where $\alpha < 1$ is a measure of the elasticity of demand.\textsuperscript{16}

To provide firms with a motive for holding liquid assets it is assumed that, due to a cash-flow mismatch, they face a cash-in-advance constraint. Firms in our model must have liquidity on hand to pay for their inputs before production commences. A firm’s per period profit maximization problem is given by:

$$ \Pi(C;A) = \max_I \{AI^\alpha - pI\} \tag{4} $$

\textsuperscript{15}Our model can be viewed as representing an extension of Miller and Orr (1966). The main extension in our framework is that we explicitly model the marginal benefit of holding liquid assets by considering how liquid asset holdings effect the production decision of a firm.

\textsuperscript{16}The functional form of revenues, $AI^\alpha$, with $A$ as a demand shock can be derived from the following problem. Let revenue = $pQ$ and demand $Q = (A/p)\epsilon$ with $p$ as the price of inputs and $Q$ as quantity. As a result, revenue = $AQ^{\epsilon-1}$. Assuming a linear production function $Q = I$, revenue can be written as $AI^{\epsilon-1}$. For conciseness, let $\alpha = \frac{\epsilon-1}{\epsilon}$. 

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image.png}
\caption{Percentage point change in cash ratio and inflation.}
\end{figure}

Notes: The predictions are from the estimates of equation (3) presented in Table (10). 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.
subject to the cash-in-advance requirement

\[ C \geq p_I I \]

where \( C \) gives the firm’s liquid asset holdings and the cost of acquiring inputs is \( p_I I \) with \( p_I \) being the fixed unit price of these inputs.

In addition to the profits generated from production, the firm also generates some real interest on its liquid assets. The gross returns on liquid asset holdings are

\[ [1 + (i - \pi)] C \]

where \((i - \pi)\) gives the real returns, and the nominal returns are given by

\[ i = \bar{i} + \zeta \pi \]

with \( \zeta \) representing the elasticity of the nominal returns to inflation. As shown in Section 2.4, liquid asset holdings are imperfectly hedged against inflation with \( 0 < \zeta < 1 \).

Put together, the firm’s period gross revenues are given by

\[ R(C; \pi, A) = \max_I \{ AI^\alpha - p_I I + [1 + (\bar{i} + \zeta \pi) - \pi)] C \} \]  

subject to

\[ C \geq p_I I. \]  

Next, the dynamic problem of the firm choosing a series of optimal liquid asset holdings can be written as

\[ V(C; A, \pi) = \max_C \{ d + \beta \mathbb{E} V(C'; A', \pi') \} \]  

where \( \beta \) is the discount factor and every period the firm must decide how much of its revenue it should allocate to its next period liquid asset holdings, \( C' \), versus dividend payments, \( d \),

\[ d + C' = R(C; \pi, A) - \frac{\psi}{2} \left( \frac{C'}{C} - 1 \right)^2. \]

The quadratic cost term above captures the frictions the firm faces in adjusting its liquid asset holdings. As seen in Section 2.5, a firm’s adjustment to the target cash ratio is gradual. Rigidities such as quadratic adjustment costs allow us to capture this feature in the model.

To close the model, the stochastic process for the demand shock and inflation are given by:

\[ A \sim \mathcal{U}(1 - \bar{A}, 1 + \bar{A}) \]

\[ \pi = (1 - \rho) \bar{\pi} + \rho \pi + \epsilon_\pi \]

where \( \epsilon_\pi \sim \mathcal{N}(0, \sigma^2_\pi) \) and \( \rho, \bar{\pi}, \) and \( \sigma^2_\pi \) represent, respectively, the persistence, mean, and standard
deviation of the AR(1) process for inflation. Note that $\bar{A}$ governs the standard deviation of the demand process.

Finally, since our model does not have an empirical counterpart to the cash ratio, we define the cash ratio in the model as

$$cr = \frac{C}{C + \bar{a}}$$

where $\bar{a} > 0$ gives a measure of non-liquid assets of the firm. In the quantitative analysis, we set $\bar{a}$ to match the mean cash ratio in the data.

