Firm Balance Sheet Liquidity, Monetary Policy Shocks, and Investment Dynamics*

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Abstract

I study the role of firms' balance sheet liquidity in the transmission of monetary policy to investment. In response to monetary contractions, U.S. firms with fewer liquid asset holdings reduce investment relatively more. This can be explained by their higher likelihood to issue debt and the implied exposure to borrowing cost fluctuations. I rationalize these results using a heterogeneous firm macroeconomic model with financial constraints, debt issuance costs, and differential returns on cash and borrowing. Compared to a framework which ignores liquidity considerations, monetary transmission to aggregate investment is slightly dampened and depends on liquid asset portfolios beyond net worth.

Keywords: monetary policy, investment, financial frictions, firm heterogeneity

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1 Introduction

It is a commonly held view that the strength of firms' balance sheets is relevant for investment dynamics in the macroeconomy. The overall indebtedness (or, *leverage*) of nonfinancial firms is often considered to be either a source of or a key factor influencing economic fluctuations.[1] However, the conventional macro-finance view regularly abstracts from the notion that firms' decisions to accumulate liquid financial assets (hereafter, *cash* for short) are distinguishable from their management of debt, and lumps them together into a net financial position (or *net worth*) measure.[2] Yet cash is not "negative debt". The distinction between firms' cash holdings and their (negative) borrowing can emerge for a variety of reasons, such as the different liquidity properties of cash and debt arising from potential costs involved in issuing the latter, or because of the return a firm gets on its liquid financial asset holdings being different from the interest it pays for borrowing.[3] Firms' liquid asset holdings can thus be relevant for investment dynamics, in and of themselves.

In this paper, I study the importance of nonfinancial firms' balance sheet liquidity, as measured by assets held in cash, for the transmission of monetary policy to aggregate investment. Based on empirical results which establish that liquidity explains firms' heterogeneous investment behavior in response to identified monetary policy shocks, I develop a macroeconomic firm dynamics model with financial frictions and debt issuance costs which gives rise to an explicit distinction between cash and (negative) debt. The model allows to illustrate and quantify the importance of firms' balance sheet liquidity in monetary transmission. Namely, in comparison to a canonical model specification which ignores firm liquidity management considerations, I show that (i) monetary transmission to aggregate investment is slightly dampened, (ii) that the firms' balance sheet liquidity distribution affects transmission over and above their balance sheet strength (i.e., net worth), and (iii) that transmission depends on the return characteristics of firms' liquid asset portfolios.

In my empirical analysis, I provide evidence on the heterogeneous sensitivity of firms' fixed capital accumulation to monetary policy announcements as predicted by their financial positions. I employ local projections in the spirit of Jordà (2005) and estimate differences in U.S. public firms' investment dynamics in response to monetary policy shocks identified using a high-frequency event-study analysis. I find that after an unexpected policy rate increase, firms with lower liquid asset holdings at the time of the shock exhibit relatively

[1] See, for example, Kiyotaki and Moore (1997), Bernanke et al. (1999), Jermann and Quadrini (2012).

[2] Examples in macro that do distinguish firms' cash from debt are Bacchetta et al. (2019) and Xiao (2022).

[3] Cash and debt also have different hedging properties, and cash management has been shown to have implications for firms' financial policies and investment behavior. For example, see Almeida et al. (2004), Acharya et al. (2007), Acharya et al. (2012), Bolton et al. (2014).

weaker capital accumulation. A 10 percentage point lower ratio of liquid assets to total assets (i.e., *liquidity ratio*) predicts approximately 0.3 pp slower cumulative growth of capital during the two years after a one standard deviation monetary policy contraction (a 25 bp unexpected increase in the federal funds rate). This responsiveness is not explained by other firm characteristics which have received attention in the recent literature on heterogeneous monetary shock effects such as size, leverage, distance to default, age, debt maturity, or sector-specific demand elasticity.[4]

Recent survey evidence corroborates these empirical findings and sheds light on the potential mechanisms involved. Sharpe and Suarez (2021) analyze the responses of Chief Financial Officers to open ended questions on why their company's investment would be insensitive to fluctuations in interest rates. The most cited reason for insensitivity was the firm having ample cash and not using debt as the marginal source of financing. Firms were also more insensitive if they were not planning to borrow to invest in the year ahead. I explore these mechanisms in the data by constructing a simple measure of the likelihood that a firm issues debt in the near future as predicted by current observables, including the liquidity ratio. I find that conditional on this predicted likelihood, the investment response differences between firms with varying liquidity ratios become statistically insignificant. This suggests that the ability of balance sheet liquidity to forecast debt issuance is an important factor in it explaining investment responsiveness to monetary policy.

The empirical evidence suggests that firms' ability to finance investment using liquid funds on hand plays a key role in the transmission of interest rate shocks to investment, and that debt is not necessarily the marginal source of financing at all times. When this is the case, interest rates on corporate debt become irrelevant as an opportunity cost of investment. To introduce these ideas into a macroeconomic framework, explain the empirical findings, and examine their relevance for monetary transmission I develop a New Keynesian general equilibrium model with heterogeneous firms in which such incentives come into play.

I extend a conventional model of firm dynamics and collateral constraints by introducing long-term debt financing subject to issuance costs.[5] Firms invest using internal funds and raising debt.[6] Whenever a firm wishes to issue new debt or repay debt faster than the repayment schedule governs, it must pay a fixed cost.[7] Because the issuance cost renders

[4]These features, respectively, are considered by Gertler and Gilchrist (1994), Anderson and Cesa-Bianchi (2023), Ottonello and Winberry (2020), Cloyne et al. (2023), Jungherr et al. (2022), Durante et al. (2022).

[5]Long-term debt allows to model firms that do not continuously adjust their debt positions, while they have non-zero debt outstanding, permitting the model to match the data on firms' financial positions.

[6]The role of equity financing in monetary transmission is studied, e.g., by Jeenas and Lagos (forthcoming).

[7]The tendency of firms to exhibit considerable inactivity in issuing or repurchasing their own securities is an established feature of empirical firm financing behavior, suggesting the existence of financial adjustment costs with a non-convex component (Leary and Roberts, 2005).

debt essentially illiquid, firms also manage liquidity by saving in cash (held as deposits in a financial intermediary). The presence of a debt issuance cost then creates an endogenous disconnect of firms from current borrowing conditions. The outstanding debt of non-issuers is a sunk decision which requires periodic coupon payments and reduces available cash flows. But the current supply of credit and the returns required by lenders do not directly affect current investment decisions. Only when actively engaging in debt issuance or prepayment does the firm consider corporate debt rates as a relevant opportunity cost.

As a second key feature, the model includes a wedge between the implicit interest rate on firms' borrowing and the return on cash. The presence of such a wedge is important for allowing the model to match the dynamics of relevant interest rates in the aftermath of a monetary policy shock. Namely, in response to an unexpected monetary tightening, the corporate sector's borrowing costs increase relatively more than the returns on their liquid asset holdings. This happens for several reasons in reality. For one, firms do not hold all their liquidity in assets which earn the risk-free (policy) rate.[8] In addition, firms borrow at interest rates greater or equal to the risk-free rate. And it is established empirically that in response to an unexpected monetary tightening, the corporate sector's (long-term) borrowing costs increase relatively more than policy rates due to considerable effects on credit and term premia, even controlling for firms' default risk.[9]

Due to the presence of the debt issuance costs and the debt-cash return wedge, a firm's liquid asset holdings become a good predictor of a lower future likelihood of debt issuance and insensitivity to monetary policy. Since cash pays a lower return than the effective rate on debt, accumulating liquid assets is a costly substitute for future debt issuances in providing liquid resources. Thus, if a firm expects to issue debt in the near future, it is less likely to hold liquid assets. And vice versa, if a firm has accumulated a cash buffer in the past, it has less need for raising debt finance and is thus isolated from fluctuations in borrowing costs generated by monetary policy. In contrast, high *leverage* could indicate firms with little internal wealth and good growth prospects – likely to issue more debt. Or it can indicate a firm having reached a near-optimal scale of operations thanks to past issuances, making new

[8]A notable share of the U.S. corporate sector's liquid asset portfolio is held in assets with (near-)zero nominal returns (e.g., checkable deposits and currency) or with returns insensitive to the policy rate (e.g., time and savings deposits). See Table A.1 in Appendix A.3 for a decomposition of the nonfinancial corporate sector's liquid asset portfolio. Drechsler et al. (2017) provide evidence on the sensitivity of checking, savings, and time deposit rates to the fed funds rate.

[9]E.g., see Gertler and Karadi (2015) on the response of the excess bond premium (EBP) by Gilchrist and Zakrajšek (2012). EBP increases are often interpreted as a reduction in the financial sector's effective risk-bearing capacity and could be introduced with conventional macro-finance models using an extra layer of financial frictions on a representative intermediary, e.g. following Bernanke et al. (1999) or Gertler and Kiyotaki (2011). Anderson and Cesa-Bianchi (2023) study firm-level EBP responses to monetary shocks. The significant effects of monetary shocks on term premia are studied, e.g., by Hanson and Stein (2015).

issuances less likely. As a result, balance sheet liquidity is a better predictor of debt issuance than, for example, leverage. Finally, the model also illustrates that the *balance sheet channel* mechanism (Kiyotaki and Moore, 1997; Bernanke et al., 1999) of monetary transmission, through which fluctuations in asset prices and cash flows caused by monetary shocks affect firms' total financial resources available for investment, is quantitatively stronger whenever a firm adjusts its debt, as compared to when it does not.

I calibrate the model to aggregate and firm-level data, matching the frequency of firms' long-term debt issuances and features of the liquid assets portfolio of U.S. corporations, among other targets, and a variety of untargeted moments on firm dynamics and financing. I then conduct a monetary policy shock experiment repeating the empirical exercise of estimating differences in firms' capital accumulation dynamics conditional on their liquidity ratios. As in the data, firms with low cash holdings reduce their capital stocks by relatively more in response to contractionary shocks. In the conservative baseline quantification which abstracts from credit and term premia, the model can explain close to three quarters of the liquidity-ratio-explained heterogeneity in capital accumulation responses seen in the data.

I then use the calibrated model to study the role of firms' balance sheet liquidity in the transmission of monetary policy to aggregate investment. To do so, I first show how the model implies that the firms' balance sheet liquidity distribution affects monetary transmission over and above their balance sheet strength (i.e., net worth). By altering firms' initial financial positions by providing them a transfer of liquid assets worth 10% of their capital stock, simultaneously increasing debt positions to keep net worth fixed, the effect of monetary shocks on aggregate capital accumulation would be 13% weaker, conditional on given price paths. Firms with more liquid balance sheets are less likely to issue new debt, and are thus shielded from temporary changes in rates on new loans and the stronger balance sheet channel mechanism. An analogous "canonical" model with borrowing constraints which abstracts from features relevant for firms' liquidity management, and does not generate a firms' cash holdings distribution in line with data, cannot provide such implications since a firm's net worth position would be sufficient for characterizing its financial state. Also, transmission to aggregate investment in this alternative is slightly stronger, as fluctuations in borrowing costs are directly transmitted to all borrowers' marginal funding costs and firms against binding financing constraints are exposed to a relatively stronger balance sheet channel.

Finally, my model illustrates that the strength of monetary transmission to aggregate investment depends on the return characteristics of firms' liquid asset portfolios. If the nominal returns on their liquid assets moved one-for-one with the policy rate (e.g., as the returns on short-term Treasuries do), the general equilibrium effects of monetary policy shocks on aggregate capital accumulation would be about 14% stronger compared to an economy where firms' liquidity portfolio returns were unresponsive to the policy rate (e.g., as the returns on non-interest-bearing currency are). As long as a firm holds liquid assets, their return is a relevant opportunity cost for investing in capital. If, all else equal, returns on liquid assets increase, firms switch towards them and out of capital. Such effects are virtually absent in model analogues which abstract from balance sheet liquidity considerations. The model in this paper thus provides a useful framework for studying the monetary policy implications of trends in corporate liquidity management in recent decades, such as the increases in balance sheet liquidity and the move towards holding interest-bearing assets, e.g., studied empirically by Bates et al. (2009) and Azar et al. (2016).

Related Literature. This paper contributes to several strands of the literature. First, there is a growing body of work which studies models of firm heterogeneity, financial frictions, and their relevance in the aggregate economy. Some prominent examples which model frictions in external financing include Gomes (2001), Cooley and Quadrini (2001, 2006), Khan and Thomas (2013), Crouzet (2018), Begenau and Salomao (2018), Bacchetta et al. (2019), and Xiao (2022). I contribute to these studies by introducing an extensive margin decision for debt financing activities which leads to a persistent distinction between cash and debt, and by emphasizing the relevance of liquid asset positions for shock-responsiveness.

Second, most relatedly, there is a literature which uses firm- or industry-level data and studies the heterogeneity in firms' responses to monetary policy shocks to investigate firm financial frictions and monetary transmission. Several earlier papers with an empirical focus, such as Gertler and Gilchrist (1994) or Oliner and Rudebusch (1996), use firm size as a proxy for financing constraints and find that small firms are relatively more responsive to contractionary monetary policy actions.[10] Kashyap et al. (1994) find that firms with low liquid asset holdings contracted their inventories significantly more during a tight monetary policy period.[11] In recent years, and in parallel to this paper, there has been a revival of this literature, with papers estimating whether different firm financials explain their responsiveness to identified monetary policy shocks, and some of them interpreting the results using a structural model. Firm characteristics which have received attention, in addition to size, are leverage and distance to default (Ottonello and Winberry, 2020; Bahaj et al., 2022; Anderson and Cesa-Bianchi, 2023), age (Cloyne et al., 2023), share of floating rate debt (Ippolito et al., 2018; Gürkaynak et al., 2022), or debt maturity (Jungherr et al., 2022). In addition, Greenwald (2019) and Caglio et al. (2022) emphasize how monetary transmission can depend on the type of debt limits and collateral constraints that firms face in practice. In

[10] Crouzet and Mehrotra (2020) scrutinize these findings on size through the lens of financing frictions.

[11] Other examples of this earlier empirical literature include Gaiotti and Generale (2002), Ehrmann and Fratzscher (2004), Peersman and Smets (2005), Bougheas et al. (2006).

reference to this literature, my work contributes by highlighting the importance of balance sheet liquidity in explaining heterogeneous investment responsiveness empirically, over and above any of these features, and in shaping monetary transmission in a general equilibrium heterogeneous firm setting.

Finally, the model of the firm that I employ is inspired by work on firm financing, liquidity, and issuance costs in corporate finance, with examples including Hennessy and Whited (2007), Gamba and Triantis (2008), Riddick and Whited (2009), Bazdresch (2013), Nikolov and Whited (2014), Eisfeldt and Muir (2016), Bolton et al. (2014), and Nikolov et al. (2019). My work builds on this literature by using a model of the firm to study the importance of balance sheet liquidity in monetary policy transmission to aggregate investment, thus also providing a bridge between the literatures on macroeconomic dynamics and structural corporate finance studies on liquidity.[12]

Layout. The rest of the paper is organized as follows. Section 2 describes the data, empirical specifications, and the estimation results for capital accumulation responses to identified monetary policy shocks. Section 3 presents the structural model and its calibration. Section 4 discusses firm behavior in the model's steady state and conducts a monetary shock experiment to shed light on the empirics of Section 2. Section 5 uses the model to study the role of firms' balance sheet liquidity in monetary policy transmission. Section 6 concludes.

2 Empirics on Response Heterogeneity to Monetary Policy

2.1 Data

Monetary Policy Shocks. I identify shocks to monetary policy following the literature which employs high-frequency movements in federal funds futures prices around Federal Open Market Committee (FOMC) press releases to make inference about the unexpected components of monetary policy announcements.[13] To construct the benchmark measure of a monetary policy shock $\nu_{\tilde{t}_k}$ at the exact time of the announcement $\tilde{t}_k$, I use the 3-month ahead raw federal funds future price changes within a 30-minute window around the FOMC announcement, as constructed by Jarocinski and Karadi (2020). To go from the high-frequency measures $\nu_{\tilde{t}_k}$ to quarterly ones (ε_t^m), I aggregate the $\nu_{\tilde{t}_k}$ by simple summation within any quarter t.[14]

[12] In related work, Gao et al. (2021) analyze the effects of interest rate changes over longer horizons on corporate money demand. Ebsim et al. (2023) study the relevance of indebtedness vs. liquidity for firm performance in large crises such as the Global Financial Crisis and the Covid-19 pandemic.

[13] Prominent examples of such event study based approaches to monetary policy are Cook and Hahn (1989), Kuttner (2001), Cochrane and Piazzesi (2002), Bernanke and Kuttner (2005), Gürkaynak et al. (2005).

[14] It is well established that such shock measures naturally lead to persistent increases in monthly or quarterly fed funds rate series, e.g., see Ramey (2016). To verify robustness to concerns about $\nu_{\tilde{t}_k}$ potentially

To be precise, ε_t^m should be thought of as imperfect measures of quarterly structural monetary policy shocks ε_t^f understood as primitive, unanticipated innovations independent of other structural shocks. As ε_t^f is unobservable, one can follow Stock and Watson (2018), and instead use ε_t^m as instruments for changes in policy rates in analogous instrumental variables regressions. However, since this amounts to instrumenting one endogenous regressor with one (strong) instrument, doing so leads to very similar results (up to a scalar multiple) as simply introducing ε_t^m as a direct measure of monetary policy shocks in ordinary least squares regressions. In line with most of the literature, I present the main empirical results based on such OLS regressions with ε_t^m. And I illustrate their close similarity to the IV specification when comparing the empirics to the model in Section 4.2.2.

Firm-Level Data. I draw the firm-level dataset from the quarterly Compustat universe of publicly listed U.S. incorporated firms. The central measure of firm i's capital accumulation is the book value of its tangible capital stock $k_{i,t}$, in place at the end of quarter t, constructed using a perpetual inventory method (see Appendix A.1). I study the responsiveness of firms' capital *stocks*, rather than investment rates because micro-level investment is lumpy and erratic (Doms and Dunne, 1998), making it potentially difficult to precisely detect systematic responses in investment rates in the cross-section, especially over longer horizons.

The main explanatory variable I consider in explaining firms' responsiveness to monetary shocks are the holdings of liquid assets. More specifically, I use the ratio of the Compustat variable *Cash and Short-Term Investments* to *Total Assets*, or *liquidity ratio* for short. This definition of *cash* directly follows the view taken in corporate finance that firms can manage their liquidity and financial savings using various marketable securities that potentially pay nonzero returns (Opler et al., 1999). The estimated local projections also include a variety of other firm-level observables as controls. As the measure of a firm's *leverage* I employ its total debt divided by its total assets, both measured at book values. I measure firms' *size* as total book assets, and I construct a proxy for firms' *age* as time since incorporation based on the Worldscope database, following Cloyne et al. (2023). I discuss further details on the sample selection and the construction of other variables used in Appendix A.1.

I focus the main analysis on firm-quarter observations between 1990Q1–2007Q4. The series for ε_t^m begins in January 1990, due to availability of the tick-by-tick data for fed funds futures. To exclude the exceptional conditions during the onset of the Great Recession and the federal funds rate hitting the zero lower bound leading to little variation in the implied ε_t^m series, I stop the sample before 2008 and focus on an unbroken spell of conventional monetary

capturing the revelation of the FOMC's private information, Section 2.4 discusses the main results holding also under monetary shock identification following Jarocinski and Karadi (2020) or Romer and Romer (2004).

policy operations.[15] Since the regression specifications include firm-level fixed effects, I only include data from firms which are observed for at least 40 quarters during 1990Q1–2007Q4. The resulting underlying unbalanced panel contains 227,787 firm-quarter observations.

Table 1 presents summary statistics of some key variables in this panel. As the sample only contains public firms, the average size is large, about \$1,550 million (in 2009 dollars). The right-skewed size distribution of firms motivates the usage of log assets as the relevant measure of size in regressions and in computing correlations. The mean liquidity ratio is approximately 14% and the mean leverage ratio approximately 24%. Both exhibit considerable variation in the cross-section, with standard deviations of 18.5% and 24.3%, respectively.[16]

Table 1: Summary statistics for Compustat sample

	Mean	Median	St. dev	Obs	cor(·, Liq)	cor(·, log(Size))
Liquidity	0.143	0.060	0.185	225,480	–	-0.255
Leverage	0.240	0.201	0.243	225,480	-0.414	0.133
Size	1549.28	146.01	6414.21	227,787	-0.102	–
$\Delta_3 \log(\text{Sales})$	0.072	0.060	0.346	208,903	0.044	0.028
$\Delta \log(k)$	0.013	0.000	0.089	219,761	0.049	0.049

Notes: Size measured as total book assets in millions of 2009 dollars; leverage as total debt to assets; liquidity as cash and short-term investments to assets ratio. $\Delta_3 \log(\text{Sales})$ is the year-on-year real sales growth and $\Delta \log(k)$ the quarterly growth in the capital stock, both in log points. All statistics computed as across-time medians of corresponding statistics in quarterly cross-sections. Leverage and liquidity trimmed at 99%, growth rates at 0.5% and 99.5% cutoffs.

Based on cross-sectional correlations, firms with higher liquidity ratios have lower leverage. Larger firms tend to have both slightly higher leverage and lower liquidity ratios. One must be careful in interpreting the liquid asset holdings as an effective measure of liquidity *per se*. Firms with high holdings of liquid assets might choose to hold them as a precautionary measure due to a lack of access to other sources of liquidity, such as trade credit or credit lines. To alleviate these concerns, in robustness tests I also consider controlling for firm size and other firm characteristics in Table 1 interacted with monetary shocks when estimating the between-firm heterogeneity in shock-responsiveness explained by liquidity ratios.[17]

[15]The main results are robust to including the Great Recession and the ZLB period (see Section 2.4).

[16]Table 1 presents statistics for the *whole* firms' cross-section, within quarter. As the regressions in Section 2.2 include time-industry fixed effects, the relevant variation for the regressions is *within* industry-time, across firms. When comparing the data to the model's firm distribution in Section 3, I consider moments within time-industry cells.

[17]The calibrated structural model of Section 3 matches the negative correlation between size and liquidity ratios as an untargeted moment, arising from the precautionary savings motives of smaller firms induced by higher expected growth opportunities thanks to a mean-reverting firm-specific productivity process.

2.2 Panel Local Projection Specifications

The goal of my analysis is to estimate how firms' capital stocks $k_{i,t+h}$, at horizon $h \geq 0$, behave in response to a monetary policy shock at time t conditional on firm i's financial position just before the shock. I do so by estimating panel regressions in the spirit of Jordà (2005) local projections, regressing the cumulative difference $\Delta_h \log(k_{i,t+h}) \equiv \log(k_{i,t+h}) - \log(k_{i,t-1})$ on interaction terms of firms' financial indicators at the end of $t-1$ and the monetary policy shock at t, alongside a set of controls. The focus is on studying the relevance of the liquidity ratio (denoted $\ell_{i,t-1}$) in characterizing firms' responses, both unconditionally and conditional on other firm characteristics that have received attention in the literature. I start with a baseline panel regression specification:

$$\Delta_h \log(k_{i,t+h}) = f_{i,h} + d_{n,h,t+h} + \Theta_h' W_{i,t-1} - \gamma_h \ell_{i,t-1}\varepsilon_t^m - \Omega_h' \ell_{i,t-1} Y_{t-1} + u_{i,h,t+h} \tag{1}$$

$h = 0, 1, \ldots, H$ denotes the horizon at which the relative effect is being estimated. $f_{i,h}$ denotes firm i's fixed effect in its cumulative $h+1$-quarter capital growth. $d_{n,h,t+h}$ is shorthand for industry-time dummies at the SIC 3-digit level for $h+1$-quarter growth measured in period $t+h$. $W_{i,t-1}$ is a vector of lagged firm-level controls and Y_{t-1} is a vector of aggregate controls. ε_t^m is the measure of the quarterly monetary policy shock as constructed in Section 2.1. Θ_h, Ω_h and γ_h are regression coefficients and $u_{i,h,t+h}$ is an error term.

In the baseline case, $W_{i,t-1}$ consists of the firm's liquidity ratio, log size, leverage, and yearly sales growth – all measured at the end of quarter $t-1$ to ensure exogeneity with respect to the shock ε_t^m. The extra controls in addition to $\ell_{i,t-1}$ serve to improve precision in predicting $\Delta_h \log(k_{i,t+h})$. The vector Y_{t-1} contains real GDP growth and the level of the federal funds rate in quarter $t-1$. Including the interaction of $\ell_{i,t-1}$ and the aggregates in Y_{t-1} serves to control for differences in sensitivities to the business cycle and to prior monetary policy actions, both exogenous and endogenous.[18] Since the main goal is to evaluate differences among firms' responses to monetary shocks conditional on liquidity ratios, including a detailed industry-time dummy to control for aggregate fluctuations allows for a flexible way to do so. This precludes including a measure of the shock ε_t^m itself and evaluating the "level" responses of $k_{i,t}$. I address this and provide the corresponding estimates in Appendix A.2.7.

For interpretability in percentages, prior to estimation I multiply the $\Delta_h \log(k_{i,t+h})$ by 100. I also rescale the shock measures' series ε_t^m by its standard deviation of approximately 9.66 basis points over the longer sample period of 1990Q1–2016Q4.[19] A positive ε_t^m stands

[18] In principle, since ε_t^m is a proxy for a structural shock, it is exogenous to Y_{t-1} in the population. Yet in finite samples, sampling variation may lead to correlations between the two which one should control for, to be conservative. Dropping Y_{t-1} from (1) strengthens the main results (see Section 2.4).

[19] An unexpected 1 bp high-frequency change in the futures' rates is usually accompanied by a larger

for a fed funds rate increase. The coefficient of interest in (1) is γ_h, measuring the relevance of balance sheet liquidity in predicting heterogeneity in firms' responsiveness at horizon h. Note that to interpret the coefficient estimates γ_h as "exposure measures" to a contractionary monetary shock, I include the *negative* of the liquidity ratio $\ell_{i,t-1}$ in (1). Thus, negative estimates of γ_h will imply that firms with lower liquidity ratio prior to a contractionary shock experience relatively weaker capital growth over horizon h after it, and conversely, relatively stronger capital growth after expansionary shocks. I drop extreme observations of firm-level variables to control for outliers (see Appendix A.1.1) and I consider standard errors clustered two-way at the industry-time and firm levels.

Finally, to show that the findings on liquidity ratios explaining investment response heterogeneity are not driven by other firm-level covariates, I extend specification (1) to:

$$\begin{aligned}\Delta_h \log(k_{i,t+h}) =& f_{i,h} + d_{n,h,t+h} + \Theta_h' W_{i,t-1} - \gamma_h \ell_{i,t-1}\varepsilon_t^m - \Omega_h' \ell_{i,t-1} Y_{t-1} \\ &+ Z_{i,t-1}' \left(\psi_h \varepsilon_t^m + \Phi_h Y_{t-1}\right) + u_{i,h,t+h} \end{aligned} \tag{2}$$

Here, $W_{i,t-1}$ includes the same firm-level controls as in (1), plus any additional covariates included in $Z_{i,t-1}$. I discuss the exact variables in $Z_{i,t-1}$ below, depending on the respective specifications. ψ_h and Φ_h are collections of regression coefficients.

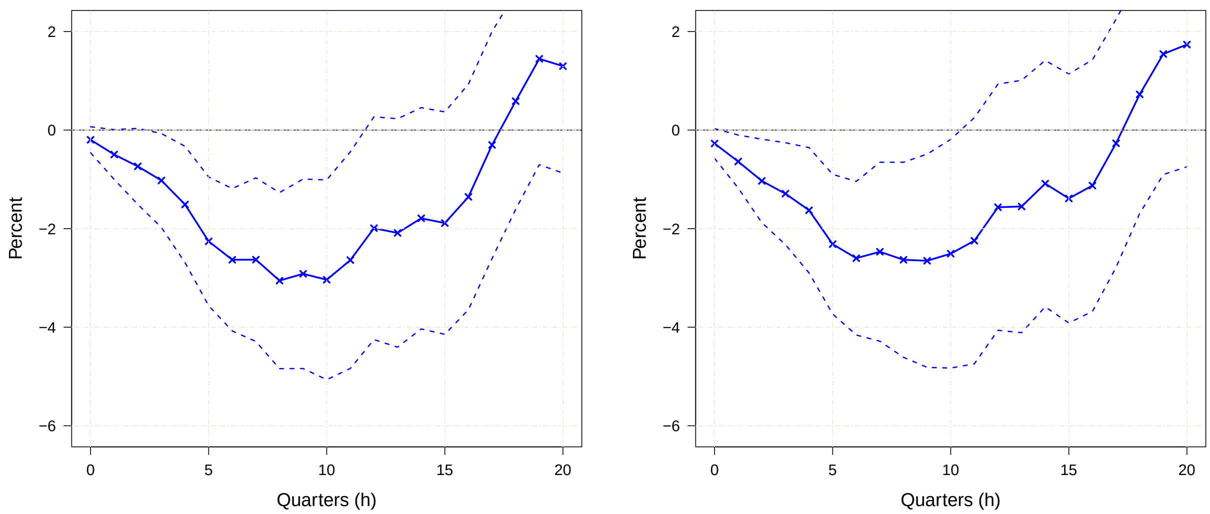
2.3 Panel Regression Estimates

Figure 1 presents the main results of the empirical analysis. Panel 1a plots the point estimates for γ_h, alongside 95% confidence intervals from the estimation of baseline specification (1). The negative estimates imply that firms with lower liquid asset holdings at the time of a contractionary monetary shock reduce their capital stock relative to others thereafter. The differences based on the point estimates become negative at shock impact, significant at the 90% level one quarter after, and more clearly statistically significant three quarters after.

The differences in fixed capital accumulation take some time to build up, in line with the response of aggregate economic activity as estimated, for example, by Gertler and Karadi (2015). The largest differences approximately two years after the shock imply that a 10 pp lower liquidity ratio predicts about 0.3 pp lower cumulative capital growth after a 1 sd mone-

than 1 bp change in the quarterly federal funds rate series due to the discrete way of how the FOMC sets the federal funds rate target. More specifically, the 1 sd shock in federal funds futures rates corresponds to a roughly 25 bp quarterly change in the annualized federal funds rate. This is exactly the conclusion one arrives at from conducting an instrumental variables estimation, using ε_t^m as a source of exogenous variation for quarterly fed funds rate changes. As seen in Section 4.2.2 the effects of a 1 sd shock in ε_t^m are virtually indistinguishable from that of an exogenous 25 bp change in the fed funds rate. These magnitudes also coincide with the proxy-SVAR estimates by Gertler and Karadi (2015) on the effect of a 1 sd identified monetary on the one-year government bond rate.

tary policy shock. Thereafter the differences slowly dissipate. While the implied magnitudes in capital growth heterogeneity are considerable, the calibrated structural model of Section 3 is able to explain them (see Section 4.2.2). Moreover, as shown in Appendix A.2.7, the response heterogeneity explained by firms' liquidity ratios is substantial in comparison to the "level" effects of monetary shocks on Compustat firms' *aggregate* capital accumulation, which at the two year horizon decreases by about 0.34%.



(a) No covariate cross-terms, spec (1)　　(b) With covariate cross-terms, spec (2)

Figure 1: Heterogeneity in responses of capital accumulation conditional on liquidity ratio
Notes: Point estimates and 95% confidence intervals for γ_h from estimating specifications (1) and (2). Covariates included in $Z_{i,t-1}$ in (2) for panel (b) are log size, distance to default, share of short-term debt, and yearly sales growth. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

Panel 1b presents the estimates for γ_h from the extended specification (2), controlling for firm-level covariates other than the liquidity ratio, that have received attention in the literature as explaining heterogeneity in firms' investment responses to monetary policy shocks. More specifically, $Z_{i,t-1}$ interacts the monetary shock with firm size (Gertler and Gilchrist, 1994), distance to default[20] (Ottonello and Winberry, 2020), and share of short-term debt (Jungherr et al., 2022). In addition to these controls, $Z_{i,t-1}$ includes the firm's yearly sales growth to control for the possiblity that firms which have recently grown relatively fast could exhibit differential investment responsiveness for reasons other than their financial condition.

The estimates in Panel 1b show that the main finding of firms with lower liquidity ratios

[20]The distance to default measure, developed by Merton (1974), has become a widely used empirical indicator of default risk for nonfinancial corporations, estimated based on values of firms' equity and liabilities. I follow Gilchrist and Zakrajšek (2012) in constructing the measure, as detailed in Appendix A.1.

exhibiting lower capital growth after contractionary monetary shocks is not explained by the covariates included in $Z_{i,t-1}$. The point estimates of γ_h are slightly smaller compared to Panel 1a, but there are no notable changes in the explanatory power of liquid assets. In regards to the model of Section 3 and existing general equilibrium models of firm financial frictions in the literature, e.g. Khan and Thomas (2013) or Ottonello and Winberry (2020), I separately discuss the power of liquidity ratios in explaining investment responsiveness conditional on firms' indebtedness, i.e. leverage, in Appendix A.2.1. The main message still stands: low liquidity predicts significantly more negative responsiveness even controlling for firms' leverage or net leverage positions.[21] The results thus point towards balance sheet liquidity being an important predictor of firms' investment responsiveness to monetary shocks beyond the covariates or channels pointed out by the remaining literature.

2.4 Robustness of Panel Local Projection Estimates

The main takeaway from the empirical analysis, that a low liquidity ratio predicts considerably weaker capital growth in the years following a contractionary monetary shock, is robust to an array of variations in the empirical approach.

First, specification (1) imposes linearity in the marginal effect of liquidity ratios on explaining firms' responsiveness, with $\frac{\partial^2 \Delta_h \log(k_{i,t+h})}{\partial \varepsilon_t^m \partial \ell_{i,t-1}}$ assumed to be constant. Appendix A.2.1 provides estimates from a less parametric specification, equation (A.1), which relaxes this assumption by grouping firms based on their positions in the cross-sectional liquidity ratio distribution at any given point in time. The estimates in Panel A.1b confirm that the response heterogeneity is indeed monotonic and close to linear. The grouping of firms into bins also alleviates concerns that the baseline results on the explanatory power of liquidity ratios might be affected by the considerable upward trend in firm balance sheet liquidity seen over the sample period (Bates et al., 2009), because the grouping is immune to joint shifts in the population's liquidity ratios and purely relies on the *ordering* of firms in the cross-section.

Figure A.3 in Appendix A.2.2 presents the results from estimating specifications (1) and (2) while not controlling for the heterogeneous cyclicality of high- versus low-liquidity firms. Figure A.4 in Appendix A.2.3 depicts the estimates extending the sample to 1990Q1–2016Q4, past the Great Recession and into the zero lower bound period. In both cases the main results stand, and strengthen to some extent. Figure A.5 in Appendix A.2.4 repeats the estimation of (1) and (2) by instead interacting the within-firm mean of liquidity ratios $(\ell_{i,t-1} - \mathbb{E}_i[\ell_{i,t}])$ with the identified monetary shocks, following Ottonello and Winberry (2020). The baseline

[21]In Appendix A.2.1, I also discuss the responsiveness estimates for leverage. While on their own, both higher leverage and net leverage predict relatively weaker capital growth after contractionary monetary policy shocks, this explanatory power virtually disappears when controlling for the liquidity ratio.

point estimates for response heterogeneity predicted by liquidity ratios from Figure 1 remain largely unchanged, with a slight widening of the confidence bands.

To verify that the estimated responses are not explained by the revelation of the FOMC's private information on the economic outlook instead of news purely about monetary policy (Nakamura and Steinsson, 2018), Figure A.6 in Appendix A.2.5 shows that the estimates for specification (1) are largely unchanged when using monetary shock series as identified by the 'poor man's sign restrictions' by Jarocinski and Karadi (2020) and the Romer and Romer (2004) approach combining Fed Greenbook forecasts with narrative methods.

Appendix A.2.6 shows that the main results are robust to controlling for firm age. It also shows that the response heterogeneity predicted by liquidity ratios is larger among younger firms, in line with the idea that financial considerations and frictions are more relevant for their performance.[22] Appendix A.2.7 estimates the "level" responses of firms' capital stocks to monetary policy shocks by excluding industry-time fixed effects from the estimation.

2.5 Inspecting the Mechanism

The cross-sectional variation in firms' liquidity positions employed in the above analysis is an endogenous outcome of firms' past decisions and realized shocks. Although the heterogeneous investment responsiveness is not explained by a variety of other firm-level observables, without instrumented exogenous variation in liquidity ratios one cannot conclusively claim that a firm's low liquidity ratio is *causing* its investment to respond more negatively to monetary contractions. Similarly, identifying the exact mechanisms behind the results without a structural model is a difficult task. I now discuss one potentially important channel.

As a first piece of motivating evidence, Sharpe and Suarez (2021) use a survey of Chief Financial Officers to study the sensitivity of firms' investment plans to interest rate changes. They find that most firms' investment tends to be rather insensitive to changes in borrowing costs. When prompted in an open-ended question for why this was the case, the most commonly cited answer was in the spirit of the firms having ample cash reserves or cash flow, and that debt was not a marginal source of finance (either stating they would not use debt financing, or they had already *locked in* financing).[23] Among other factors predicting reported borrowing cost sensitivity, one of the most influential was whether the firm had

[22] Further analysis in Jeenas (2019), applying an analogous empirical approach as this paper, shows that low liquidity ratios predict more negative responsiveness of capital accumulation also when controlling for Standard & Poor's Long-Term Issue credit ratings and for whether firms have paid dividends at any given point in the preceding year, or when considering a balanced panel of firms between 1990Q1–2007Q4.

[23] Among those insensitive to borrowing rate increases, 49% cited ample cash reserves or cash flows as a reason, and 32% did for decreases. To contrast, only 1% and 4%, respectively, stated a high level of debt or a weak balance sheet as the reason. 2% among both groups cited lack of access to credit.

plans to borrow to finance investment in the year ahead.[24]

The survey evidence suggests that firms not expecting to borrow were less prone to consider the borrowing interest rate as a relevant opportunity cost for their investment and they exhibit inactivity in responding to marginal changes in borrowing costs. Such inactivity would, for example, arise if there were non-convex adjustment (or, transaction) costs, even small ones, in issuing or repurchasing debt. Evidence for the presence of fixed cost components in adjusting financial positions has been well-documented in corporate finance research, based on the observed infrequent rebalancing of firms' capital structures (Leary and Roberts, 2005), the explicit lumpiness in debt issuance behavior, exceeding lumpiness in investment (Bazdresch, 2013), or the considerable economies of scale in explicitly observed commercial banks' underwriting spreads of debt issues (Kim et al., 2008).[25]

In the following, I provide suggestive evidence for the relatively stronger performance of high-liquidity firms' investment after monetary contractions being explained by their lower likelihood of raising new debt, and thus implicitly being less exposed to the resulting increases in the cost of borrowing. To do so, I construct a simple proxy for the likelihood of a firm engaging in debt issuance in the aftermath of a monetary shock, as measured by observable firm characteristics (including the liquidity ratio) prior to the shock. If its individual circumstances, such as a low liquidity buffer make a firm likely to issue debt in a given quarter t, then a monetary contraction at t or earlier increases its marginal cost of borrowing, influencing its investment and borrowing compared to the no-shock counterfactual.

I construct the proxy by estimating a linear forecasting equation for the likelihood that a firm issues debt in a year from now, conditional on its currently observable characteristics:[26]

$$D_{i,t+4} = d_{n,t+4} + \Theta' X_{i,t} + u_{i,t+4} \tag{3}$$

$D_{i,t+4}$ is a binary indicator variable for whether firm i issued (long-term) debt in quarter $t{+}4$.[27] $X_{i,t}$ contains firm characteristics which include all the variables in $W_{i,t}$ from estimating (1). In addition, as other variables that could statistically predict future debt issuances, $X_{i,t}$ includes the firm's Tobin's q, its log capital stock, its lagged yearly capital stock growth, the lagged indicator for debt issuance in $t-1$, and dummy variables indicating the firm's fiscal quarter to capture any seasonality in the fiscal year. Since the prior local projection

[24] Firms with no plans to borrow were 29 pp less likely to plan investment cuts if borrowing rates increased.

[25] I further discuss the nature and evidence on non-convex debt adjustment costs in Appendix B.1.

[26] I consider the year-ahead issuance activity to allow for the full effects of a potential monetary shock in $t+1$ on borrowing costs and the environment to take effect.

[27] I measure the extensive margin of firms' debt issuance activity based on the Compustat variable *Long-Term Debt – Issuance*, and register an event of issuance whenever gross quarterly issuances are above 1% of the previous quarter's total assets. See Appendix A.1.2 for a discussion on these measurement choices.

analysis employs within industry-time variation, I also include industry-time dummies at the SIC 3-digit level and allow these to forecast the firms' likelihood of debt issuance.

Table 2 presents some of the Θ coefficient estimates in (3) and shows that firms with higher leverage, lower liquidity ratios, and higher recent sales growth are more likely to issue debt in one year. Higher Tobin's q predicts a very slightly lower likelihood of issuance and firm size is not predictive, conditional on the controls. Notably, among these characteristics, the liquidity ratio is the strongest predictor of future debt issuances in that a one standard deviation increase in the liquidity ratio (Table 1) predicts an approximately 5.6 pp drop in the likelihood of issuing debt, followed by leverage predicting a 4.6 pp rise correspondingly.