### 3.1.1 Model analysis without adjustment costs

To understand the mechanics of our framework, we analyze the model in the absence of adjustment costs ($\psi = 0$), and assume, as shown empirically, that cash holdings are imperfectly hedged against inflation ($\zeta < 1$). In our model, firms benefit from holding liquid assets because it allows them flexibility to adjust the purchases of inputs in response to demand shocks. In particular, if the firm holds a significant amount of liquid assets, then during periods of increased demand it is able to acquire enough inputs to freely meet the demand without facing a binding cash-in-advance constraint. The cost of holding liquid assets, however, is its loss of real value as inflation rises. Consequently, as inflation rises the relative cost of holding these assets rises, which in turn causes the firm to reduce its liquid asset holdings. This provides for the first theoretical proposition:

**Proposition 1** If $\psi = 0$ and $\zeta < 1$, then the optimal level of liquid asset holding, $C$, decreases as inflation, $\pi$, increases.

**Proof** Proof is in Appendix A.

Next, because we explicitly model the benefits of holding liquid assets – by including the relationship between liquid assets and production – we are also able to study how inflation, through its impact on liquid asset holdings, impacts real variables. Our next theoretical proposition formalizes this effect by studying the relationship between inflation and the real variable, average revenue:

**Proposition 2** If $\psi = 0$ and $\zeta < 1$, then as inflation, $\pi$, increases, expected revenue, $E(Af^\alpha)$, decreases.

**Proof** Proof is in Appendix A.

The brief intuition for Proposition 2 is as follows. As inflation increases, the firm’s liquid asset holdings fall. This causes the firm to be more cash constraint, affecting its ability to freely alter production to meet any large increases in consumer demand. Hence, the firm’s average revenue decreases. For the full mathematical intuition, we begin by solving the firm’s period profit maximization problem. For a given level of $\pi$ and $C$, the optimal level of inputs are given by:
\[ I = \begin{cases} \left( \frac{\alpha A}{p_I} \right)^{\frac{1}{\alpha}} \frac{C}{p_I} & A \leq \frac{p_I C^{1-\alpha}}{\alpha} \\ \alpha \left( \frac{A}{p_I} \right)^{\frac{1}{\alpha}} & A \geq \frac{p_I C^{1-\alpha}}{\alpha} \end{cases} \] 

which translates into production levels

\[ AI^\alpha = \begin{cases} \left( \frac{\alpha A}{p_I} \right)^{\frac{1}{\alpha}} \frac{C}{p_I} & A \leq \frac{p_I C^{1-\alpha}}{\alpha} \\ \alpha \left( \frac{A}{p_I} \right)^{\frac{1}{\alpha}} & A \geq \frac{p_I C^{1-\alpha}}{\alpha} \end{cases} \]

Holding the size of the demand shock fixed, equation (12) shows how the level of revenues are a function of liquid asset holdings. The level of liquid assets affect the optimal level of inputs from equation (11), which in turn effects the level of revenues.

Next, Figure 7 illustrates the relationship in equation (12) between revenue, \( AI^\alpha \), and the demand shock \( A \) for two different firms; one firm with low liquid asset balances, \( C = C_L \), and one with high liquid asset holdings, \( C = C_H \). In the figure, \( A_j^* \) for \( j = \{H, L\} \) denote the cutoff demand shock for firms with low and high liquid assets. Firms are constrained in their input use if \( A > A_j^* \) and are unconstrained if \( A < A_j^* \).

Let us compare the two firms. First, the cutoff demand shock level between being constrained and unconstrained in production is increasing with liquid assets (\( A_H^* > A_L^* \)). As firms hold more liquid assets, the probability that a firm would realize a demand shock that would render them constrained in production is reduced. Second, in the regions where both firms are constrained in their input use, \( A > A_j^* \), for an increase in \( A \) the firm with higher levels of liquid assets can increase their revenues more than firms holding fewer of these assets. Having more liquid assets on hand allows these firms to hire more inputs, i.e. \( \frac{\partial A(I_H)^\alpha}{\partial A} > \frac{\partial A(I_L)^\alpha}{\partial A} \). In sum, the figure shows that for all possible demand shocks the revenue of the firm with the higher level of liquid assets is either higher or the same as the firm with low levels of these assets. Therefore, one can conclude that the expected revenue levels are higher for firms with higher liquid asset balances. Taken together with