Table 2: Debt issuance regression estimates

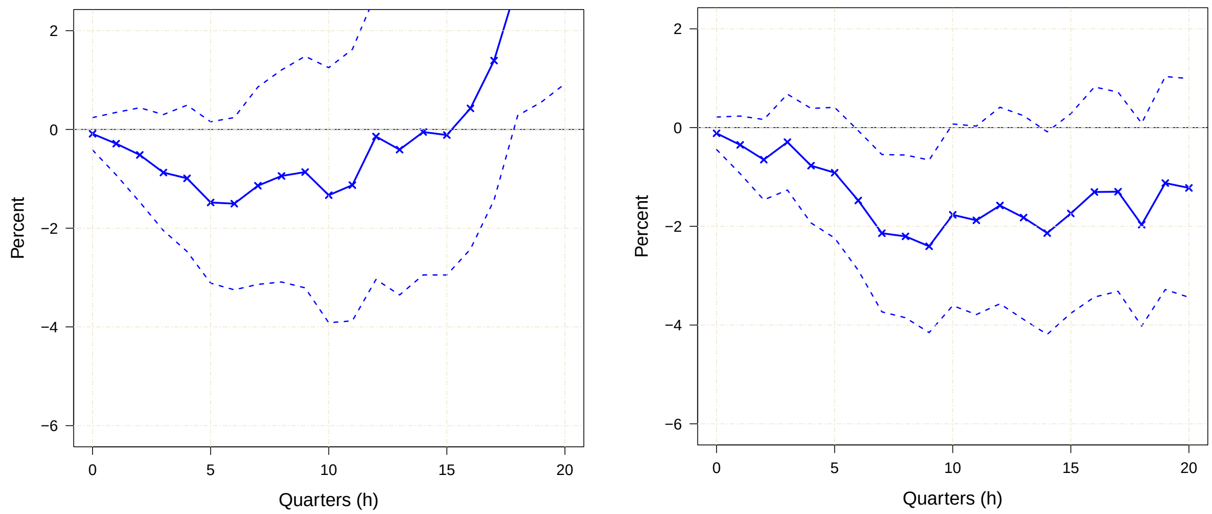
	Tobin's q	Leverage	Liquidity	Δ_3 log(Sales)	log(Size)
Dep. var.: $D_{i,t+4}$	-0.003	0.189	-0.303	0.033	0.004
	(0.001)	(0.011)	(0.013)	(0.004)	(0.003)
Observations: 147,676, R^2: 0.262, Adj. R^2: 0.173					

Notes: Estimates and standard errors (in parentheses) for selected coefficients in (3). Standard errors clustered two-way at firm and SIC 3-digit industry-time levels.

I use the implied fitted values $\hat{D}^4_{i,t-1} \equiv \hat{D}_{i,t-1+4}$ from (3) as a proxy for future debt issuance probabilities, as of quarter $t-1$, and include them as a covariate predicting firms' responsiveness to monetary shocks, $Z_{i,t-1}$, alongside $\ell_{i,t-1}$ in specification (2). The resulting local projection estimates are shown in Figure 2. The estimates in Panel 2a indicate that once one controls for the one year ahead debt issuance probability $\hat{D}^4_{i,t-1}$ (in which the liquidity ratio itself plays a considerable role), a low liquidity ratio no longer predicts statistically significantly weaker capital accumulation after contractionary monetary shocks. At the same time, a higher debt issuance probability does predict significantly weaker capital growth over the two year horizon, as seen in Panel 2b.[28] Although based on this analysis one cannot conclusively establish that the predictive power of liquidity ratios on investment responsiveness works *through* the channel of predicting debt issuance, the results do suggest that the ability of low balance sheet liquidity to forecast debt issuance can considerably affect its power in explaining heterogeneous investment responses to monetary policy shocks.

Based on this empirical evidence, a framework which aims to explain the (heterogeneous) transmission of monetary policy to investment based on balance sheet liquidity considerations should include the following ideas often not present in conventional macro-finance models.

[28] Appendix A.2.8 provides further suggestive evidence for the channel, showing that after a monetary contraction, firms with a higher debt issuance probability $\hat{D}^4_{i,t-1}$ also experience a relatively stronger increase of the average interest rates they pay on their debt, and a more negative response in their borrowing.



(a) Liquidity ratio ($\ell_{i,t-1}$) (b) Debt issuance probability ($\hat{D}^4_{i,t-1}$)

Figure 2: Heterogeneity in responses of capital accumulation conditional on liquidity ratio and debt issuance probability

Notes: Point estimates and 95% confidence intervals from estimating specification (2). The covariates collection $Z_{i,t-1}$ consists of only $\hat{D}^4_{i,t-1}$, as predicted from estimating (3). Panel (a): Estimates of γ_h on monetary shock and $\ell_{i,t-1}$ cross-term. Panel (b): Estimates of ψ_h on monetary shock and $\hat{D}^4_{i,t-1}$ cross-term. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

First, the marginal source of financing matters and it might not always be external funds but rather internal cash buffers and flows. Second, the timing of debt issuances matters and has direct consequences for firms' interest-sensitivity since the opportunity cost of investing at a given time is not necessarily the rate on corporate borrowing. Finally, this implies that accounting for fluctuations in the relevant interest rates, such as corporate borrowing rates vs. returns on internal savings, is not inconsequential. In the following, I study a model that introduces these insights into a macroeconomic framework.

3 Model

In this section I construct a heterogeneous firm model which allows to explain the empirics in Section 2 and study the role of balance sheet liquidity in monetary transmission. It builds on a conventional New Keynesian structure with nominally rigid prices of a final good. I consider stationary equilibria and perfect foresight transition paths in response to unexpected aggregate shocks, so aggregate uncertainty is not explicitly included in the notation below.[29]

[29] *Stationary* equilibrium, or the *steady state* refers to all aggregates, including the firm distribution, being constant, while agents face idiosyncratic risk. Time-subscripts denote variation in prices, aggregates and

3.1 Environment

Time is discrete and infinite. There is a final good that is used for consumption and as input in producing new capital goods. The key agents in the economy are heterogeneous firms producing wholesale goods, while facing financial and capital adjustment frictions.[30] There is also a representative household, a financial intermediary, a capital goods producer, and a government. To model price setting outside the firms facing financial frictions, the economy also includes a representative final good producer and a unit mass of monopolistically competitive intermediate retail goods producers, following Bernanke et al. (1999). Wages and the prices of wholesale goods are flexible. In its essence, the model employs the underlying structure used by Khan and Thomas (2013), introducing nominal rigidities, long-term debt subject to issuance costs, and a working capital constraint. I present the model in real terms, with the final good as numeraire and being explicit about movements in nominal variables over and above real fluctuations whenever relevant. I provide a deeper discussion of key modeling assumptions, such as the fixed debt adjustment costs, working capital constraints, or different interest rates on borrowing and cash, and their implications in Appendix B.1.

3.1.1 Firms, Production, and Financial Frictions

In every period, a unit mass of incumbent firms produces a homogeneous wholesale good using labor n and predetermined capital k operating a production function $y = z^{1-\nu}k^{\alpha}n^{\nu}$, with $\alpha + \nu < 1$. Labor is flexible and hired in a perfectly competitive labor market for real wage w_t. z is a firm's idiosyncratic total factor productivity and follows a Markov chain $z \in \mathbf{Z} \equiv \{z_1, \ldots, z_{N_z}\}$, with $\mathbb{P}(z' = z_j | z = z_s) \equiv \pi_{sj} \geq 0$, and $\sum_{j=1}^{N_z} \pi_{sj} = 1, \forall s = 1, \ldots, N_z$. In period t, firms sell the wholesale good at nominal price P_t^w, while P_t is the nominal price of the final good, taking both as given. Each firm producing in t faces a constant probability $\eta \in [0, 1]$ of receiving an exit shock that forces it to exit the economy after production. Exiting firms are replaced by an equal mass of entrants with initial states described below.

A firm's capital depreciates at rate $\delta \in (0, 1)$ and adjustments to the individual capital stock are subject to convex adjustment costs. Q_t is the real price of a unit of capital. If a firm which enters period t with capital stock k and wishes to acquire k' going forward, it must spend $Q_t[k' - (1 - \delta)k]$, plus the adjustment costs $Q_t \cdot AC(k', k) \equiv Q_t \cdot \frac{\kappa}{2} \left(\frac{k'}{k} - 1\right)^2 k$.

In addition to holding illiquid capital k, firms can save in liquid assets m, interchangeably referred to as *cash*, with m denoting the real value of cash in the period at which it is acquired by the firm. Liquid assets acquired in period t provide a net nominal return r_{t+1}^m in period

value functions out of steady state. Primes denote agents' future state variables in optimization problems.

[30] To distinguish them from other productive entities, the heterogeneous wholesale goods producers are the only entities which I refer to as "firms".

$t+1$. Firms cannot borrow using cash, facing the constraint $m' \geq 0$. In general equilibrium, these liquid assets are held as deposits in the financial intermediary.

Firms can borrow using long-term debt contracts. I model long-term debt as a geometrically decaying coupon, with one unit of debt issued in period t stipulating that the debtor pay the creditor c_b nominal units in $t+1$, γc_b in $t+2$, $\gamma^2 c_b$ in $t+3$ etc. q_t^b is the nominal price of a unit of such debt raised in t. Whenever a firm wants to issue new debt, or repurchase existing debt to repay it faster than the repayment schedule dictates, it must pay a real fixed cost ξ. In each period, the firm draws a new cost ξ, i.i.d. across firms and time, distributed uniformly: $\xi \sim U[0, \bar{\xi}]$. I assume that ξ can be paid by the firm's equityholders, and an exiting firm does not have to pay any cost when repaying its debt outstanding.

For notational ease in working with spreads between borrowing rates and the return on cash, I reformulate the firm's problem in period t as that of choosing a real market value of debt outstanding b' at the end of the period whenever adjusting. A net nominal interest rate r_t^b must be paid per unit of incoming b. If a firm does not adjust its debt in t, it must repay a fraction $(1-\gamma_t)$ of the principal b and carry $b' = \gamma_t b$ forward. Appendix B.2 shows how a nominal long-term debt contract with a geometrically decaying coupon can be rewritten in such a form. Essentially, r_{t+1}^b is the nominal net return received by a lender holding the debt from t to $t+1$, and the time-varying γ_t is a readjustment of parameter γ due to inflation and changes in the price of long-term debt outside steady state. r_t^b and γ_t must be conformable with q_t^b as shown in Appendix B.2. In all equilibria considered below, $r_{t+1}^b > r_{t+1}^m, \forall t$.

The firm also faces a borrowing constraint which states that the market value of its debt outstanding entering the upcoming period must be less than a fraction θ of the market value of its capital stock brought into that period.[31] In the calibrations considered, the loan-to-value parameter θ is low enough such that a firm can always afford to repay all of its debt outstanding by liquidating its undepreciated capital, and it is not allowed to default. Firms cannot save in long-term debt. Incumbent firms cannot issue equity. Entering firms are fully equity-financed. All firms are also subject to a flat corporate income tax, at rate τ.[32] Capital depreciation and interest payments are tax-deductible, introducing a tax advantage of debt.

Finally, I assume that when firms producing in t hire labor and pay the wage bill $w_t n$ at the beginning of production, they only have access to a fraction $\phi_w \in [0,1]$ of their revenues. Any remaining part of the wage bill must be covered by cash held between $t-1$ and t. No additional intra-period credit is available at this point. This gives rise to a working capital

[31] *Ex post*, after fully unexpected aggregate shocks realized in period t, firms are allowed to be in violation of the $t-1$ borrowing constraint when they enter t.

[32] A tax on profits, with tax-deductible interest payments, is a common feature of firm financing models. The implied tax advantage of debt incentivizes firms to continuously and perpetually use debt, allowing to better fit mature firms' financing behavior observed empirically. See Appendix B.1 for further discussion.

constraint on the wage bill, written in real terms, with $\Pi_t \equiv P_t/P_{t-1}$ as gross inflation:

$$w_t n \leq \frac{m}{\Pi_t} + \phi_w \frac{P_t^w}{P_t} z^{1-\nu} k^\alpha n^\nu \tag{4}$$

Such a working capital constraint generates an *operational motive* for holding cash. In its absence, firms would still want to hold it (even with debt outstanding) due to the *precautionary motive* induced by debt issuance costs and productivity shocks. The precautionary motive drives the between-firm variation in cash holdings and monetary shock responsiveness relevant for my analysis. The operational motive simply allows the model to fit empirically observed average cash levels without requiring all of firms' cash demand to come from precautionary incentives. (See Section 3.2.1 and Appendix B.1 for further discussion.)

At the beginning of a period, after having realized its productivity shock z, a firm is defined by capital $k \in \mathbf{K} \subset \mathbb{R}_+$, the incoming real value of available cash $m \in \mathbf{M} \subset \mathbb{R}_+$, the incoming real market value of debt outstanding $b \in \mathbf{B} \subset \mathbb{R}_+$, and $z \in \mathbf{Z}$. Given this idiosyncratic state, the firm then takes a collection of decisions to maximize its value to its shareholders. First, it hires labor, produces and pays its wage bill. If the firm must exit, it repurchases all outstanding debt, liquidates its undepreciated capital not subject to adjustment costs, and pays any remaining funds as dividends to shareholders. Conditional on survival, it draws a fixed cost ξ. If the firm pays the cost, it chooses the market value of debt b' going forward, liquid assets m', the capital stock k', and current dividends, subject to the borrowing constraint and the non-negativity constraints on the assets and dividends. Otherwise, it sets $b' = \gamma_t b$ and chooses m', k', and dividends. I summarize the distribution of firms over (k, m, b, z), engaging in production in t using the probability measure μ_t defined on the Borel σ-algebra $\mathcal{S}$ generated by the open subsets of the product space $\mathbf{S} \equiv \mathbf{K} \times \mathbf{M} \times \mathbf{B} \times \mathbf{Z}$.

Entrants. The entrants replacing the exiting mass η of incumbents in t enter at the end of t with initial capital stock k_0 and cash m_0, both calibrated parameters, and no debt. They draw an initial level of productivity z from a distribution π^e defined over $\mathbf{Z}$, and continue as incumbents, hiring labor and producing at the beginning of period $t+1$.

3.1.2 Representative Household and Financial Intermediary

There is a representative infinitely-lived household which consumes the final good c^h and supplies labor n^h for real wage w_t, with a momentary utility function $u(c^h, n^h) = \log(c^h) - \psi n^h$, and $\psi > 0$ a parameter. The household saves in one-period risk-free debt L^h at net nominal return r_{t+1}^f and in firm shares.[33] The household also owns the financial intermediary

[33] Since in equilibrium the return on deposits in the financial intermediary will be strictly below r_{t+1}^f, I assume without loss of generality that the household does not hold cash, i.e. deposit in the intermediary.

and the capital, retail, and final good producers. Without loss of generality, the household does not save nor borrow in the long-term debt with which firms borrow.[34] As a benchmark, I assume that the aggregate debt issuance and price adjustment costs are rebated lump sum to the household. I present the household's dynamic problem in Appendix B.3.1.

There is a representative, perfectly competitive "pass-through" financial intermediary who takes in deposits D from firms (paying net nominal return r^m_{t+1} between t and $t+1$), potentially borrows in the one-period risk-free debt market L (at nominal rate r^f_{t+1}), and lends the funds out in the form of purchasing long-term debt B from firms (yielding an effective nominal return r^b_{t+1}).[35] In addition, the intermediary faces a statutory reserve requirement which imposes that at least a fraction $\alpha_r \in [0,1]$ of the deposits have to be held by the intermediary as reserves at the monetary authority, paying a fixed net nominal return of $\bar{r}^r$. The intermediary makes choices to maximize its value to the owner (household), paying dividends and facing no other financial constraints apart from the statutory reserve requirement. I present its dynamic problem in Appendix B.3.2.

3.1.3 Capital Production, Retail Goods, Final Good Production, and the Government

Capital Goods Production. There is a representative capital goods producer who produces new capital goods with the production technology $\Phi\left(\frac{I_t}{K_t}\right) K_t$, where I_t are the units of the final good used in capital production, K_t is aggregate capital in place at the beginning of t, and $\Phi(\iota) = \frac{\delta^{\varphi}}{1-\varphi}\iota^{1-\varphi} - \delta\frac{\varphi}{1-\varphi}$, with $\varphi \in [0,1)$ a parameter.[36]

Retail Goods Production. There is a unit mass of retailers $j \in [0,1]$, each with a linear production function that transforms wholesale goods into intermediate retail goods: $y_{j,t} = y^w_{j,t}$, with $y^w_{j,t}$ the amount of wholesale goods employed as input by retailer j in period t. The retailers purchase from the heterogeneous firms producing wholesale goods in a competitive market for the nominal price P^w_t, and sell their production for price $p_{j,t}$. They take the demand curve for their retail good as a function of $p_{j,t}$ as given. In setting their prices, the retailers face Rotemberg (1982) adjustment costs $\frac{\phi_p}{2}\left(\frac{p_{j,t}}{p_{j,t-1}} - \bar{\Pi}\right)^2 Y_t$, e.g. as in Kaplan et al. (2018). Here, $\bar{\Pi} > 0$ is a parameter that denotes the steady state gross inflation rate, thus effectively allowing for "price indexing" and a non-unitary steady state gross inflation rate. Y_t is the aggregate production of the final good.

Final Good Production. The final good is produced by a perfectly competitive final

[34] As seen below, this is without loss of generality because along the perfect foresight equilibrium path, the returns on the household's one-period risk-free debt and the firms' long-term debt are equal, period-by-period.

[35] After extending the debt, the intermediary can trade any debt outstanding in a frictionless secondary market where the only participants are the intermediary and any adjusting firms trading in their *own* debt.

[36] This form of $\Phi(\iota)$ ensures that in steady state with $I_{SS} = \delta K_{SS}$, we have $\Phi\left(I_{SS}/K_{SS}\right) K_{SS} = \delta K_{SS}$, $Q_{SS} = 1$, and $\frac{d\log(Q_t)}{d\log(I_t/K_t)} = \varphi, \forall t$ – common normalizations in the literature, e.g., see Bernanke et al. (1999).

good producer who takes the prices of the final good and the retail goods as given. It has a constant elasticity of substitution production function, combining the retail goods into the final good with elasticity of substitution $\varepsilon > 1$: $Y_t = \left(\int y_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}$.

Government and Monetary Authority. I combine the conduct of fiscal and monetary policy under the hood of the government. The monetary authority sets the nominal one-period risk-free rate r^f_{t+1} between t and $t+1$ following a standard Taylor rule, in nonlinear form, with $\phi_\pi > 1$:

$$(1 + r^f_{t+1}) = (1 + r^f_{SS}) \left(\frac{\Pi_t}{\bar{\Pi}}\right)^{\phi_\pi} e^{\zeta^f_t} \tag{5}$$

ζ^f_t is an exogenous deviation from the rule. When studying the response of the economy to an unexpected monetary policy shock, I assume that ζ^f_t follows an AR(1) process $\zeta^f_t = \rho_f \zeta^f_{t-1} + \varepsilon^f_t$, where ε^f_t is the monetary shock.

The government also sets the tax and reserve requirement policy parameters, τ, α_r, and $\bar{r}^r$. The reserves held by the financial intermediary are the government's liability and it pays the return on reserves. Since lump sum taxes on the representative household adjust to satisfy the government's budget constraint and Ricardian equivalence holds, I assume without loss of generality that the government does not borrow nor save in the one-period risk-free debt market. The government's budget constraint is thus given by:

$$T_t + \tau \mathcal{P}_t = \frac{1 + \bar{r}^r}{\Pi_t} R_t - R_{t+1} \tag{6}$$

where $\mathcal{P}_t$ are the aggregate operating profits earned by firms and taxed by the government, and R_{t+1} are the real reserves held by the financial intermediary at the end of t. T_t denotes lump sum taxes raised on the household to ensure that the budget constraint is satisfied.

3.2 Equilibrium and Analysis

3.2.1 Heterogeneous Firms' Optimization

I characterize the problem of a firm recursively. Let $V_{0,t}(k, m, b, z)$ represent the real beginning-of-period expected discounted value of a firm that enters t with idiosyncratic state (k, m, b, z):

$$\begin{aligned} V_{0,t}(k,m,b,z) =& \eta \left\{ (1-\tau)\Upsilon_t(k,m,z) + [1-(1-\tau)\delta] Q_t k + \frac{1+(1-\tau)r^m_t}{\Pi_t} m - \frac{1+(1-\tau)r^b_t}{\Pi_t} b \right\} \\ &+ (1-\eta)\mathbb{E}_\xi \left[V_{1,t}(k,m,b,z,\xi) \right] \end{aligned} \tag{7}$$

$$\text{where } \Upsilon_t(k,m,z) \equiv \max_n \left[\mathcal{M}_t^{-1} z^{1-\nu} k^\alpha n^\nu - w_t n \right] \text{ , s.t. (4)}$$

$\mathcal{M}_t \equiv \frac{P_t}{P_t^w}$ is the gross markup of the retailers. $V_{1,t}(k,m,b,z,\xi)$ is the value of a continuing firm that has drawn an issuance cost ξ. $\mathbb{E}_\xi$ is the expectations operator with respect to ξ. An exiting firm chooses labor n to maximize current operating profits Υ, subject to the working capital constraint (4), and pays them out to shareholders alongside the returns from capital liquidation and cash, net of debt repayment. The value conditional on continuing is:

$$V_{1,t}(k,m,b,z,\xi) = \max_{div,k',m',b'} \left\{ div - \xi \mathbb{1}_{[b' \neq \gamma_t b]} + M_{t+1}\mathbb{E}_{z'}\left[V_{0,t+1}\left(k',m',b',z'\right)|z\right] \right\} \tag{8}$$

$$\text{s.t.} \quad 0 \leq div \leq (1-\tau)\Upsilon_t(k,m,z) - \frac{1+(1-\tau)r_t^b}{\Pi_t}b + b' + \frac{1+(1-\tau)r_t^m}{\Pi_t}m - m' + Q_t\left\{\left[1-(1-\tau)\delta\right]k - k' - AC(k',k)\right\}$$

$$0 \leq \frac{1+r_{t+1}^b}{\Pi_{t+1}}b' \leq \theta Q_{t+1}k'; \quad m' \geq 0$$

As derived in Appendix B.2, the assumed long-term debt contract with a geometrically decaying nominal coupon implies a debt repayment schedule with the real market value of debt outstanding evolving as $b' = \gamma_t b$, with $\gamma_t \equiv \frac{q_t^b}{q_{t-1}^b}\frac{1}{\Pi_t}$. Whenever the firm wishes to issue new long-term debt, or repurchase any of its outstanding debt, i.e. set $b' \neq \gamma_t b$, it must pay the cost ξ. Note that in case the firm does choose to pay ξ, as long as the working capital constraint (4) is not binding, the firm's cash m and debt b become an irrelevant state variable over and above a measure of its net financial position, such as $a \equiv \frac{1+(1-\tau)r_t^m}{\Pi_t}m - \frac{1+(1-\tau)r_t^b}{\Pi_t}b$.

Since labor is flexible, in the absence of the working capital constraint (4) a firm's unconstrained labor demand would be a function of (k,z) and the real wage and aggregate markup: $n_t^*(k,z) \equiv z\left[\nu/(\mathcal{M}_t w_t)\right]^{\frac{1}{1-\nu}} k^{\frac{\alpha}{1-\nu}}$. This implies a wage bill of $w_t n_t^*(k,z)$ which is simply a share ν of the firm's (unconstrained) revenues given (k,z): $z\mathcal{M}_t^{-\frac{1}{1-\nu}}\left[\nu/w_t\right]^{\frac{\nu}{1-\nu}} k^{\frac{\alpha}{1-\nu}}$. Plugging these into (4), one can thus conclude that in order to operate at $n_t^*(k,z)$, a firm's cash holdings m must satisfy: $m \geq m_t^o(k,z) \equiv \Pi_t\left(\nu-\phi_w\right) z\mathcal{M}_t^{-\frac{1}{1-\nu}}\left[\frac{\nu}{w_t}\right]^{\frac{\nu}{1-\nu}} k^{\frac{\alpha}{1-\nu}}$, where $m_t^o(k,z)$ defines the *"operational cash needs"* that a firm with (k,z) requires to operate at an unconstrained level of labor in t. Note that $\phi_w \geq \nu \Rightarrow m_t^o(k,z) \leq 0$, which simply states that as long firms have access to at least the share of revenues corresponding to labor, ν, at the time of paying the wage bill, then the working capital constraint would never bind and firms would not need cash for operational purposes. Yet as soon as $\phi_w < \nu$, the "shortfall" governed by $\nu - \phi_w$ must be covered by cash. If a firm does not have sufficient cash to do so, it will have to operate at a suboptimal level of labor, as determined by a binding (4).

Since ξ enters the payoffs in (8) linearly, the firm's optimal decision to pay the debt issuance cost follows a simple cutoff policy, adjusting debt whenever $\xi \leq \hat{\xi}_t(k,m,b,z) \equiv V_{1,t}(k,m,b,z,0) - V_{1,t}^N(k,m,b,z)$, where $V_{1,t}^N(k,m,b,z)$ is defined as the specific case of problem (8), with the imposed restriction that $b' = \gamma_t b$. The problem of a non-adjuster in (8) illustrates the relevance of debt issuance costs in decoupling firms' investment from corporate debt rate dynamics. Because the non-adjuster is not making any active decisions regarding borrowing b', the interest rates on corporate debt are not a relevant opportunity cost of investing in k'.[37] This mirrors the indifference of firms' CFOs to borrowing cost fluctuations whenever they are not planning to raise new debt to fund investment (Sharpe and Suarez, 2021). The structure of long-term debt contracts implies that the nominal value of coupon payments is determined by the units of nominal debt outstanding, decided at the time of issuance and invariant to any shocks thereafter, while inflation influences their real value.

What is more, the *balance sheet channel* mechanism, through which fluctuations in asset prices (i.e., capital) and operating profits caused by monetary shocks affect firms' total financing available for investment, is quantitatively stronger whenever a given firm adjusts its debt, as compared to when it does not. This is because a firm that does not actively access the debt market must only cover the coupon payments due on its debt outstanding. And its total available funds for investment are given by the market value of incoming capital plus its *liquid* net financial position (capital + operating profits + cash − coupon). However, for a debt adjuster, the total available funds equal a leveraged multiple of its *full* net financial position (capital + operating profits + cash − debt outstanding). By a conventional leverage effect, a persistent 1% drop in capital prices thus has a smaller relative effect on the non-adjusting firm's available funds, as compared to the adjuster. I provide an analytical illustration of how debt-adjusting firms are relatively more exposed to both the direct interest rate and the balance sheet channels using a simplified version of the firm's problem in Appendix B.8.

In the calibrated model's steady state equilibrium $M_{SS}\frac{1+(1-\tau)r^m_{SS}}{\Pi_{SS}} < 1$, meaning that the return to cash inside the firm is strictly below the owners' discount rate. This implies that firms do not have the incentive to save themselves out of financial constraints and they start paying dividends before having ensured that they will never face a binding equity issuance or borrowing constraint in the future.[38] Moreover, in steady state $M_{SS}\frac{1+(1-\tau)r^b_{SS}}{\Pi_{SS}} < 1$, so that the effective cost of debt financing is below the owners' discount rate, introducing an explicit benefit to using debt financing over equity. Yet not all debt issuing firms always want to hit the borrowing constraint. Rather, firms with currently low z do not exhaust their borrowing

[37] If a current non-adjuster expects to adjust in the near future, then the path of future r^b_{t+j} can affect also its choices in t, to a lesser extent. Also, while a non-adjuster does not treat the borrowing rate r^b_{t+1} as a direct opportunity cost, if its dividends choice is interior ($div > 0$) then its owners' effective discount rate, as implied by M_{t+1} (equal to $r^f_{t+1} = r^b_{t+1}$ in equilibrium) *is* a relevant cost. However, in the baseline calibration, about 8.6% of all firms pay dividends in any given quarter, suggesting this margin is quantitatively less significant.

[38] This contrasts with settings where the owners' discount rate equals the rate on savings within the firm and firms would retain earnings, not paying dividends until they become *financially unconstrained* – defined as being able to follow the n- and k-policies of firms who face no financial constraints *ad infinitum*.

capacity. Instead they borrow little and build up cash, so that when their TFP reverts and they want to expand their capital, they can do so by decumulating cash and increasing debt – highlighting the precautionary motive for holding cash. Firms thus fluctuate perpetually between varying financial positions, paying dividends or hitting the borrowing constraint only occasionally, depending on their realized TFP and debt issuance cost shocks.[39]

3.2.2 Household, Intermediary and Capital Producer Optimality, Prices and Equilibrium

Using c_t^h and n_t^h to denote the household's decisions in equilibrium, optimality implies:

$$\beta \left(\frac{c_{t+1}^h}{c_t^h} \right)^{-1} \frac{1 + r_{t+1}^f}{\Pi_{t+1}} = 1 \tag{9}$$

$$w_t = \psi c_t^h \tag{10}$$

Thus, the stochastic discount factor used by all entities owned by the household in equilibrium equals $M_{t+1} = \beta \left(c_{t+1}^h / c_t^h \right)^{-1}$, and in steady state $M_{SS} = \beta$ and $\beta \frac{1+r_{SS}^f}{\Pi_{SS}} = 1$.

As for the financial intermediary's problem, I parameterize the model so that the government sets the return on reserves to yield $\bar{r}^r < r_{t+1}^f$ in steady state and in response to the monetary shocks considered. Since there are no frictions in the intermediary's financing by equity or by one-period debt (both requiring a return of r_{t+1}^f), whenever there is lending to firms in equilibrium, it must be the case that on the perfect foresight equilibrium path:

$$M_{t+1} \frac{1 + r_{t+1}^b}{\Pi_{t+1}} = 1 \Leftrightarrow r_{t+1}^b = r_{t+1}^f \tag{11}$$

In addition, given that in the considered parametrizations $\bar{r}^r < r_{t+1}^f$, the intermediary's reserve requirement ($R \geq \alpha_r D$) binds in optimum. And whenever firms hold a non-zero aggregate amount of cash, the strict positivity of intermediary deposits requires that in equilibrium:

$$r_{t+1}^m = (1 - \alpha_r) r_{t+1}^f + \alpha_r \bar{r}^r \tag{12}$$

This means that whenever there is a non-zero reserve requirement ($\alpha_r > 0$), and the government sets $\bar{r}$ strictly below the policy rate r_{t+1}^f, firms' liquid asset holdings earn a return below that of their effective cost of borrowing ($r_{t+1}^m < r_{t+1}^f = r_{t+1}^b$).

The capital goods producer chooses final goods spent on capital goods production, I_t, to maximize profits $Q_t \Phi \left(\frac{I_t}{K_t} \right) K_t - I_t$. Therefore, in equilibrium the relative capital price Q_t

[39] Such intricate dynamics of firms' financial positions in the presence of corporate taxation are common and analyzed in depth in structural models of corporate finance, e.g. see Hennessy and Whited (2007).

equals:

$$Q_t = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1} = \left(\frac{I_t/K_t}{\delta}\right)^{\varphi} \tag{13}$$

Optimization by the final goods producers gives rise to the demand for retail good $j \in [0,1]$, of $y_{j,t} = \left(\frac{p_{j,t}}{P_t}\right)^{-\varepsilon} Y_t$. Given this demand curve and the quadratic price adjustment costs, retailers choose optimal prices $p_{j,t}$. Under initial price symmetry, this gives rise to a New Keynesian Phillips Curve, with $\hat{\pi}_t \equiv \log(\Pi_t) - \log(\Pi_{SS})$, of:

$$\hat{\pi}_t = -\kappa_p \log(\mathcal{M}_t/\mathcal{M}_{SS}) + \beta\hat{\pi}_{t+1} \tag{14}$$

which I consider in the log-linearized form around a steady state with $\Pi_{SS} = \bar{\Pi}$, and $\mathcal{M}_{SS} = \frac{\varepsilon}{\varepsilon-1}$, as common in the literature. $\kappa_p \equiv \frac{\varepsilon-1}{\phi_p \Pi_{SS}^2}$ is the slope of the Phillips curve.

I present the details of the retail and final good producers' optimization in Appendix B.3.3, the equilibrium law of motion for the distribution of firms in Appendix B.3.4, and the full definition of a perfect foresight equilibrium, given a series of monetary policy shock ε_t^f realizations in Appendix B.4. Therein, I also clarify how interest rates and debt prices are determined along a perfect foresight equilibrium path and in response to unexpected shocks.

3.3 Model Calibration and Untargeted Moments

3.3.1 Calibration

The model period is one quarter. In the calibration of most parameters, I follow prior work and use values which allow to either match common aggregate moments directly, or values deduced based on methods independent of model specifics. For the remaining parameters central to the mechanisms of interest, I employ internal calibration, matching moments of the model's stationary equilibrium to time-averages observed in the data. When using any target moments calculated from the Compustat sample from Section 2, I approximate firm selection by firm age. Namely, when computing moments corresponding to Compustat targets in the model, I consider a sample of firms at least 5 years old.[40] Ensuring that the model "public" firms sample matches certain features of the empirical Compustat sample allows for a more precise validation of the model's performance in light of the empirics of Section 2. For this reason, I also employ empirical targets from the period 1990Q1–2007Q4 wherever possible.

Externally calibrated parameters. I use a depreciation rate δ of 0.025 to match the

[40] See Wilmer Cutler Pickering Hale and Dorr LLP (2017) for data on median IPO age of firms during the relevant sample period. Such an approach to account for Compustat sampling is also considered by Ottonello and Winberry (2020). The 5-year threshold also ensures that the difference in the age of the average "public" and "private" firms matches the data (see Appendix B.5.3).

aggregate investment-to-capital ratio, a common target in the business cycle literature. I set $\beta = 1.02^{-1/4}$ to target a steady state annual real risk-free return on one-period debt of 2%. I calibrate the steady state annualized inflation rate to 2%, with $\bar{\Pi} = 1.02^{1/4}$. I determine α_r and $\bar{r}^r$ by requiring that the steady state nominal return on firm's cash r^m_{SS} equals $(1 - 0.255) \times r^f_{SS}$, and that in response to fluctuations in r^f_{t+1}, r^m_{t+1} has a relative exposure of $\frac{\partial r^m_{t+1}}{\partial r^f_{t+1}} = 1 - \alpha_r = 0.618$ (see Appendix B.5.1 for detail). Conceptually, the wedge between the risk-free (policy) rate over the return on liquid assets arises because firms hold liquid assets in their portfolio which do not earn the full risk-free policy rate. And as documented by Drechsler et al. (2017), the responsiveness of the returns on some of these assets (e.g., time and savings deposits) to changes in policy rates is less than one-for-one.[41]

I assume that idiosyncratic TFP z follows a discretized (Rouwenhorst, 1995) lognormal AR(1) process $\log z' = \bar{z} + \rho_z \log z + \epsilon'_z$, with $\epsilon'_z \sim N(0, \sigma^2_\epsilon)$, $\mathbb{E}[z] = 1$ and $N_z = 5$. I use a conventional persistence of $\rho_z = 0.90$ and discuss σ_ϵ below. I set $\nu = 0.64$, as a conventional labor share, and $\alpha = 0.23$ implying returns to scale of 0.87 (Clementi and Palazzo, 2016).[42] I use the quarterly exit rate $\eta = 0.022$, to match an annual exit rate of 8.8%, in line with Business Dynamics Statistics (BDS) and the value used by Ottonello and Winberry (2020).

I calibrate the duration of firms' debt captured by $\gamma = 1 - 1/16$ to yield an average expected maturity of 4 years. This duration is relatively short compared to the maturity of firms' new debt issuances observed in the data. It is approximately in line with the maturity of bank debt but shorter than the average corporate bond.[43] I choose to calibrate the model to a relatively low maturity to be conservative and rather deviate less from the existing models of heterogeneous firms and financial frictions with one-period debt.

Following Nikolov and Whited (2014), I consider a tax rate of $\tau = 0.20$ which is an approximation of the statutory corporate tax rate relative to personal tax rates in the U.S. Following Kaplan et al. (2018), I employ conventional values of the elasticity of substitution $\varepsilon = 10$, resulting in a steady state markup of about 11%, price adjustment cost ϕ_p to yield a slope of the Phillips curve of $\kappa_p = 0.1$, a Taylor rule coefficient $\phi_\pi = 1.25$ on inflation, and a persistence of monetary policy shocks of $\rho_f = 0.61$. I consider an elasticity of capital prices to aggregate investment of $\varphi = 0.25$ following Bernanke et al. (1999).

Internally calibrated parameters. I derive some targets for internal calibration from the Compustat sample of Section 2, and others from the population of U.S. firms. Although the

[41] Appendix A.3 provides a decomposition of the U.S. nonfinancial corporate sector's liquid asset portfolio.

[42] The implied labor share $\frac{\varepsilon-1}{\varepsilon}\nu$ is also considered, for example, by Ottonello and Winberry (2020) and it is in line with recent estimates by Karabarbounis and Neiman (2013) for the U.S.

[43] Rauh and Sufi (2010) study new loan and bond issuances of a random sample of Compustat firms with a long-term issuer credit rating and find a median maturity of 5 years for most credit ratings. Choi et al. (2017) find the median residual maturity of debt outstanding for Compustat firms to be 3.93 years.

relevant model moments are potentially affected by all parameters, it is helpful to discuss the parameters and the moments most relevant for identifying their values in pairs.

I set the maximum loan-to-value ratio θ to generate an aggregate leverage ratio among public firms equal to the Compustat across-time median of about 0.302 between 1990Q1-2007Q4. Analogously, I match the Compustat aggregate liquidity ratio of 0.062 over the same period by choosing ϕ_w, i.e. the strength of the operational motive for holding cash.[44] To determine the degree of convex capital adjustment costs κ and the volatility of the idiosyncratic TFP process σ_ϵ, I match the autocorrelation (0.33) and cross-sectional standard deviation (0.315) of annual investment rates for Compustat firms, following Bai et al. (2022).

I set k_0 by targeting an average annual investment rate of 0.26 in the whole population of firms, following Crouzet and Mehrotra (2020). The entrants draw their idiosyncratic log TFP from the ergodic distribution of $\log z$, shifted by the parameter z_0.[45] I choose z_0 to match the entering firms' average employment per firm relative to the average employment per firm in the population of 0.255, following calculations based on BDS. I set the entrants' cash holdings m_0 to equal the "operational cash needs" of a firm with k_0 capital and idiosyncratic TFP at its ergodic mean of 1, i.e., $m_0 = m^o_{SS}(k_0, 1)$. The entrants start with no debt. Finally, to calibrate $\bar{\xi}$, I match the fraction of "public" firms issuing long-term debt in the stationary distribution of the model to the frequency of 0.251 of Compustat firm-quarters between 1990Q1-2007Q4 exhibiting long-term debt issuances.[46]

The joint calibration leads to the values of $\left[\theta,\ \phi_w,\ \sigma_\epsilon,\ \kappa,\ k_0,\ z_0,\ m_0,\ \bar{\xi}\right]$ = [0.422, 0.622, 0.245, 0.158, 1.84, -0.24, 0.0090, 0.0615]. I set the disutility of labor supply parameter ψ so as to normalize the steady state real wage to $w_{SS} = 1$. Table B.1 in Appendix B.5.1 provides an overview of the full set of calibration targets and parameter values used. Given that there is an equal number of parameters and target moments, the model is able to match all targets, subject to negligible deviations which can be minimized with added computational time.

3.3.2 Untargeted Firm Dynamics Moments

In addition to matching the calibration targets, the model does well at generating a distribution of "public" firms that fits the Compustat sample from Section 2 along various relevant

[44]The calibrated $\phi_w = 0.622$ is just slightly below $\nu = 0.64$, meaning that the precautionary motives of holding cash, driven mostly by σ_ϵ and $\bar{\xi}$, themselves generate a considerable amount of liquid asset holdings.

[45]That is, π^e, defined over $\mathbf{Z}$, is a discretization of $\log N(\mu_z + z_0, \sigma_z^2)$, where $\mu_z = -0.5\sigma_\epsilon^2/(1-\rho_z)^2$ and $\sigma_z = \sigma_\epsilon/\sqrt{1-\rho_z^2}$ are the unconditional mean and standard deviation of the ergodic distribution of $\log z$.

[46]I compute the empirical frequency based on the extensive margin debt issuance variable $D_{i,t}$ used in Section 2.5. I focus on *gross* issuances in both model and data to yield more adequate, and conservative, estimates of the debt issuance costs, e.g., also capturing instances where *net* issuance may be non-positive, even though the firm is actively issuing new debt but in a smaller amount than currently maturing past debt. The calibrated model generates an average observed ratio of the issuance cost to funds raised of about 2.1%.

margins. The analysis in Appendix B.5.2 shows how it replicates several features of the firms' liquidity ratio distribution, such as its cross-sectional variation, correlation with firm size and investment rates, its strong negative relation to leverage ratios, and the frequency of near-zero liquid asset holdings. Also, the model matches the degree of right-skewness of the firms' fixed capital holdings cross-section, frequency of annual dividend payments, and the positive unconditional relationship between firm size and debt issuance frequency. Below, Section 4.1.2 provides a more detailed analysis comparing model vs. data along debt issuance frequencies conditional on liquidity ratios and leverage. Finally, Appendix B.5.3 illustrates how the age-based approximation approach to public firm sample selection generates differences between public vs. private firms in the model that are in line with the data along several relevant dimensions, such as liquidity ratios or shares in aggregate investment.

4 Baseline Model Results

4.1 Firm Behavior in Steady State

In this section I discuss firm behavior in steady state, focusing on how a firm's financial position affects its extensive margin decisions to issue debt and why liquidity ratios are a good predictor of issuance – better, for example, than leverage. Since monetary shocks move debt rates relatively more than returns to cash and debt-issuers are exposed to a relatively stronger balance sheet channel, all else equal, this provides a backdrop for the heterogeneous shock-responsiveness of firms. Appendix B.5.4 discusses firms' life cycle dynamics further.

4.1.1 The Effect of Financial Positions on Debt Issuance

Figure 3 shows how a typical growing firm's probability of debt issuance in the stationary equilibrium depends on its current debt and liquid assets position, with the only remaining source of uncertainty being the draw of ξ. Fixing $(k = 5, z = z_3)$, the Figure plots a heatmap for the values of debt issuance probabilities $\mathbb{P}\left[\xi \leq \hat{\xi}_{SS}(k, m, b, z)\right]$ in the $\left(\frac{b}{k}, \frac{m}{k}\right)$-space.[47]

Conditional on indebtedness b, an increase in the firm's cash holdings m unambiguously decreases its probability of issuing debt. For example, at a debt-to-capital ratio of 0.1, going from a cash-to-capital ratio of 0 to 0.2 decreases the probability from more than 0.70 to 0.30. A firm with more cash, all else equal, can take advantage of its growth opportunities by using cash to invest, lowering the marginal benefit of raising debt. At the same time,

[47] $k = 5$ is slightly less than half of the capital the firm would converge to, if it continuously drew the TFP level z_3. While I define the leverage and liquidity ratio as debt and cash relative to *total* assets $(m + k)$ throughout, Figure 3 focuses on ratios relative to k to keep the denominator in the financial ratios constant.