Figure 7: The relationship between demand shocks and revenue for firms with low and high liquid asset balances

Let us compare the two firms. First, the cutoff demand shock level between being constrained and unconstrained in production is increasing with liquid assets (\( A_H^* > A_L^* \)). As firms hold more liquid assets, the probability that a firm would realize a demand shock that would render them constrained in production is reduced. Second, in the regions where both firms are constrained in their input use, \( A > A_j^* \), for an increase in \( A \) the firm with higher levels of liquid assets can increase their revenues more than firms holding fewer of these assets. Having more liquid assets on hand allows these firms to hire more inputs, i.e. \( \frac{\partial A(I_H)^\alpha}{\partial A} > \frac{\partial A(I_L)^\alpha}{\partial A} \). In sum, the figure shows that for all possible demand shocks the revenue of the firm with the higher level of liquid assets is either higher or the same as the firm with low levels of these assets. Therefore, one can conclude that the expected revenue levels are higher for firms with higher liquid asset balances. Taken together with
Proposition 1, as inflation increases, liquid asset holdings fall, which in turn causes the expected
revenue to fall. Intuitively, in periods of high inflation the chance of firms being constrained in its
input usage increases, which in turn lowers the potential revenues of all firms.

Liquid asset balances also impact the second moment of revenues. Compared to a firm with
low liquid asset holdings, Figure 7 shows that a firm with higher liquid assets has a wider range
of revenue possibilities. The wider range of revenue possibilities results in a higher variance of
revenues for such firms. Intuitively, the variance of revenues is increasing with liquid assets since
having a high level of liquidity allows the firm to fully meet demand at a wider range of demand
shocks. Increases (decreases) in inflation lead to both lower (higher) first and second moment of
real revenues through inflation’s impact on liquid asset holdings.

3.2 Quantitative Results

We next parameterize our model and undertake a quantitative exercise to illustrate the effects
of inflation on both liquid asset holdings and real variables.

3.2.1 Parameterization

Table 11 gives the parameter values for the model. Consistent with the empirical analysis, a
period is one year. Without loss of generality, we normalize the value of $p_I = 1$. We then set the
labor share to $\alpha = 0.75$ to match a marginal cost markup of 33%, and the subjective discount
factor to a standard value of $\beta = 0.96$. Parameters $\bar{i} = 0.021$ and $\zeta = 0.385$ respectively are the
intercept and the coefficient of the responsiveness to inflation reported in Table 4. We estimate the
AR(1) process for inflation using the GDP Deflator series for 1962 to 2013. This estimation gives us
$\rho = 0.886$, $\bar{\pi} = 0.0358$, and $\sigma_\pi = 0.0107$.

We set the standard deviation of the demand process, $\bar{A}$, and the costs associated with adjusting
liquid assets, $\psi$, by simultaneously matching two empirical moments: (1) the standard deviation of
real sales growth in the data, 0.16 and (2), the average persistence of the aggregate cash ratio in the
data, 0.95. This implies $\bar{A} = 0.095$ and $\psi = 0.118$. Finally, $\bar{a} = 1.77$ is set to match the mean cash
ratio in the data of 0.136.

Table 11: Parameter values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.96</td>
<td>Discount factor</td>
<td>$\rho$</td>
<td>0.886</td>
<td>Persistence of inflation</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.75</td>
<td>Measure of markup</td>
<td>$\pi$</td>
<td>0.0358</td>
<td>Mean of inflation</td>
</tr>
<tr>
<td>$p_I$</td>
<td>1.0</td>
<td>Price of inputs</td>
<td>$\sigma_\pi$</td>
<td>0.0107</td>
<td>St.Dev. of inflation</td>
</tr>
<tr>
<td>$\bar{i}$</td>
<td>0.021</td>
<td>Constant interest rate</td>
<td>$\bar{A}$</td>
<td>0.095</td>
<td>Bounds on demand</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>0.385</td>
<td>Elasticity of interest rate to inflation</td>
<td>$\psi$</td>
<td>0.118</td>
<td>Cash adjustment cost</td>
</tr>
</tbody>
</table>
3.3 Simulations

Figure 8 plots the simulated inflation – cash ratio pair. The negative relationship between liquid assets and inflation is consistent with Proposition 1 and the observations in the data. The unconditional correlation between the two series is negative. In the model, inflation erodes the real value of liquid asset balances, inducing the firm to reduce its liquid asset holdings.