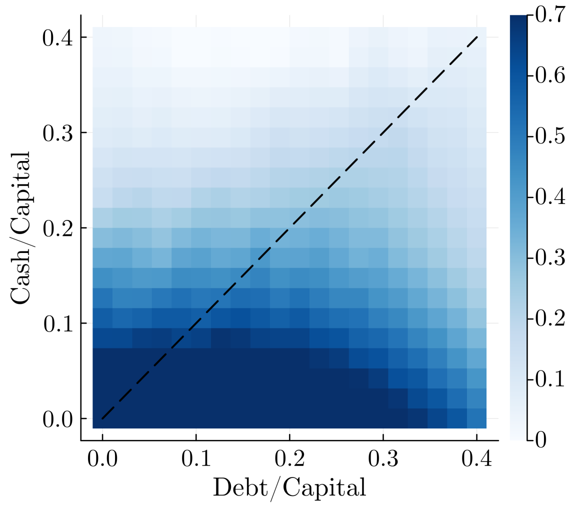


Figure 3: Heatmap of debt issuance probability

Notes: Heatmap of debt issuance probability $\mathbb{P}\left[\xi \leq \hat{\xi}_{SS}(k,m,b,z)\right]$, given $k=5$, $z=z_3$, as a function of b/k and m/k ratios, based on policy functions in the stationary equilibrium. Black dashed line: portfolio combinations implying zero net financial wealth. Right hand scale: color–probability correspondences.

fixing cash and increasing debt affects the likelihood by less, suggesting a slight decrease in issuance probabilities for the most part. When debt increases, there are two opposing forces operating in this regard. First, conditional on not issuing new debt, a more indebted firm must service higher coupon payments, exhausting part of its cash flows which could otherwise be used for investment. The restricted ability to invest implies a higher marginal benefit of issuance. However, this effect is counteracted by the fact that for a more levered firm, the amount of new debt that can be raised is smaller, discouraging the payment of ξ.

The black dashed line in Figure 3 depicts combinations of portfolios which imply a zero net financial position, so that cash holdings exactly cover the debt outstanding. In a model with liquid debt and no working capital constraint, firms along this line would behave identically because the sources of net financial wealth would be irrelevant. Yet in a model with debt issuance costs, the liquidity position affects debt issuance, also influencing investment and production. Going from a firm with zero cash and debt along the dashed line to one which has both ratios at around 0.2, the probability of debt issuance drops from over 0.70 to 0.30. Instead of issuing, the more liquid firm can directly use funds on hand to invest and grow.

The above shows how exogenous changes in a firm's financial position change its likelihood of issuing debt. However, estimating specifications in the spirit of (1), where the cross-sectional variation in liquidity ratios is not exogenous, does not establish the causality of the financial positions affecting firms' sensitivity to monetary shocks. Rather, the positions are endogenously determined and depend on firms' past decisions and expected investment opportunities. Thus, to explain the empirics of Section 2, one must study the determination of firms' liquidity ratios and leverage jointly with the likelihood of debt issuance, and consider how these are distributed in the observed firm population. I do this in the following.

4.1.2 Liquid Assets, Leverage, and Debt Issuance in the Population

To increase its liquid resources available in any period t, for example to finance investment or service debt payments due, a firm has two main alternatives: acquire cash previously and bring it forward into t, or issue new debt in t. If debt was perfectly liquid, meaning $\bar{\xi} = 0$, and the quantitatively small operational cash holding motives introduced by the working capital constraint were eliminated, no firm would simultaneously borrow and hold cash because $r^b_{t+1} > r^m_{t+1}$. However, if $\bar{\xi} > 0$, firms have an incentive to economize on the fixed debt issuance costs, lump issuances together, and avoid accessing the debt market frequently. Because of convex capital adjustment costs, a firm which issues debt to grow capital optimally invests only part of the raised funds immediately, and puts the remainder in cash to deplete it by investing in subsequent periods. Because of the presence of costs in accessing the debt market, a firm without current incentives to grow may use earnings not invested in capital to build up cash buffers, instead of repurchasing previously issued debt.

Although $\bar{\xi} > 0$ incentivizes firms to acquire cash at the time of borrowing, the spread $r^b_{t+1} > r^m_{t+1}$ makes it costly to do so. Cash accumulation is thus a *costly substitute* for future debt issuances in providing liquidity. So if a firm expects to issue debt in the near future, it is less likely to acquire liquid assets today. And vice versa, by Section 4.1.1, firms with high cash holdings are less likely to issue debt in the near future. A firm's acquired cash is thus a good predictor of a low likelihood of accessing the debt market. A high level of indebtedness, however, can be associated with both a high or low likelihood of near future issuances. A large amount of outstanding debt can either indicate that a firm has good growth prospects and relatively low internal net worth, and thus it may likely issue debt again soon to finance growth further. Or, past issuances could have driven up the firm's indebtedness but further issuances might not be necessary if its capital stock is near optimal size, given z. Also, high debt means that the firm is closer to its debt limit, reducing the benefits of new issuances.

To show how these forces materialize in the observed distribution of firms, Figure 4 depicts how in the model's stationary equilibrium, public firms' debt issuance probabilities differ across the leverage and liquidity ratio dimensions. I split firms into high/low leverage and liquidity groups based on the medians of the respective cross-sectional distributions and plot the group-specific issuance probability densities, alongside the implied mean issuance probabilities. For empirical validation, I compare these means to the corresponding observed issuance frequencies from Compustat, given an analogous grouping of firms based on medians.

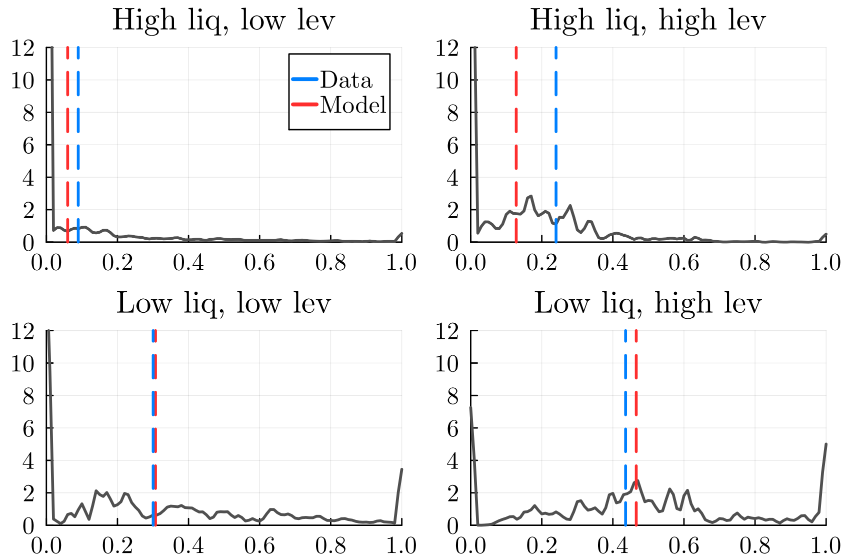


Figure 4: Debt issuance probabilities in model and Compustat public firm populations

Notes: Grey solid: density implied by model stationary distribution; blue and red dashed: group-specific mean issuance frequency in data and model, respectively. Horizontal axis: debt issuance probability with respect to ξ. Compustat groups defined based on one quarter lagged cross-sections of leverage and liquidity ratios; frequencies computed based on long-term debt issuance indicator $D_{i,t}$ as constructed in Section 2.5.

The firms in the bottom-right corner of Figure 4, with high leverage and low cash, have the highest likelihood of issuing debt, of more than 0.40 both in model and data. They have good growth opportunities (high z) and low internal wealth relative to their optimal level of capital, and will want to grow and borrow in the near future. In the background, these firms have the highest mean marginal productivity of capital (MPK) among the four groups, indicating these incentives. Second, the top-right group with high leverage and high liquidity have mostly satiated their growth opportunities by borrowing in the past, indicated by them having the third-highest mean MPK among the four groups. They accumulate cash to finance future growth opportunities if good z shocks realize, and they issue debt due to its tax advantage, implying a relatively low probability ($\sim$0.20) of issuance in model and data.

Third, the bottom-left group of firms with low leverage and low cash holdings includes firms which have relatively good growth opportunities, indicated by the second-highest mean z and MPK among the four groups, but potentially due to past high issuance costs have not yet driven up their leverage by accessing the debt market. They have relatively high debt issuance probabilities ($\sim$0.30) in model and data. Finally, in the top-left, firms with low leverage and high liquidity have the lowest probabilities of issuing debt, below 0.10, in model and data. They have the weakest current growth incentives among the groups, with the lowest z and MPK values, indicating having reached their optimal (small) scale. Yet due to mean-reversion in z, they expect to receive better TFP draws in the future, incentivizing them to accumulate cash and debt capacity to be able to fund such growth opportunities.

Figure 4 thus shows how variation along the liquidity dimension is associated with considerable changes in debt issuance probabilities, for example more so than leverage. Both groups with high liquidity ratios have a lower average likelihood of issuing debt than either of the two low-cash groups, independently of leverage. Also, comparing the group-specific mean frequencies to the data, the model matches well the cross-sectional variation in empirical debt issuance probabilities conditional on financial positions, while only the unconditional mean issuance probability was a calibration target. This provides added validation for the model capturing empirically relevant incentives in firms' debt issuance behavior. In the following, I employ it to study monetary transmission to firms' choices and the aggregate economy.

4.2 Monetary Policy Shock Experiment

To explain the empirical results of Section 2 and analyze monetary transmission in the model economy, I study its behavior in response to a one-time, fully unexpected time $t = 0$ innovation of 25 bp (annualized) to ε_0^f, starting from steady state.

4.2.1 Aggregate Response to Monetary Shock

Figure 5 presents the responses of key aggregates in response to the monetary shock. The overall dynamics look qualitatively similar to those of a baseline New Keynesian model with capital and no firm heterogeneity or financial frictions. The shock increases the nominal policy rate r_{t+1}^f, and due to sticky prices leads to increased retailer markups and a fall in inflation. The real interest rate increases, reducing consumption through a conventional intertemporal substitution mechanism. Since the firms' return on cash r_{t+1}^m and the owners' discount rate increase with r_{t+1}^f, conventional intertemporal forces due to higher real rates push down firms' demand for investment.[48] Moreover, the general equilibrium effects from lower demand that increase retailers' markups lower the relative price at which the firms sell their output, further reducing incentives to invest and to hire labor. Also, the borrowing rate r_{t+1}^b increases from $t = 0$ onwards, pushing any debt-issuers to borrow and invest less. The unexpected economy-wide increase in rates reduces the real value of outstanding long-term debt and bond prices q_0^b drop. The realized nominal return on the bonds r_0^b thus falls at

[48] Since my analysis focuses on the *differences* in the real rates implied by r_{t+1}^m and r_{t+1}^f, after adjusting both for inflation, I will for brevity refer to the relevant rates through the notation for their nominal counterparts, keeping in mind that firms' investment choices depend, first and foremost, on *real* interest rates in this model.

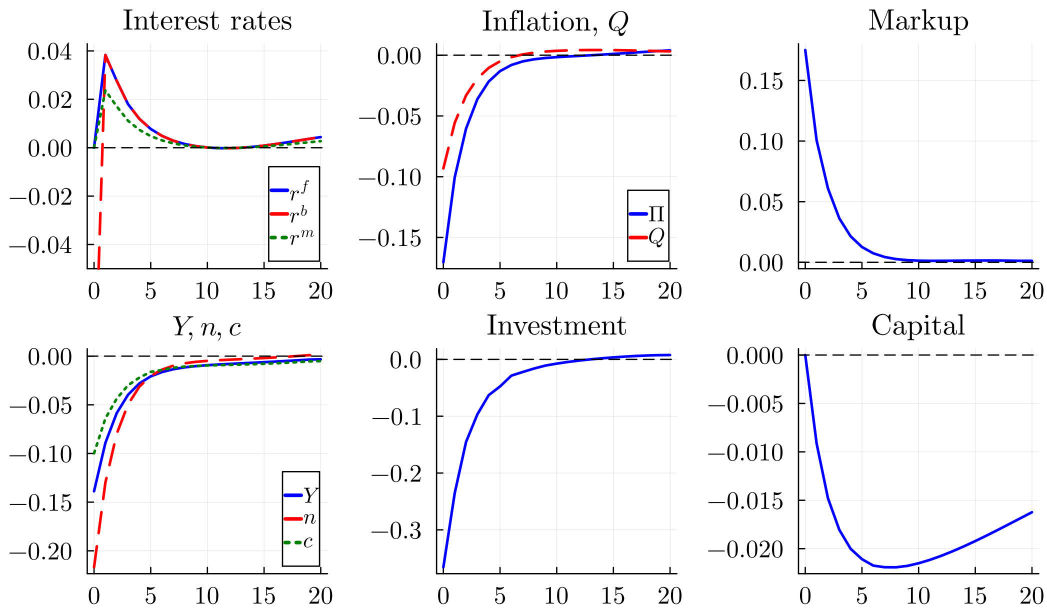


Figure 5: Impulse responses of model aggregates to monetary policy shock

Notes: Impulse responses of aggregate outcomes in response to a 25 bp annualized shock to ε_0^f. All in percentage deviations from steady state values, except interest and inflation rates which are reported percentage point deviations in annualized rates. Horizontal axis: quarters since shock.

impact and the bond-holding financial intermediary suffers unexpected losses.

The drop in investment at impact is almost 0.4%, slowly recovering thereafter. This implies a persistent drop in aggregate capital, at the peak of about 0.022% around 8 quarters after the shock. The fall in aggregate investment also decreases relative capital prices Q_t, inducing two opposing forces on firms' investment levels. On the one hand, for a firm that does not currently face binding financial constraints, the drop in Q_t makes investing relatively cheaper and has in itself an positive effect. On the other hand, the fall in Q_t decreases the value of firms' assets and thus reduces their available funds, leading firms with binding financial constraints to be able to finance fewer investments – the *balance sheet channel* already discussed above. The strength of the balance sheet channel relative to the "direct" effects of changes in rates and Q_t is studied in depth by Ottonello and Winberry (2020).

4.2.2 Heterogeneity of Firm Responses to Monetary Shock

To replicate the main empirical exercise of Section 2 in the model, I estimate γ_h in an analogous specification as (1) using a representative sample of "public" firms from the stationary distribution. To provide an empirically valid quantitative evaluation, it is important to keep in mind the relation between the size of ε_0^f and the observed innovation to r_1^f in the model. As the monetary authority follows a Taylor rule (5) which adjusts the policy rate r_{t+1}^f to inflation, an unexpected 25 bp innovation to ε_0^f, which causes inflation to fall, is observed by an econometrician as a *less* than 25 bp unexpected innovation to r_1^f. Since the empirical high-frequency monetary shock proxies are derived from federal funds futures data, i.e., contracted on r^f, they measure monetary-authority-caused changes in r_{t+1}^f, not in ε_t^f. To account for this, I scale the responses in both model and data in units of a 25 bp annualized unexpected quarterly change in the policy rate r_{t+1}^f when comparing them.[49] In the data, I do this by estimating an instrumental variable (2SLS) analog approach to (1):[50]

$$\Delta_h \log(k_{i,t+h}) = f_{i,h} + d_{n,h,t+h} + \Theta_h' W_{i,t-1} - \gamma_h \ell_{i,t-1} \Delta r_{t+1}^f - \Omega_h' \ell_{i,t-1} Y_{t-1} + u_{i,h,t+h} \quad (15)$$

where Δr_{t+1}^f is the quarterly change in the fed funds rate set at t vs. $t-1$ (in line with model notation) scaled so that $\Delta r_{t+1}^f = 1$ is a 25 bp change in the annualized rate. I instrument Δr_{t+1}^f with the monetary shock proxy ε_t^m. The controls $W_{i,t-1}$ and Y_{t-1} are exactly as in (1). Figure 6 presents the point estimates and confidence intervals for γ_h from (15) in Compustat data, alongside the corresponding estimates from the model simulated data. In response to a contractionary monetary shock, model firms with lower liquid asset holdings contract their capital stocks by relatively more. A 10 pp decrease in the liquidity ratio is associated with an approximately 0.21 pp stronger contraction in the firm's capital stock at peak – slightly more than 70% of the quantitative peak effect seen in the empirical estimates.

While the model generates hump-shaped dynamics in the heterogeneity of capital accumulation, peaking slightly before a year after the monetary shock, the empirical estimates peak at about two years. Adding features such as planning lags (Lamont, 2000), or convex adjustment costs to *investment* (not capital), noted to be helpful in matching empirical investment behavior both at aggregate (Christiano et al., 2005) and firm levels (Eberly et al., 2012), are natural candidates to bring the model closer to the data in this regard. Yet since the model aims to focus on the key features behind the empirically observed response heterogeneity, I abstract from such details that would complicate the analysis further. Nontheless, the differences in firms' capital stocks exhibit more sluggish dynamics than the interest rate paths in Figure 5. While the convex capital adjustment costs can partly explain this, a role is also played by the monetary shock having heterogeneous effects on firms' net worth – a slow-moving state variable fundamental in a model with financial frictions. This echoes a key

[49] Although the experiment incorporates empirically valid fluctuations in the policy rate and the return on liquid asset portfolios, it does not introduce additional changes in credit spreads exogenous to firms, or in long-term rates due to term premia. As mentioned above, the empirically observed responses in credit spreads not explained by firms' default risk (e.g., the EBP) and in term premia are notable, providing one potential reason for why the model does not generate the full response heterogeneity observed in the data.

[50] I detail the identification and estimation of γ_h in the model in Appendix B.6. $k_{i,t}$ is capital in place at the end of t in both model and data.

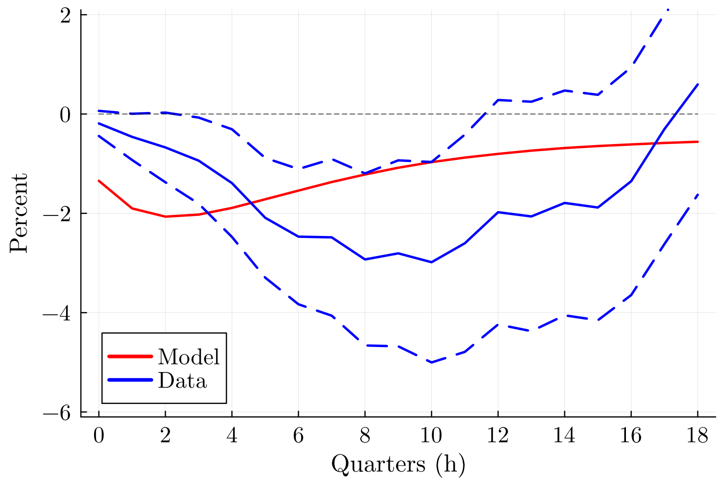


Figure 6: Heterogeneity in responses of capital accumulation conditional on liquidity ratio in the data and model

Notes: Data – point estimates and 95% confidence intervals for γ_h from estimating (15) via 2SLS. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels. *Model* – point estimates for γ_h from estimating (B.6) on sample of 50,000 "public" firms from stationary distribution.

idea in Bernanke and Gertler (1989): not only can net worth dynamics add persistence to the aggregate economy's response to shocks, but also to the differences in agents' outcomes.

Finally, note that in addition to the heterogeneous direct exposure to interest rate fluctuations discussed throughout, firms' investment is also differentially affected by the balance sheet effect (see Appendix B.8.3), induced by the fall in operating profits and Q_t. Less financially constrained firms with high cash holdings (and low leverage) are not directly impacted by this drop in available funds since they can reduce dividend payments and their cash buffers to keep investment from dropping. Some of them actually *increase* investment, in line with the empirics in Appendix A.2.7, as the drop in Q_t makes it a beneficial time for them to accumulate capital. Yet for the more financially constrained firms, the lower available funds driven by profits and the market value of held capital are central in determining investment.

5 Balance Sheet Liquidity and Monetary Transmission

Section 4 demonstrates that the baseline model performs in line with the data in regards to several key untargeted features, such as the cross-sectional distribution of firms' cash holdings (Section 3.3.2), correlation between liquidity positions and debt issuance (Section 4.1.2), and the heterogeneity in investment responsiveness to monetary shocks (Section 4.2.2). In the following, I use the model to study the main question at hand: what is the role of firms' balance sheet liquidity in the transmission of monetary policy to aggregate investment?

To answer this, I consider two counterfactual exercises. First, I show how the strength of monetary transmission to investment weakens when the initial balance sheet liquidity of the whole firm population is increased. And second, I illustrate that transmission weakens whenever the return on firms' cash r^m_{t+1} is less sensitive to fluctuations in the policy rate r^f_{t+1}.

Throughout, I also contrast the results of these counterfactuals in my baseline model to the same counterfactuals conducted in a "canonical" special case of the model which abstracts from the key features that drive firms' liquidity management considerations. Namely, this alternative version has liquid long-term debt ($\bar{\xi} = 0$) and no working capital constraint ($\phi_w \geq \nu$). I recalibrate this *"No liquidity"* specification to target the same empirical moments from Section 3.3.1, just omitting the public firms' aggregate cash-to-assets ratio and debt issuance frequency targets.[51] This alternative model fails to generate a realistic cash holdings distribution, implying an aggregate public firms' cash-to-assets ratio of 0.022, with 77.5% of them holding exactly zero cash. Their debt issuance frequency is approximately 0.60.

5.1 State-Dependence of Transmission on Balance Sheet Liquidity

The preceding analysis (Section 4.1.1) suggests that changes in firms' liquidity positions can have considerable effects on their behavior, even keeping net worth fixed. This feature is not present in financial frictions models which abstract from liquidity management, such as my "No liquidity" special case. In such an alternative, the net financial position $a \equiv \frac{1+(1-\tau)r^m_t}{\Pi_t} m - \frac{1+(1-\tau)r^b_t}{\Pi_t} b$ is a sufficient state variable to capture a firm's financial condition, independently of the split across m and b. I now explore to what extent changes in the whole firm population's balance sheet liquidity affect monetary transmission in the aggregate.[52]

I do so by computing the effect of a monetary policy shock on aggregate investment, conditional on alternative initial distributions μ over the firms' state space $\mathbf{S}$. As the default, I consider the stationary equilibrium distribution, and I perturb it by giving each firm a transfer of cash, equal to a share $\hat{m}$ of their individual capital stock. I simultaneously increase their debt outstanding b to keep each firm's net financial position a unchanged.[53] Since the perturbation of μ by $\hat{m}$ leads to aggregate effects and a transition back to steady state in itself, I compute the effects of a monetary policy shock, conditional on a given $\hat{m}$, as

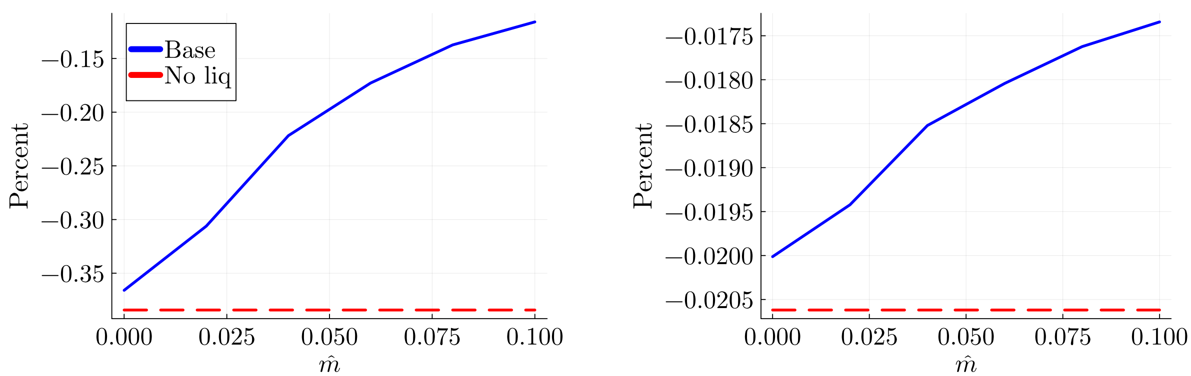
[51] The resulting vector of the remaining internally calibrated parameter values is $[\theta, \sigma_\epsilon, \kappa, k_0, z_0, m_0] = [0.417, 0.253, 0.166, 1.94, \text{-}0.32, 0]$, not too different from their values in the baseline.

[52] The work by Ottonello and Winberry (2020) shows how changes in firms' net worth can influence aggregate monetary transmission. While the model in this paper also features implications for the relevance of firms' net worth, this section emphasizes balance sheet liquidity over and above net worth.

[53] If this adjustment to m and b were to push a given firm into a position that implies a violation of the borrowing constraint in $t-1$, I instead provide the maximal possible transfer to m so that the implied incoming b, conditional on an unchanged a, exactly satisfies the borrowing constraint with equality.

the relative difference in aggregates under the monetary shock and the no monetary shock scenarios. To illustrate the strength of the mechanism, I conduct the perturbations in partial equilibrium, computing firm aggregates conditional on equilibrium price paths in the steady state (for the no monetary shock scenario) and in the case of a monetary shock with an unperturbed initial distribution (for the monetary shock scenario).

Figure 7 presents the effects of a 25 bp annualized ε_0^f shock on investment at impact and capital one year after, conditional on perturbation $\hat{m}$, in the baseline and "No liquidity" models. Focusing first on the baseline model, Panel 7a shows a significant effect of changes in balance sheet liquidity on the responsiveness of investment. Compared to the drop of about 0.36% when considering the steady state distribution ($\hat{m} = 0$), the 10 pp liquidity transfer case ($\hat{m} = 0.1$) implies a fall of about 12% – a three times weaker partial equilibrium investment responsiveness coming from higher balance sheet liquidity at the same net worth levels. The improved liquidity positions reduce incentives to access the debt market, isolating firms from borrowing rate fluctuations and the relatively stronger balance sheet channel.



(a) Investment (I_0)

(b) Capital stock (K_4)

Figure 7: Monetary transmission conditional on initial balance sheet liquidity distribution

Notes: Impulse responses of investment at impact quarter (a) and capital one year after (b) a 25 bp annualized shock to ε_0^f, depending on perturbation of $\hat{m}$ to firms' cash and debt positions, as explained in the text. *Base* (blue solid) – baseline model calibration from Section 3.3.1. *No liq* (red dashed) – model calibration without liquidity considerations, i.e. $\bar{\xi} = 0$ and $\phi_w = 1$. All in percentage deviations from steady state values.

In the quarters following the shock, the response of aggregate investment is slightly *stronger* in the $\hat{m} > 0$ counterfactuals than with $\hat{m} = 0$, potentially undoing some of the effects on the accumulated capital stock over longer horizons. Panel 7b illustrates this by showing that one year after, aggregate capital drops by about 0.017% in the $\hat{m} = 0.1$ counterfactual, compared to 0.020% in the baseline. While the state-dependency of monetary transmission is thus more moderate in terms of the cumulative effect on the capital stock, firms' balance sheet liquidity influences the dynamics of investment flow responses notably.

As for the "No liquidity" model, as noted, changes in balance sheet liquidity conditional on unchanged net financial positions have no effect and Figure 7 thus plots horizontal lines correspondingly. Comparing monetary transmission across the two models at their respective steady states ($\hat{m} = 0$), corresponding to general equilibrium transmission in both models, Figure 7 also shows that monetary transmission in the "No liquidity" model is slightly amplified compared to the baseline. The relative responsiveness of investment in the shock impact quarter is about 5% larger (-0.384% vs. -0.365%), accumulating into an approximately 3% larger relative effect on capital a year later.[54] Transmission in the "No liquidity" model is stronger because, unlike in the baseline, all firms who choose to maintain a positive outstanding debt position continuously adjust their behavior to fluctuations in the cost of borrowing r^b_{t+1}. Due to the tax benefits of debt, such firms form a large majority. In the baseline economy, only about a third of all firms engage in active debt adjustment in any given quarter. For the non-adjusters, r^b_{t+1} is not an immediately relevant marginal opportunity cost of investing and they are exposed to a relatively weaker balance sheet channel mechanism.[55]

5.2 Dependence of Transmission on Liquid Asset Return Characteristics

Prior discussion has emphasized that the less than one-for-one responsiveness in the return on firms' cash r^m_{t+1} to fluctuations in the policy rate r^f_{t+1} influences monetary transmission to investment. I now evaluate this argument in general equilibrium by comparing monetary transmission in the baseline calibration to two alternatives which change the responsiveness of r^m_{t+1} by setting $\frac{\partial r^m_{t+1}}{\partial r^f_{t+1}}$ equal to either 0 or 1, all else equal.[56] This effectively shows how monetary transmission would change if firms held all their liquidity in assets with the return-responsiveness of non-interest-bearing currency, or on the contrary, of short-term Treasuries.

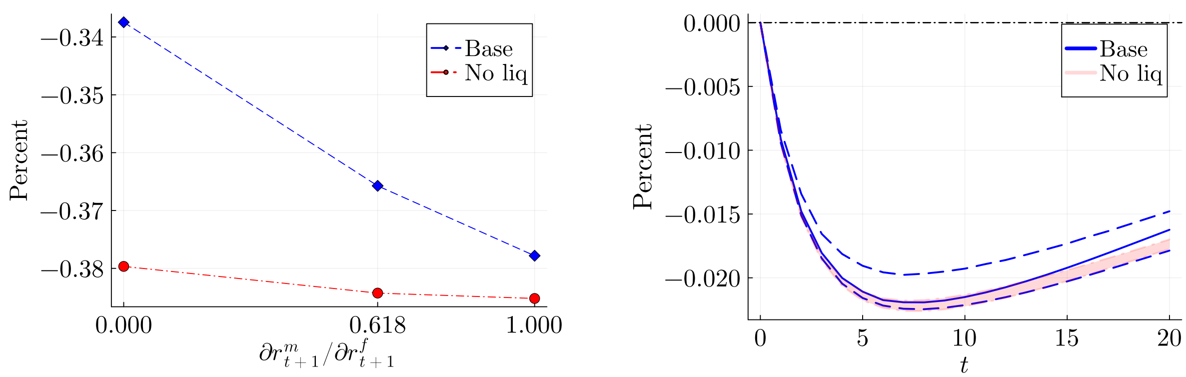
Panel 8a presents the corresponding impulse responses of aggregate investment in the quarter of the monetary shock, in percentage deviations from steady state, both in the baseline and "No liquidity" models. Higher responsiveness of r^m leads to stronger monetary transmission. In the baseline model, the one-to-one r^m-responsiveness case implies an impact

[54]Output responsiveness in the two economies is more similar, with 2.4% stronger response in the "No liquidity" case. This is mostly explained by the fact that investment consitutes less than a fifth of steady state output, although it accounts for a more notable share of the *response* of output to monetary shocks.

[55]Note that while the different exposure to r^b_{t+1} *across* firms *within* a given model can lead to considerable heterogeneity in investment responses (seen in Section 4.2.2), the aggregate equilibrium effects of changing *all* firms' exposure are considerably dampened by general equilibrium forces through adjustments in interest rates and capital prices, explaining the small differences across the baseline and "No liquidity" models.

[56]To isolate the r^m-*responsiveness* mechanism, I keep the steady state return calibration of $r^m_{SS} = (1 - 0.255) \times r^f_{SS}$ unchanged. To explicitly model firms holding zero nominal return currency, for example, the recalibration would require $r^m_{SS} = 0$ and a stronger operational motive of holding cash (higher ϕ_w), likely altering the transmission mechanism compared to the baseline for reasons other than r^m-responsiveness.

effect of monetary shocks on aggregate investment that is about 12% larger in relative terms, as compared to the zero-response case. Panel 8b depicts the corresponding implications for the accumulated capital stock paths, illustrating the range of amplification in impulse responses introduced by moving $\frac{\partial r^m_{t+1}}{\partial r^f_{t+1}}$ from 0 to 1 (the interval between the dashed lines). In contrast, r^m-responsiveness is virtually irrelevant for transmission in the "No liquidity" model, illustrated by the flatness of the corresponding line in Panel 8a and the thin shaded area in Panel 8b. Only a fraction of (relatively small) firms hold cash in this alternative model, leading to the irrelevance of r^m for aggregate investment behavior.



(a) Investment at impact (I_0)

(b) Capital stock path (K_t)

Figure 8: Monetary transmission conditional on r^m responsiveness

Notes: Panel (a): Impulse response of aggregate investment at impact (I_0), as function of $\partial r^m_{t+1}/\partial r^f_{t+1}$ on horizontal axis. Panel (b): Range of impulse response paths of aggregate capital K_t, quarters since shock on horizontal axis; solid line corresponding to baseline $\partial r^m_{t+1}/\partial r^f_{t+1} = 0.618$, dashed bounds to $\partial r^m_{t+1}/\partial r^f_{t+1} = 0$ and $= 1$ cases. Shaded area depicts the same interval for the *No liq* model. All in response to a 25 bp annualized shock to ε^f_0, as percentage deviations from steady state values. *Base* – baseline model calibration from Section 3.3.1. *No liq* – model calibration without liquidity considerations, i.e. $\bar{\xi} = 0$ and $\phi_w = 1$.

Azar et al. (2016) suggest that one reason why U.S. firms' cash holdings have increased notably since the 1980s is the fact that their liquid asset portfolios have moved from traditional, non-interest-bearing assets towards interest-bearing ones implying a lower cost of carry (i.e., smaller $r^f_{t+1} - r^m_{t+1}$ spread).[57] The results from my baseline model thus suggest that while the lower cost of carry would increase cash holdings in steady state, potentially reducing exposure to borrowing cost fluctuations, the implied higher sensitivity in liquid asset returns would itself introduce a force strengthening monetary transmission to investment.

[57]Factors contributing to this shift include the lifting of restrictions related to Regulation Q, legalization of NOW accounts, emergence of money market funds, easier conversion of interest-bearing assets into currency, or the lower need for non-interest-bearing currency due to electronic payment technologies (Azar et al., 2016).

6 Conclusion

In this paper I have studied the relevance of firm balance sheet liquidity in the transmission of monetary policy to investment. Employing firm-level panel data and identified monetary policy shocks, I document that firms with low liquid asset holdings exhibit relatively weaker fixed capital growth after unexpected policy rate increases. This responsiveness is not explained by other firm characteristics, such as leverage, default risk, size, or age. I develop a general equilibrium model of heterogeneous firms that introduces long-term debt financing and fixed debt issuance costs in a conventional framework with collateral constraints. The issuance costs give rise to firm liquidity management and debt issuance behavior in line with the data, and generate an endogenous disconnect of firms from the borrowing costs currently prevalent in the debt market. Firms' balance sheet liquidity predicts debt issuances and investment responsiveness to monetary shocks in the model, explaining the empirics.

Compared to a canonical model which abstracts from firm liquidity management considerations, I show that the firms' balance sheet liquidity distribution affects monetary transmission beyond their net worth; conventional monetary policy transmission to investment is slightly dampened; and monetary transmission depends on the return characteristics of firms' liquid asset portfolios. The model developed in this paper provides a useful toolbox for studying the monetary policy implications of recent trends in corporate liquidity management, such as the significant increase in firms' cash holdings, and the shift in firms' portfolio composition towards interest-bearing assets, as studied in the empirical work by Bates et al. (2009) and Azar et al. (2016). Also, the introduction of debt adjustment costs can give rise to firms who have a slack collateral constraint and relatively high net worth, but exhibit large marginal propensities to invest out of cash flows – a firm-sector analog to the notion of "wealthy hand-to-mouth" households in the consumption literature (Kaplan and Violante, 2014). The presence of such firms could considerably alter the efficacy of fiscal policy in promoting investment, suggesting another potential avenue for future research.

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Appendix – For Online Publication

A Data Appendix

A.1 Compustat Data for Panel Regressions

This Appendix details the steps taken to construct the variables and select the sample of Compustat firm-quarters employed in the regression estimations of Section 2 and the computation of the model's calibration targets.

A.1.1 Sample Selection

I follow sample selection criteria that are standard practice in the literature. I exclude all firm-quarters for which:

1. The firm is not incorporated in the United States.

2. The firm is in the financial industry (SIC code between 6000 and 6999), utilities (SIC between 4900 and 4999), or quasi-governmental sectors (SIC code between 9000 and 9999).

3. The measurements of *Total assets* (Compustat data item 44, $ATQ_{i,t}$), *Property, Plant and Equipment (Net)* (item 42, $PPENTQ_{i,t}$), *Sales* (item 2, $SALEQ_{i,t}$) are missing or not positive.

4. The measurements of *Debt in Current Liabilities* (item 45, $DLCQ_{i,t}$), *Total Long-Term Debt* (item 51, $DLTTQ_{i,t}$) and *Cash and short-term investments* ($CHEQ_{i,t}$, item 38) are missing or negative.

5. All firm-quarters before a firm's first observation of *Property, Plant and Equipment (Gross)* (item 118, $PPEGTQ_{i,t}$) in the full quarterly Compustat dataset.

6. All firms which are observed for less than 40 quarters between 1990Q1–2007Q4.

7. I also drop observations of a firm's capital stock in quarters in which acquisitions are larger than 5% of assets, constructed based on the quarterly acquisitions inferred from the Year-to-Date variable *Acquisitions* (item 94, $AQCY_{i,t}$).

In addition to these sample selection criteria, when estimating the local projection specifications such as (1) or (2), etc., I drop observations of specific firm-level variables in given firm-quarters identified as outliers which might significantly affect the estimates. For the controls in $W_{i,t-1}$, I drop the individual firm-quarter observations of the liquity ratio and leverage for which the observation is above the 99th percentile of the corresponding variable's quarter t cross-section. And I analogously drop the sales growth observations below the 0.5th or above the 99.5th percentiles. I drop the outcome variable, capital growth rate observations below the 1st and above the 99th percentile. I do this separately based on each $(h+1)$-quarter log-growth rate $\Delta_h \log(k_{i,t})$ by quarter t, prior to estimation for any given h.

A.1.2 Construction of Variables

I construct the key variables employed in Section 2 as follows.

1. To construct a measure of the firms' *fixed capital stocks*, I use a perpetual inventory method, as is commonly done for Compustat data, as for example by Mongey and Williams (2017). I measure the initial value of firm i's capital stock as the earliest available entry of $PPEGTQ_{i,t}$, and then iteratively construct $k_{i,t}$ from $PPENTQ_{i,t}$ as

$$k_{i,t+1} = k_{i,t} + PPENTQ_{i,t+1} - PPENTQ_{i,t}$$

2. As the measure of firm *Size*, I employ *Total Assets* $ATQ_{i,t}$.

3. I define *Leverage* as total debt divided by $ATQ_{i,t}$, with total debt computed as the sum of debt in current liabilities and total long-term debt $(DLCQ_{i,t} + DLTTQ_{i,t})$.

4. I measure the *Liquidity ratio* as $CHEQ_{i,t}/ATQ_{i,t}$.

5. I measure the extensive margin of firms' debt issuance activity based on the quarterly issuances inferred from the Compustat Year-to-Date variable *Long-Term Debt – Issuance* (item 86, $DLTISY_{i,t}$). I construct an indicator for the event of active long-term debt issuance in a given quarter $(D_{i,t})$ based on whether gross quarterly issuances were above 1% of the beginning-of-period total assets $ATQ_{i,t-1}$.

   The reason for focusing on this long-term debt related variable is that it provides a measure of *gross* issuances, relevant for capturing firms' active decisionmaking regarding the issuance of new debt, in contrast to keeping debt contracts on one's balance sheet and not adjusting the amount of debt outstanding. E.g., if a long-term debt contract matures at t and a firm chooses to borrow an identical amount to roll the maturing debt over, measures of (net) changes in debt would not capture such issuance activity at t, whereas gross issuance measures do. Compustat does not report gross issuance measures for *all* debt issuance, independently of maturity. Also, given the focus of the paper being on the relevance of debt financing for fixed capital investment, decisions regarding long-term debt issuances are more likely to be reflecting investment financing than movements in short-term debt.

I condition on issuances of at least 1% of total assets to alleviate the effects of potential measurement and misreporting errors of values near zero. Employing such cutoff rules is common practice in the corporate finance literature on capital structure adjustment, e.g. see Leary and Roberts (2005) or Bazdresch (2013). I employ the same cutoff when working with model data in Sections 3 and 4.

6. I construct the *Share of short-term debt* as the ratio $DLCQ_{i,t}/(DLCQ_{i,t}+DLTTQ_{i,t})$, following the analogy in Jungherr et al. (2022).

7. To construct a measure of firm *Age*, I follow Cloyne et al. (2023) and use data from Thomson Reuters' WorldScope database to infer time since the firm's incorporation.

8. In constructing the *Distance to default* measure, I follow the algorithm employed by Gilchrist and Zakrajšek (2012), combining the quarterly Compustat data with daily stock price data from CRSP.

Whenever the deflating of variables is necessary, e.g., for the measures of gross and net fixed capital used in the perpetual inventory method, I deflate them using the implied price index of gross value added in the U.S. nonfarm business sector (BEA-NIPA Table 1.3.4 Line 3).

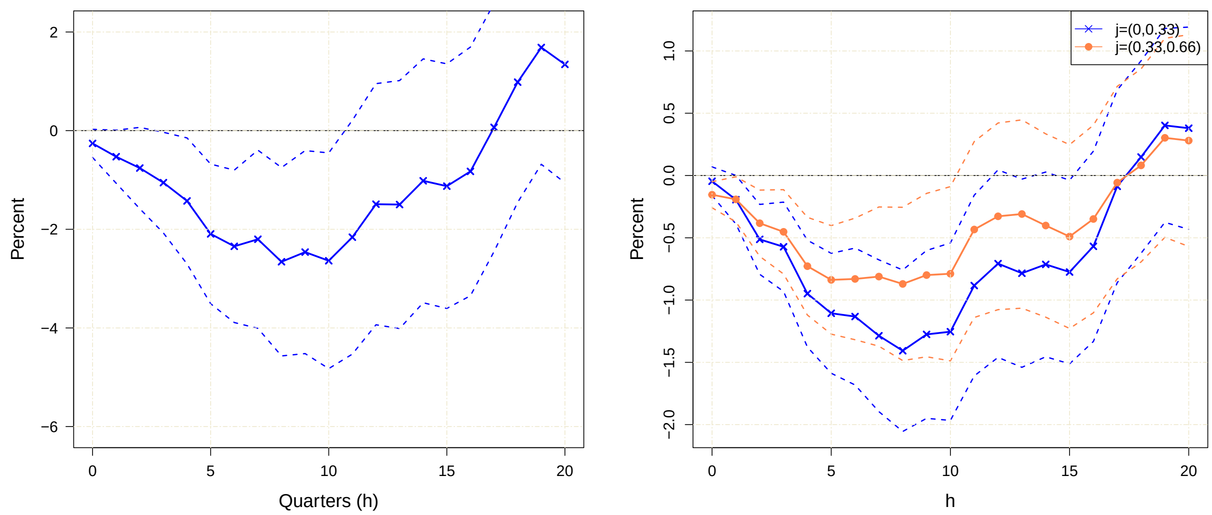
A.2 Robustness and Additional Panel Regression Estimates

A.2.1 Response Heterogeneity Conditional on Leverage Measures

In regards to the model of Section 3 and existing general equilibrium models of firm financial frictions in the literature, e.g. Khan and Thomas (2013) or Ottonello and Winberry (2020), in this Appendix I separately discuss the power of balance sheet liquidity in explaining investment response heterogeneity conditional on firms' indebtedness, i.e. leverage.[58] In canonical models of the firm with constraints on accessing external finance but without features introducing an explicit distinction between financial assets held versus debt outstanding, i.e. in which cash is "negative debt", the firm's *net* leverage position (debt minus held financial assets) is a sufficient state variable to fully characterize its financial condition and its choices going forward.