Dynamics of liquid asset holdings in response to inflation. The inclusion of frictional adjustment costs to liquid assets allows us to further study the dynamics of these assets. In response to a change in inflation, firms gradually adjust their liquid assets holdings towards the new optimal long-run level. Figure 9 highlights this gradual adjustment process by comparing impulse responses of liquid assets to a 1% increase in inflation for simulations with and without adjustment costs. With the adjustment costs, the response to inflation is dampened. Firms are not able to immediately reach their ‘optimal’ liquid asset balance.

We further explore the adjustment process for firms in the model with adjustment costs. Figure 10 shows the percentage point adjustment to firms’ cash ratios between periods based on how far away their cash ratio is from their target. The target cash ratio, $\bar{\psi}$, is defined as the cash ratio firms would have in the absence of adjustment costs ($\psi = 0$). The distance of a firm from its target at the end of $t - 1$ is calculated as $cr_{t-1} - \bar{\psi}_{t-1}$. Case 1 shows the cash ratio adjustments when inflation is unchanged and remains at $\bar{\pi}$ between periods. This case is comparable to panel B of Figure 4. Segments A and D represents the firms that are at the top deciles below and above their target, respectively, at the end of period $t - 1$. These firms are the farthest away from their target. Segments B and C are the remaining firms below and above their target, respectively, at the end of period $t - 1$. The magnitude of the adjustments for firms farthest away from their target, segments A and D, are the largest. This is consistent with the empirical observations in Section 2.5.2. For
example, firms in segment A adjust their cash ratio by 0.27 percentage points versus 0.09 percentage points for firms in segment B who are also below, but closer to their target.

Case 2 shows the percentage point change in cash ratios when inflation increases from \( \bar{\pi} \) in \( t - 1 \) to \( \bar{\pi} + 1\% \) in period \( t \). When inflation increases, the target cash ratio decreases. This case is comparable to panel C of Figure 4. Compared to case 1, the magnitude of the cash ratio adjustments for firms farthest above their target at the end of period \( t - 1 \), segment D, has nearly doubled. These firms must now aggressively reduce their liquid asset balances to reach their new target. On the other extreme, firms farthest below their target at the end of period \( t - 1 \) still increase their liquid asset holdings. However, the size of the adjustment is now smaller.

In our model, the magnitude of liquid asset adjustments in response to inflation is heterogeneous based on both the direction and magnitude of the firm’s liquid asset holdings from its target. These results are in line with our empirical analysis.

![Figure 9: Responses of liquid asset holdings to a 1% inflation shock](image)

**Figure 9:** Responses of liquid asset holdings to a 1% inflation shock

![Figure 10: Effects of inflation on cash ratio adjustments](image)

**Figure 10:** Effects of inflation on cash ratio adjustments
Real effects. We use our model to study the effects of inflation on real variables. Panels A and B of Figure 11 plot the relationship between liquid asset holdings and both the mean level and the standard deviation of revenue. In Panel A the mean level of revenues are increasing as a function of liquid asset holdings before leveling out at very high levels of liquid assets. As firms accumulate more liquid assets, the probability of them realizing a demand shock that leaves them constrained in their input use decreases. The less constrained the firm is the more likely it is to take advantage of high demand shocks leading to higher mean production and thus revenues. In the extreme, if the firm holds sufficiently high levels of liquid assets, the constraint is never binding and revenues are no longer a function of liquid assets. Thus, revenues level out for very high levels of liquidity.