[58] The predictive power of leverage in firms' responsiveness has been studied more in depth by Ottonello and Winberry (2020) and Anderson and Cesa-Bianchi (2023).

Figure A.1 presents the estimates for investment response heterogeneity explained by balance sheet liquidity, controlling for firms' indebtedness. First, Panel A.1a plots the estimates for γ_h from estimating specification (2), with $Z_{i,t-1}$ consisting of leverage (debt to total assets ratio), denoted $b_{i,t-1}$. Due to the strong (negative) cross-sectional correlation between liquidity ratios and leverage (see Table 1), doing so leads to a slight reduction in the heterogeneity of investment responses predicted by liquidity ratios. However, the main message stands and low liquidity remains a significant predictor of more negative responsiveness.



(a) Controlling for leverage, spec (2)

(b) Controlling for net leverage, spec (A.1)

Figure A.1: Heterogeneity in responses of capital accumulation conditional on liquidity ratio, controlling for leverage measures

Notes: Panel (a): Point estimates and 95% confidence intervals for γ_h from estimating specification (2), with $Z_{i,t-1}$ consisting of leverage. Panel (b): Point estimates and 95% confidence intervals for $\gamma_{j,h}$ from estimating specification (A.1). In both panels, confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

Panel A.1b illustrates the explanatory power of liquid asset holdings when controlling for *net* leverage, $\tilde{b}_{i,t-1}$. Due to the implicit multicollinearity between liquidity ratios and net leverage introduced by the definition of the latter (*net leverage* $\equiv \frac{\textit{debt}-\textit{liquid assets}}{\textit{total assets}} =$ *leverage* $-$ *liquidity ratio*), potentially obscuring the explanatory power of either of the two financial ratios, I instead estimate an analogue of (2) which groups firms into bins based on their position in the cross-sectional distributions of liquidity ratios and net leverage in a given quarter. To do so, I partition the collection of firms $\mathcal{I}_t$ in the panel at quarter t into groups based on percentiles of the conditioning variable x, with x referring to the liquidity ratio ℓ, or net leverage $\tilde{b}$: $\mathcal{I}_t^{x,(\alpha,\beta)} \equiv \left\{ i \in \mathcal{I}_t | x_{i,t} \in \left[q_{x,t}^{\alpha}, q_{x,t}^{\beta} \right] \right\}$. $q_{x,t}^{\alpha}$ refers to the 100α-th percentile of variable x in the cross-section of firms in the sample at quarter t. For both liquidity ratios and net leverage, I consider a partitioning based on terciles[59], and as the base group in the regressions I consider the *highest* liquidity ratio group and the *lowest* net leverage group. Thus, defining the sets of labels $\mathbb{J}^{\ell} \equiv \{(0, 0.33), (0.33, 0.66)\}$ and $\mathbb{J}^{\tilde{b}} \equiv \{(0.33, 66), (0.66, 1)\}$, I estimate the specification:

$$\begin{aligned}\Delta_h \log(k_{i,t+h}) =& f_{i,h} + d_{n,h,t+h} + \Theta_h' W_{i,t-1} + \sum_{j\in\mathbb{J}^{\ell}} \left[\gamma_{j,h}\varepsilon_t^m + \Omega_{j,h}' Y_{t-1}\right] \times \mathbb{1}_{\left[i\in\mathcal{I}_{t-1}^{\ell,j}\right]} \\ &+ \sum_{j\in\mathbb{J}^{\tilde{b}}} \left[\psi_{j,h}\varepsilon_t^m + \Phi_{j,h}' Y_{t-1}\right] \times \mathbb{1}_{\left[i\in\mathcal{I}_{t-1}^{\tilde{b},j}\right]} + u_{i,h,t+h} \qquad \text{(A.1)}\end{aligned}$$

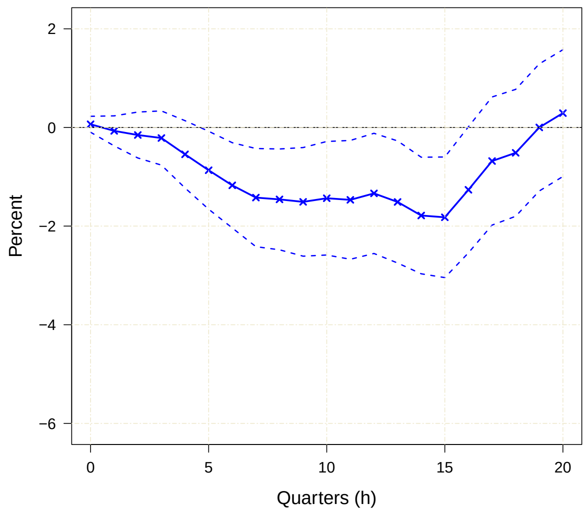
where $\mathbb{1}_{\left[i\in\mathcal{I}_{t-1}^{x,j}\right]}$ is an indicator function of firm i belonging in group $\mathcal{I}_{t-1}^{x,j}$. For example, the estimate for $\gamma_{(0,0.33),h}$ now captures the difference in capital accumulation between firms in the bottom tercile of liquidity ratios relative to those in the top tercile h quarters after a one standard deviation monetary shock.[60]

Panel A.1b presents the estimates for $\gamma_{j,h}$ in specification (A.1). In line with the results from the baseline continuous interaction specifications (1) and (2), the estimates show that firms with low liquidity ratios contract their capital relative to the firms in the top tercile, even when controlling for their position in the net leverage cross-section. And the heterogeneity in responsiveness is monotonic in the liquidity ratios. During the first two years after a 1 sd monetary shock, the firms in the middle group exhibit a 0.9% slower cumulative capital growth compared to the group, whereas for the bottom liquidity group this difference is almost 1.5%.

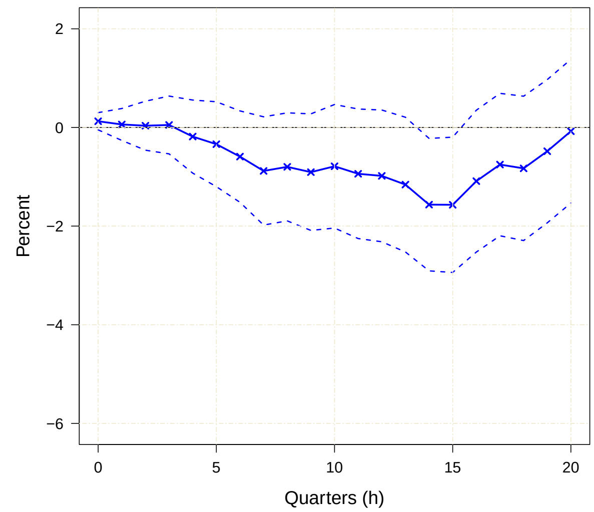
Figure A.2 presents estimates pertaining to the heterogeneity of capital accumulation responses as explained by firms' leverage and net leverage positions from the various specification alternatives above. Panel A.2a plots the coefficients on the leverage and monetary shock interaction without other cross-terms interacted with the monetary shock, i.e. the analogue of specification (1), replacing the negative of the liquidity ratio with the leverage ratio. The negative estimates indicate that firms with higher leverage at the time of a contractionary monetary shock tend to experience relatively slower capital growth in the years to follow. The differences become statistically significant five quarters after, and start to revert about three years after the shock. Quantitatively, the estimates imply that in response to a 1 sd monetary policy shock as measured by fed funds futures rates, 10 pp higher leverage predicts about 0.17 pp lower fixed capital growth over the two years following the shock.

[59]That is, $\mathcal{I}_t$ is partitioned into the groups $\left\{\mathcal{I}_t^{x,(0,0.33)}, \mathcal{I}_t^{x,(0.33,0.66)}, \mathcal{I}_t^{x,(0.66,1)}\right\}$, separately for $x \in \{\ell, \tilde{b}\}$.

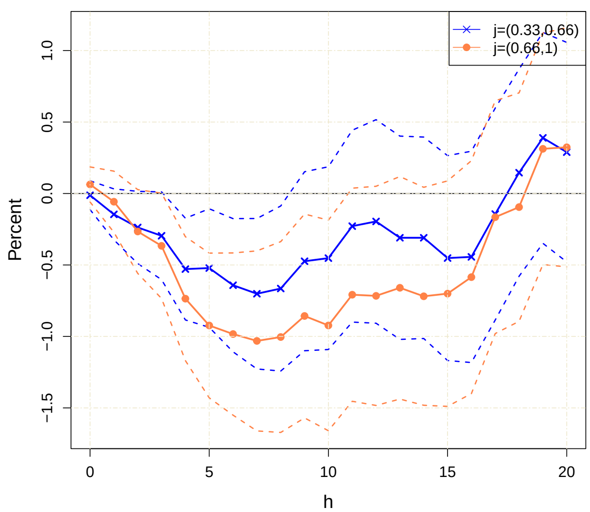
[60]$W_{i,t-1}$ contains log(size), and yearly sales growth, alongside the financial position indicators $\mathbb{1}_{\left[i\in\mathcal{I}_{t-1}^{x,j}\right]}$, for $x \in \{\ell, \tilde{b}\}$, $j \in \mathbb{J}^x$. Y_{t-1} again contains real GDP growth and the level of the federal funds rate in quarter $t-1$.



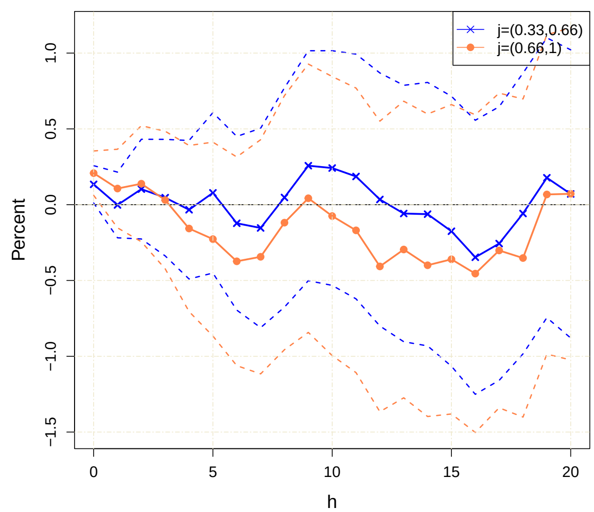
(a) Leverage, spec (1)



(b) Leverage, spec (2)



(c) Net leverage, no liquidity ratio bins



(d) Net leverage, spec (A.1)

Figure A.2: Heterogeneity in responses of capital accumulation conditional on leverage

Notes: Point estimates and 95% confidence intervals for the response heterogeneity predicted by firms' leverage or net leverage positions. Panel (a): Estimates for ψ_h from estimating the leverage (b) only analogue of specification (1), without controlling for liquidity ratio and monetary shock cross-term:

$$\Delta_h \log(k_{i,t+h}) = f_{i,h} + d_{n,h,t+h} + \Theta_h' W_{i,t-1} + \psi_h b_{i,t-1}\varepsilon_t^m + \Phi_h' \tilde{b}_{i,t-1} Y_{t-1} + u_{i,h,t+h}$$

Panel (b): Estimates for ψ_h from estimating specification (2), with $Z_{i,t-1}$ consisting of leverage. Panel (c): Estimates for $\psi_{j,h}$ from estimating the net leverage ($\tilde{b}$) only analogue of specification (A.1), without controlling for liquidity ratio bin and monetary shock interactions:

$$\Delta_h \log(k_{i,t+h}) = f_{i,h} + d_{n,h,t+h} + \Theta_h' W_{i,t-1} + \sum_{j \in \mathbb{J}^{\tilde{b}}} \left[\psi_{j,h}\varepsilon_t^m + \Phi_{j,h}' Y_{t-1}\right] \times \mathbb{1}_{\left[i \in \mathcal{I}_{t-1}^{\tilde{b},j}\right]} + u_{i,h,t+h}$$

Panel (d): Estimates for $\psi_{j,h}$ from estimating specification (A.1). Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

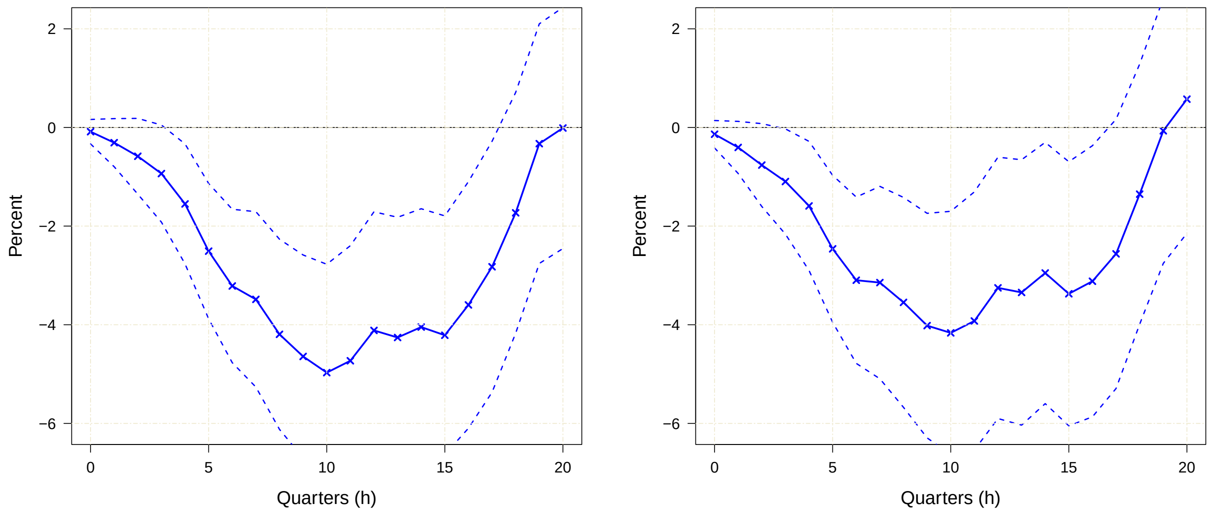
Panel A.2b illustrates that when simultaneously controlling for the liquidity ratio, as in specification (2), the relevance of leverage in explaining differences in firms' capital accumulation responses over the medium run disappears, with slightly significant estimates remaining at the 14 and 15 quarter horizon. On the other hand, as seen in Figure A.1a, the explanatory power of low liquid assets in characterizing more negative capital stock responses over the one- and two-year horizons survives while controlling for leverage.

Analogously, when grouping firms into tercile-bins based on net leverage, and not controlling for liquidity ratio positions, the estimates in Panel A.2c show that firms with higher net leverage at the time of a contractionary monetary policy shock tend to experience relatively slower fixed capital growth thereafter. During the first two years after a 1 sd monetary shock, the firms in the middle net leverage group exhibit a 0.7% slower cumulative capital growth compared to firms with net leverage in the bottom tercile, whereas for the top net leverage group this difference is about 1.0%. And again, in Panel A.2d one sees that when including controls which interact the monetary shock with indicators for firms' positions in the cross-section of liquidity ratios, the predictive power of the net leverage bins disappears.

These results on higher indebtedness predicting more negative responses of capital accumulation in response to contractionary monetary shocks are well in line with the findings by Anderson and Cesa-Bianchi (2023). On the contrary, Ottonello and Winberry (2020) emphasize estimates based on Compustat data which suggest that firms with higher leverage respond relatively *more positively* (or equivalently, less negatively) to contractionary monetary shocks. They point out the importance of using *within-firm* variation in leverage, namely $b_{i,t-1} - \mathbb{E}_i[b_{i,t}]$, to help in controlling for permanent differences in firm leverage when reaching this result. Because of this sensitivity of the results on leverage to such data transformation considerations, I focus this paper's main empirical predictions on the liquidity ratio dimension. I verify in Appendix A.2.4 below that the main result of lower liquidity ratios predicting more negative capital accumulation responses to contractionary monetary policy shocks survives when considering only within-firm variation in liquidity ratios.

A.2.2 Dropping Aggregate Controls

Figure A.3 presents the coefficient estimates for γ_h from alternative versions of specifications (1) and (2) in which the liquidity ratio and the other firm-level controls are not interacted with the aggregates' vector Y_{t-1} which contains real GDP growth and the level of the federal funds rate. The estimates indicate that when dropping these controls, the main results of Section 2.3 on the explanatory power of liquidity ratios for capital accumulation after monetary shocks become significantly stronger.



(a) No covariate cross-terms, spec (1), no Y_{t-1} (b) With covariate cross-terms, spec (2), no Y_{t-1}

Figure A.3: Heterogeneity in responses of capital accumulation conditional on liquidity ratio, not controlling for interactions with aggregates Y_{t-1}

Notes: Point estimates and 95% confidence intervals for γ_h from estimating specifications (1) and (2), when dropping the interaction terms between aggregate controls Y_{t-1} and firm characteristics $\ell_{i,t-1}$ and $Z_{i,t-1}$. Covariates included in $Z_{i,t-1}$ in the (2) analogue for panel (b) are log size, distance to default, share of short-term debt, and yearly sales growth. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

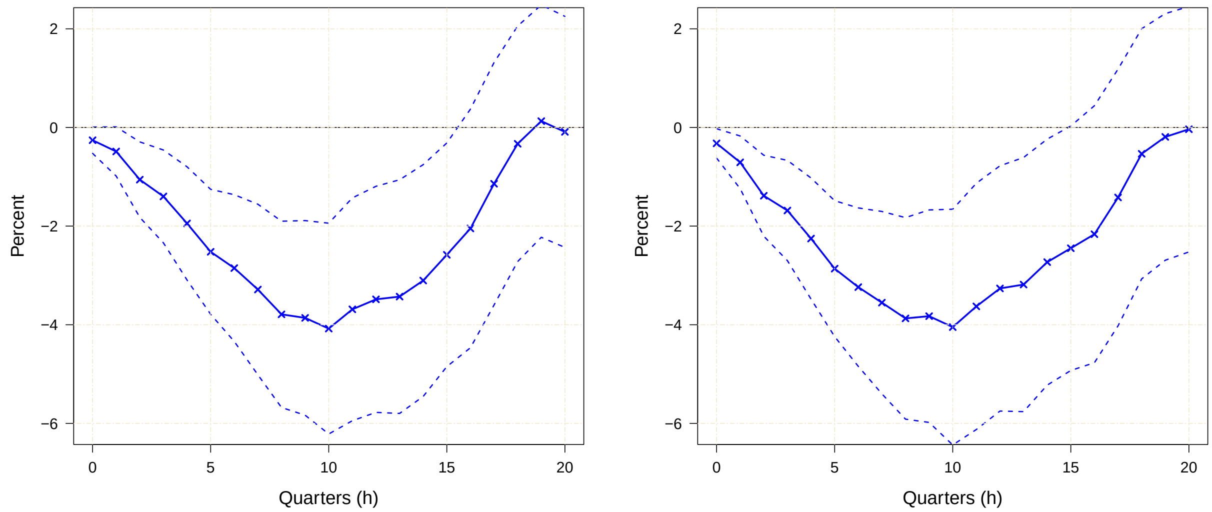
A.2.3 Extending Sample Period Past the Great Recession

Figure A.4 presents the coefficient estimates for γ_h from specifications (1) and (2) when extending the sample period to 1990Q1–2016Q4, past the Great Recession and into the zero lower bound period. The estimates indicate that the main results of Section 2.3 on the explanatory power of liquidity ratios for capital accumulation after monetary shocks become stronger, both economically and statistically.

A.2.4 Firm-Level Demeaned Liquidity Positions

The analysis by Ottonello and Winberry (2020) emphasizes that when estimating heterogeneity in firms' responsiveness to monetary policy shocks by interacting simple measures of observables such as leverage or the liquidity ratio with the monetary shock, part of the uncovered response heterogeneity could be explained by permanent differences across firms. And this could potentially affect the interpretation of the estimates.