Panel B plots the standard deviation of revenue for each level of liquid assets. Volatility is increasing with liquid asset holdings. Once again, as firms accumulate more liquid assets, the probability of them realizing a demand shock that leaves them constrained in their input use decreases. Consequently, as a firm’s liquid asset holding increases the firm is able to take advantage of a larger range of demand shocks. This leads to a higher volatility of production and thus revenue. If liquid asset balances are very low, the constraint is always binding regardless of the size of the demand shock. Where the standard deviation of revenue plateaus, liquid asset balances are high enough that the constraint never binds.

The positive relationship between liquid asset holdings and the first two moments of revenue illustrates a unique channel through which inflation can have real effects. As inflation increases, a firm’s liquid asset holdings fall. This constrains the firm’s production causing both the mean and standard deviation of its revenue stream to fall. Panels C and D of Figure 11 plot simulated data showing the negative relationship between inflation and the first two moments of revenue.
The second moment effects of inflation are interesting, because many papers, including this one, find that the second moment of production and the cash ratio are correlated. It is, however, often conjectured that due to a precautionary motive the causality runs from higher variance to higher cash ratios. Our model provides an alternative direction of the causality running from higher cash ratios to higher variance. As the underlying volatility process in our model is constant, our results suggest that firm-level volatility changes may be partially governed by inflation. Furthermore, our observation that low inflation causes the second moment of production to increase also provides a part explanation for rising firm-level sales volatility shown in Comin and Philippon (2006) and Comin and Mulani (2006) and output volatility in Chun et al. (2011).17 Another interesting implication is that the model shows that relaxing the cash-in-advance constraint can lead to higher firm-level volatility. If firms are never constrained in their ability to buy inputs then the pass-through of demand shocks to production is higher.

4 Conclusion

This paper makes two main contributions.

First, to the best of our knowledge, this is the first paper that explicitly shows that inflation is an important determinant of the cash ratio. At the individual firm level a 1 percentage point increase in aggregate inflation results in a statistically significant 0.44 percentage point decrease in a firm’s liquid asset holdings. 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-third of the increase thereafter.

Second, with a combination of empirical and theoretical analysis 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 fall as inflation rises, which in turn induces the firm to reduce their liquid assets holdings. In this way, the paper also formalizes this explanation by constructing a dynamic theoretical model.

One interesting result from our theoretical model is that changes in inflation, through inflation’s impact on liquid asset holdings, can have an effect on a firm’s real production process. Periods of low inflation can lead to both higher average revenues and volatility in firm-level output. Future research could further quantitatively explore the relationship between inflation and moments of production via the liquid asset channel developed in our model.

17Since revenues and sales are isomorphic in our model, our results line up closer to the empirical findings of Comin and Philippon (2006) and Comin and Mulani (2006). They show that firm level sales volatility for publicly traded firms began to increase in the late 1960s. Inflation may just be one of many factors that contribute to rising firm level volatility.
References


A Proofs of propositions

Proposition 1 If $\psi = 0$ and $\zeta < 1$, then the optimal level of liquid asset holdings, $C$, decreases as inflation, $\pi$, increases.

Proof If $\psi = 0$, the firm’s problem simplifies to a static optimal liquid asset holding problem every period that is given by:

$$\max_C \{ \mathbb{E} \Pi(C; A) + (1 - \beta + \bar{\i} + (\zeta - 1) \mathbb{E} \pi) C \}$$

where

$$\mathbb{E} \Pi(C; A) = \mathcal{F}(C)$$

$$= \begin{cases} 
\frac{(1-\alpha)^2}{(2-\alpha)^2} \left( \frac{\alpha}{p^I} \right)^{\frac{\alpha}{1-\alpha}} \left[ \frac{1}{2\bar{A}} \left( (1 + \bar{A})^{\frac{2-\alpha}{1-\alpha}} - (1 - \bar{A})^{\frac{2-\alpha}{1-\alpha}} \right) \right] & \text{if } C \geq \left( \frac{\alpha(1+\bar{A})}{p^I} \right)^{\frac{1}{1-\alpha}} \\
\frac{1}{2\bar{A}} \left( \frac{p^I_{p^I}}{p^I} \right)^{\frac{C^{2-\alpha}}{2-\alpha} - \frac{(1-\alpha)^2}{(2-\alpha)^2} \alpha^{\frac{1-\alpha}{1-\alpha}} p^I_{p^I} \left( 1 - \bar{A} \right)^{\frac{2-\alpha}{1-\alpha}} + \frac{1}{2} C^\alpha p^I_{p^I} (1 + \bar{A})^2 - C(1 + \bar{A}) \right) & \text{if } \left( \frac{\alpha(1-\bar{A})}{p^I} \right)^{\frac{1}{1-\alpha}} \leq C \leq \left( \frac{\alpha(1+\bar{A})}{p^I} \right)^{\frac{1}{1-\alpha}} \\
\left( \frac{C}{p^I} \right)^\alpha - C & \text{if } C \leq \left( \frac{\alpha(1-\bar{A})}{p^I} \right)^{\frac{1}{1-\alpha}} 
\end{cases}$$

with $\mathcal{F} \in \mathcal{C}^0, \mathcal{C}^1$

Consequently, the optimal level of liquid assets are given as the solution to the following first order condition

$$\mathcal{F}'(C) + 1 - \beta = (1 - \zeta) \mathbb{E} \pi$$

To show that liquid asset holdings, $C$, decreases as inflation, $\pi$, increases it suffices to show that $\mathcal{F}(C)$ is concave (i.e. $\mathcal{F}''(C) \leq 0$). If $\zeta < 1$, then as $\mathbb{E} \pi$ increases, for the above equation to hold liquid asset holdings, $C$, must change such that $\mathcal{F}'(C)$ also increases. If $\mathcal{F}(C)$ is concave, then a decrease in liquid asset holdings, $C$, cause $\mathcal{F}'(C)$ to increase.

As a result, to complete our proof we next show that $\mathcal{F}(C)$ is concave.

$$\mathcal{F}''(C) = \begin{cases} 
0 & \text{if } C > \left( \frac{\alpha(1+\bar{A})}{p^I} \right)^{\frac{1}{1-\alpha}} \\
\frac{1}{2\bar{A}} \left[ \frac{(1-\alpha)^2}{2\alpha} C^{-\alpha} - \frac{(1-\alpha)^2}{2p^I_{p^I}} C^{\alpha-2}(1 + \bar{A})^2 \right] & \text{if } C < \left( \frac{\alpha(1+\bar{A})}{p^I} \right)^{\frac{1}{1-\alpha}} \text{ and } C > \left( \frac{\alpha(1-\bar{A})}{p^I} \right)^{\frac{1}{1-\alpha}} \\
-\frac{\alpha(1-\alpha)C^{\alpha-2}}{p^I_{p^I}} & \text{if } C < \left( \frac{\alpha(1-\bar{A})}{p^I} \right)^{\frac{1}{1-\alpha}} 
\end{cases}$$
It can be seen that for $C \geq \left(\frac{a(1+A)}{p_t^f}\right)^{\frac{1}{1-a}}$ and $C \leq \left(\frac{a(1-A)}{p_t^f}\right)^{\frac{1}{1-a}}$ we have $\mathcal{F}''(C) \leq 0$. For $(\frac{a(1-A)}{p_t^f})^{\frac{1}{1-a}} < C < (\frac{a(1+A)}{p_t^f})^{\frac{1}{1-a}}$, we know that

$$C < \left(\frac{a(1+A)}{p_t^f}\right)^{\frac{1}{1-a}} \iff C^{2(1-a)} < \left(\frac{a(1+A)}{p_t^f}\right)^{2}$$

$$\iff \frac{p_t^f}{\alpha^a} < C^{2(\alpha-1)}(1 + \bar{A})^2$$

$$\iff \frac{p_t^f}{\alpha^a} < C^{\alpha-2}(1 + \bar{A})^2$$

$$\iff \frac{1}{2A} \left[\frac{(1-a)p_t^f}{\alpha^a} C^{-a} - \frac{(1-a)p_t^f}{2\alpha^a} C^{\alpha-2}(1 + \bar{A})^2\right] < 0$$

As a result, $\mathcal{F}''(C) \leq 0$ for all three cases and thus $\mathcal{F}(C)$ is a concave function. □

**Proposition 2** If $\psi = 0$ and $\zeta < 1$, then as inflation, $\pi$, increases, expected revenue, $\mathbb{E}(AI^\alpha)$, decreases.

**Proof** From Proposition 1 we know that as inflation, $\pi$, increases liquid asset holding, $C$, decrease. As a result to prove the above proposition we need only show that the $\mathbb{E}(AI^\alpha)$ is increasing in the value of $C$.

Solving for the optimal level of input, $I$, we get

$$AI^\alpha = \begin{cases} A^{\frac{1}{1-a}} \left(\frac{a}{p_t^f}\right)^{\frac{a}{1-a}} & A \leq \frac{p_t^f}{\alpha} \left(\frac{a}{p_t^f}\right)^{\frac{a}{1-a}} \\ A \left(\frac{C}{p_t^f}\right)^{\alpha} & A > \frac{p_t^f}{\alpha} \left(\frac{a}{p_t^f}\right)^{\frac{a}{1-a}} \end{cases}$$

Next,

$$\mathbb{E}[AI^\alpha] = \begin{cases} \frac{1}{2A} \left[\frac{(1-a)p_t^f}{\alpha^a} C^{-a} - \frac{(1-a)^2}{2\alpha^a} p_t^f C^{-a} (1 - \bar{A})^{\frac{2-a}{1-a}}\right] & \text{if } C \geq \left(\frac{a(1+A)}{p_t^f}\right)^{\frac{1}{1-a}} \\ \frac{1}{2A} \left[-\frac{p_t^f}{\alpha^a}(2-a) - \frac{(1-a)\alpha}{2\alpha^a} p_t^f \left(1 - \bar{A}\right)^{\frac{2-a}{1-a}} \right] & \text{if } \left(\frac{a(1+A)}{p_t^f}\right)^{\frac{1}{1-a}} \leq C \leq \left(\frac{a(1-A)}{p_t^f}\right)^{\frac{1}{1-a}} \\ \left(\frac{C}{p_t^f}\right)^{\alpha} & \text{if } C \leq \left(\frac{a(1-A)}{p_t^f}\right)^{\frac{1}{1-a}} \end{cases}$$

It can be seen that for $C \geq \left(\frac{a(1+A)}{p_t^f}\right)^{\frac{1}{1-a}}$ and $C \leq \left(\frac{a(1-A)}{p_t^f}\right)^{\frac{1}{1-a}}$ we have $\frac{\partial \mathbb{E}[AI^\alpha]}{\partial C} \geq 0$. For $(\frac{a(1-A)}{p_t^f})^{\frac{1}{1-a}} < C < (\frac{a(1+A)}{p_t^f})^{\frac{1}{1-a}}$, we have
\[
\frac{\partial \mathbb{E}[AI^\alpha]}{\partial C} = -\frac{p_l^\alpha}{2\alpha} C^{1-\alpha} + \frac{\alpha}{2} C^{\alpha-1} p_l^{-\alpha} (1 + \bar{A})^2
\]

We can show that this partial derivative is positive

\[
C < \left( \frac{\alpha(1+\bar{A})}{p_l^\alpha} \right)^{\frac{1}{1-\alpha}}
\]
\[
\Leftrightarrow \quad C^{2(1-\alpha)} < \left( \frac{\alpha(1+\bar{A})}{p_l^\alpha} \right)^2
\]
\[
\Leftrightarrow \quad \frac{p_l^\alpha}{2\alpha} C^{1-\alpha} < \frac{\alpha}{2} C^{\alpha-1} p_l^{-\alpha} (1 + \bar{A})^2
\]
\[
\Leftrightarrow \quad -\frac{p_l^\alpha}{2\alpha} C^{1-\alpha} + \frac{\alpha}{2} C^{\alpha-1} p_l^{-\alpha} (1 + \bar{A})^2 > 0
\]

As a result, for all possible C we have \( \frac{\partial \mathbb{E}[AI^\alpha]}{\partial C} \geq 0 \). That is, as liquid asset holdings, \( C \), increase the expected value of sales, \( \mathbb{E}[AI^\alpha] \), also increases. ■