Figure A.5 presents the estimates of γ_h from variations of specifications (1) and (2) where instead of the liquidity ratio $\ell_{i,t-1}$ I interact with the monetary shock the within-firm de-



(a) No covariate cross-terms, spec (1) (b) With covariate cross-terms, spec (2)

Figure A.4: Heterogeneity in responses of capital accumulation conditional on liquidity ratio, 1990Q1–2016Q4 sample

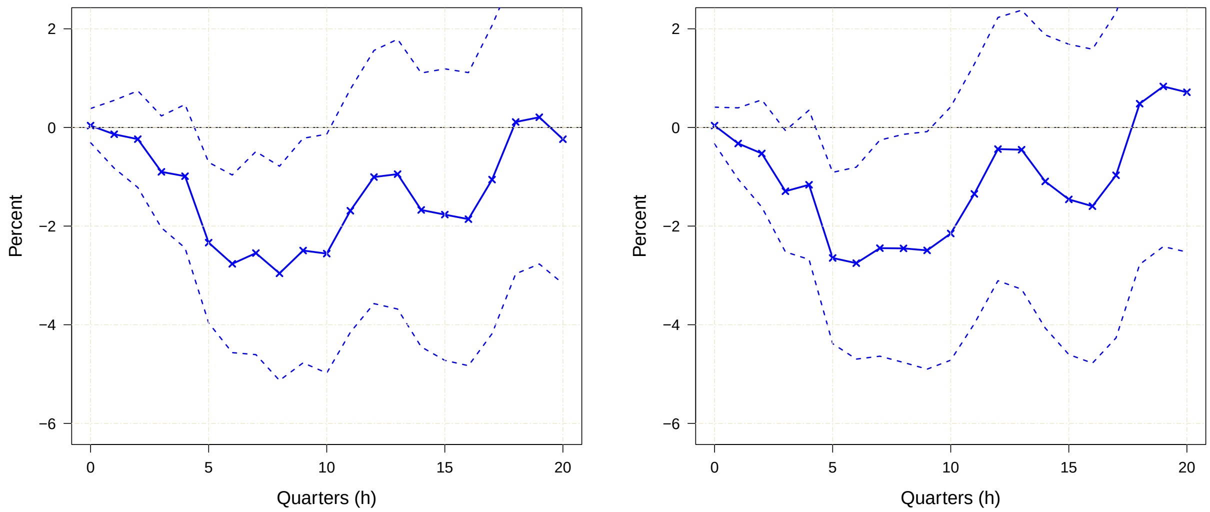
Notes: Point estimates and 95% confidence intervals for γ_h from estimating specifications (1) and (2), when using sample period 1990Q1–2016Q4. Covariates included in $Z_{i,t-1}$ in specification (2) for panel (b) are log size, distance to default, share of short-term debt, and yearly sales growth. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

meaned liquidity ratio $(\ell_{i,t-1} - \mathbb{E}_i[\ell_{i,t}])$. Comparing these estimates to those in Figure 1 shows that the main results on lower liquidity ratios predicting more negative capital accumulation in response to contractionary monetary shocks still stand, even when considering only within-firm variation in liquidity ratios. Moreover, the point estimates of the peak response heterogeneity and their dynamics are very similar across the demeaned and non-demeaned specifications. It is only that the demeaned specification yields slightly less precise estimates, which is why I present the results at the industry-standard 90% confidence level and not at the more conservative 95% level as in the remaining figures.[61] In Appendix B.7, I illustrate with data simulated from the model of Section 3 that this drop in precision could be explained by the fact that removing firm-specific means from finite sample time-series of observables can actually lead to bias towards zero of the relevant estimates.

A.2.5 Jarocinski and Karadi (2020) or Romer and Romer (2004) Shock Identification

Figure A.6 presents the estimates for γ_h from specification (1) when using two alternative monetary shock identification approaches. Panel A.6a plots the estimates from employing

[61] The estimates remain statistically significant at the 95% level in a slightly smaller subset of horizons h.



(a) No covariate cross-terms, spec (1) (b) With covariate cross-terms, spec (2)

Figure A.5: Heterogeneity in responses of capital accumulation conditional on within-firm demeaned liquidity ratio

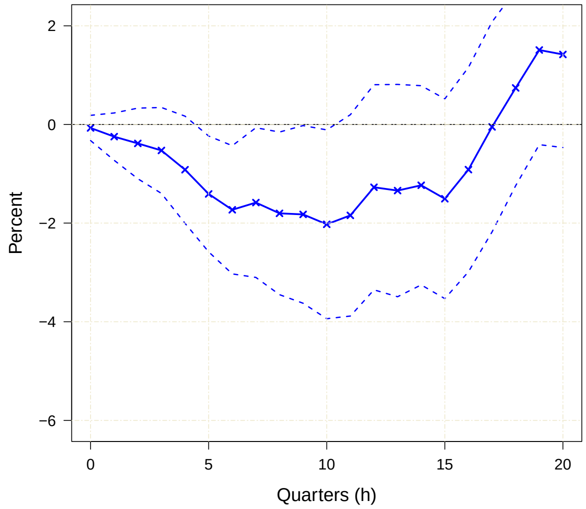
Notes: Point estimates and 90% confidence intervals for γ_h from estimating alternative versions of specifications (1) and (2), where $\ell_{i,t-1}$ is replaced by the within-firm demeaned $(\ell_{i,t-1} - \mathbb{E}_i[\ell_{i,t}])$. Covariates included in $Z_{i,t-1}$ in the (2) analogue for panel (b) are log size, distance to default, share of short-term debt, and yearly sales growth. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

measures of monetary policy shocks ε_t^m constructed using the 'poor man's sign restriction shock series' by Jarocinski and Karadi (2020). Panel A.6b presents the estimates from using shocks constructed using the approach of Romer and Romer (2004).[62] In both cases, I aggregate the corresponding monthly shock series to quarterly by summing within quarter and normalizing the ε_t^m series by their standard deviation between 1990Q1–2016Q4. The Romer and Romer (2004) shocks induce differences between firms' capital accumulation which appear slightly earlier than with the baseline high-frequency identified shocks in Figure 1, in line with the fact that in local projections, the latter induce long-lived hump-shaped responses of short rates while the effects of the Romer-Romer shocks are more short-lived – see Figures 2B and 3B in Ramey (2016).

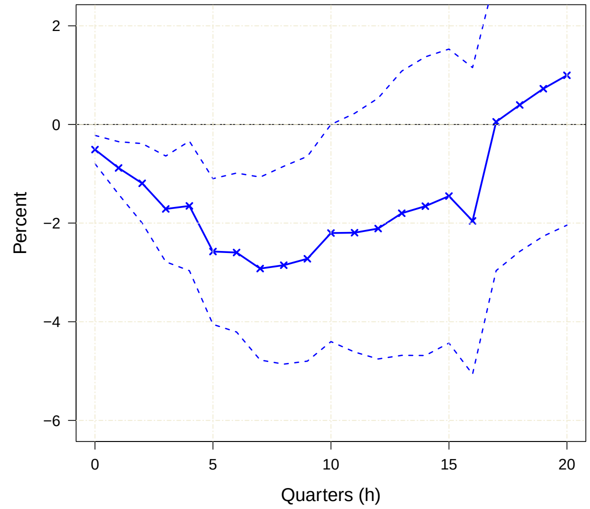
A.2.6 Panel Regression Estimates Conditional on Firm Age

Following Cloyne et al. (2023), I construct a proxy for firms' age as time since incorporation based on the Worldscope database. To illustrate that the main empirical findings of Section

[62] More specifically, I use the shock series constructed by Ramey (2016) and updated by Wieland and Yang (2017).



(a) Jarocinski and Karadi (2020) shocks



(b) Romer and Romer (2004) shocks

Figure A.6: Heterogeneity in responses of capital accumulation conditional on liquidity ratio, with alternative shock identification approaches

Notes: Point estimates and 95% confidence intervals for γ_h from estimating specification (1) using alternative monetary shock identification approaches. Panel (a): ε_t^m constructed based on the Jarocinski and Karadi (2020) 'poor man's sign restrictions' approach. Panel (b): ε_t^m constructed based on the Romer and Romer (2004) approach. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

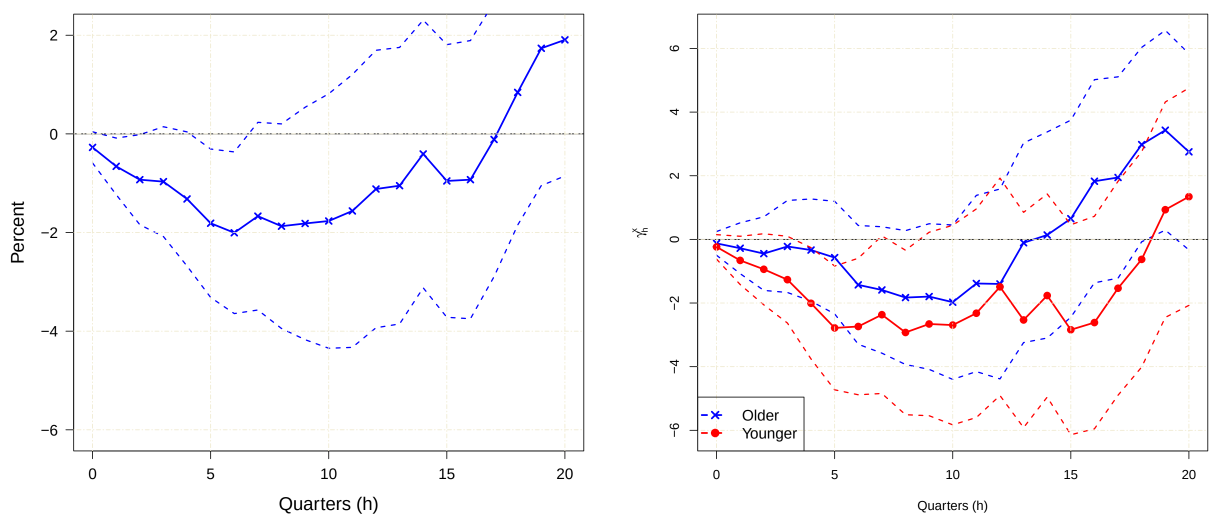
2.3 hold also when controlling for firm age, I conduct two different estimations.

First, I consider firm age simply as an additional, continuous covariate among the vector $Z_{i,t-1}$ in specification (2). Panel A.7a presents the estimates for γ_h from doing so. The estimates for γ_h are slightly smaller in absolute magnitude compared to the baseline estimates in Panel 1b, but still indicate that firms with low liquid asset holdings exhibit relatively weaker capital growth after contractionary monetary shocks. It is important here to note that while the confidence bands for the estimates widen considerably, this is not caused by the fact that controlling for age interacted with the monetary shock takes away any explanatory power from the liquidity ratio, but rather the fact that for many firms the incorporation date data are missing, and the number of observations used in the estimation for Panel A.7a is more than 25% smaller than in the baseline. That is, the estimates for γ_h would be virtually indistinguishable from those in A.7a if one dropped firm age from the vector $Z_{i,t-1}$ and simply replicated the estimation of the baseline specification (2) for the restricted sample of firms for whom age is observable.[63]

Second, I consider the "triple-interaction" specification between liquidity ratio positions,

[63]Results not shown, but available upon request.

a firm age indicator and the monetary shock to estimate whether the baseline heterogeneity in capital accumulation responses predicted by liquidity ratios is different for younger versus older firms. That is, I allow the estimate for γ_h (and all other coefficients) in specification (1) to differ depending on whether firms were young or old at the time of the monetary shock. To do so, I consider the cutoff for being "younger" as 15 years. The estimates for γ_h for younger and older firms are presented in Panel A.7b. Among both young and old firms, the point estimates are negative, indicating that within both groups, lower liquidity ratios predict more negative capital growth after contractionary monetary shocks. However, due to the lower coverage of age data and the loss of implied observations discussed above, the heterogeneity predicted by liquidity ratios among older firms is not statistically significant at the 95% level. The larger economical and statistical significance of heterogeneity among the young compared to the older firms aligns with the common idea that financial considerations and frictions are very likely more important for the investment behavior of younger firms.



(a) With age cross-term, spec (2) (b) Age-specific liquidity ratio cross-terms

Figure A.7: Heterogeneity in responses of capital accumulation conditional on liquidity ratio, controlling for firm age

Notes: Panel (a): Point estimates and 95% confidence intervals for γ_h from estimating specification (2), with covariates included in $Z_{i,t-1}$ being log size, distance to default, share of short-term debt, yearly sales growth, and age. Panel (b): Point estimates and 95% confidence intervals for γ_h from estimating the extension of (1), allowing for the coefficients in γ_h, Θ_h, and Ω_h to differ depending on whether the firm was "Younger" or "Older" at time $t-1$. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

A.2.7 Level Effects of Monetary Shocks on Capital Accumulation

As the main local projection specifications in Section 2 include an industry-time fixed effect to focus the analysis on between-firm variation within industry, they do not allow to identify the overall "level" effect of monetary shocks on firms' capital accumulation and compare them to the heterogeneity explained by firms' liquidity positions. In order to do so, I consider a variation of specification (A.1) which drops the industry-time dummies $d_{n,h,t+h}$, allows response heterogeneity to be explained only by firms' liquidity ratio positions, and includes the monetary shock ε_t^m as a separate regressor:

$$\Delta_h \log(k_{i,t+h}) = f_{i,h} + \delta_h \varepsilon_t^m + \Theta_h' W_{i,t-1} + \sum_{j \in \mathbb{J}^\ell} \left[\gamma_{j,h} \varepsilon_t^m + \Omega_{j,h}' Y_{t-1}\right] \times \mathbb{1}_{\left[i \in \tilde{\mathcal{I}}_{t-1}^{\ell,j}\right]} + u_{i,h,t+h} \quad \text{(A.2)}$$

Following the main specifications in Section 2, the aggregate vector Y_{t-1} again contains real GDP growth and the level of the federal funds rate in quarter $t-1$. The firm-specific controls included in $W_{i,t-1}$ again contain log(size), and yearly sales growth, alongside the liquidity ratio group indicators $\mathbb{1}_{\left[i \in \tilde{\mathcal{I}}_{t-1}^{\ell,j}\right]}$.[64] In addition, for notational brevity, $W_{i,t-1}$ also includes the aggregate controls included in Y_{t-1}, and the sampled firms' mean cross-sectional lagged yearly capital growth – to control for the cycle in the outcome variable.

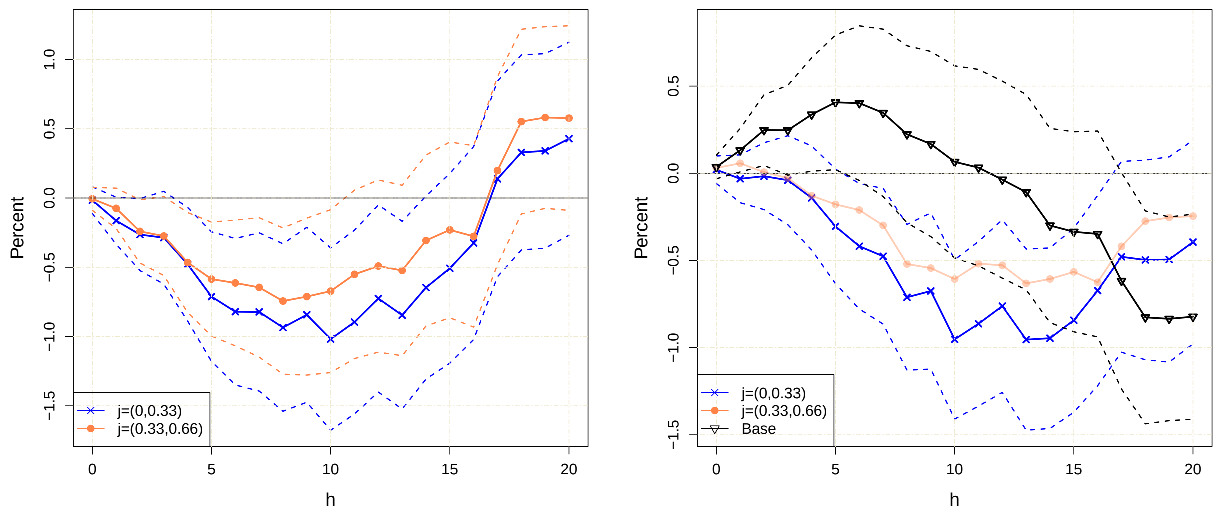
Now, δ_h in (A.2) captures the effect of monetary policy shocks on the h-quarter capital accumulation of the reference group (high-liquidity) firms, and $\delta_h + \gamma_{j,h}$ on the remaining liquidity groups. In order to conveniently relate the groups' responsiveness to the implied aggregate capital accumulation of sampled firms, I consider a slightly different partitioning of firms into liquidity bins. Instead of partitioning them based on terciles into groups $\mathcal{I}_t^{\ell,j}$ which contain exactly a third of the firms in the sample at time t, I construct high-, medium- and low-liquidity groups $\tilde{\mathcal{I}}_t^{\ell,j}$ which contain exactly one third of the total fixed capital of firms in the Compustat sample at time t.[65] This way, each group contributes an equal share to aggregate capital accumulation, and to first order, the monetary shock elasticity of the aggregate Compustat capital stock equals the mean of the groups' individual elasticities.

Panel A.8a presents the estimates for $\gamma_{j,h}$ in (A.2), again illustrating the main results that firms with lower liquidity ratios contract their capital stock relative to others in response to a contractionary monetary shock. Although with the partitioning done based on equal

[64] Note that because the left hand side of (A.2), i.e. h-quarter capital growth is stationary, I demean the nonstationary log firm size variable on the right hand side by subtracting the quarter t sample mean log firm size.

[65] To be precise, the partitioning is constructed into the groups, $\left\{\tilde{\mathcal{I}}_t^{\ell,(0,0.33)}, \tilde{\mathcal{I}}_t^{\ell,(0.33,0.66)}, \tilde{\mathcal{I}}_t^{\ell,(0.66,1)}\right\}$ based on $\tilde{\mathcal{I}}_t^{\ell,(\alpha,\beta)} \equiv \left\{i \in \mathcal{I}_t | \ell_{i,t} \in \left[\tilde{q}_{\ell,t}^{\alpha}, \tilde{q}_{\ell,t}^{\beta}\right]\right\}$ where $\tilde{q}_{\ell,t}^{\alpha} \equiv \max_{i \in \mathcal{I}_t} \left\{\ell_{i,t} \middle| \sum_{i' \in \mathcal{I}_t : \ell_{i',t} \leq \ell_{i,t}} k_{i,t} \leq \alpha \sum_{i' \in \mathcal{I}_t} k_{i',t}\right\}$.

capital size, the differences between the middle- and low-liquidity groups' responses become relatively small, they still contract significantly compared to the high-liquidity group.



(a) $\gamma_{j,h}$ estimates

(b) δ_h and $\delta_h + \gamma_{j,h}$ estimates

Figure A.8: Heterogeneity and absolute responses of capital accumulation conditional on liquidity ratio

Notes: Panel (a): Point estimates and 95% confidence intervals for $\gamma_{j,h}$ from estimating specification (A.2). Panel (b): Point estimates and 95% confidence intervals for δ_h (*Base*) and $\delta_h + \gamma_{j,h}$ from estimating specification (A.2), with $j = (0.33, 0.66)$ shaded and confidence intervals omitted. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

Panel A.8b presents the absolute, level responses of the three liquidity groups. The estimates indicate a slight expansion of the high-liquidity group during the first two years after the contractionary monetary shock, and a turnaround to negative cumulative effects at longer horizons. Through the lens of the structural model of Section 3, this expansion is explained through general equilibrium effects leading to a fall in capital prices, inducing high-liquidity firms to take advantage and expand early on after the shock. At the same time, the middle- and low-liquidity firms contract their capital stocks, by about 0.5% over the two year horizon after a 1 sd contractionary monetary shock, with the low group reaching a peak effect of almost 1% about three years after.

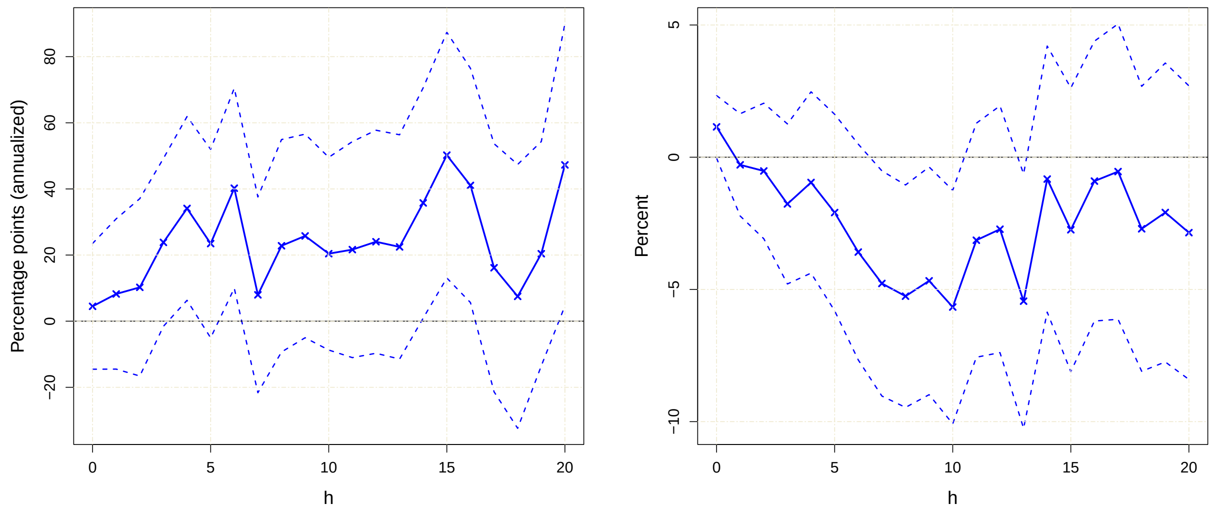
As for the implied responsiveness of aggregate capital of the sampled Compustat firms, taking the average of the responses depicted in Panel A.8b implies that at the two year ($h = 8$) horizon, the capital stock drops by about -0.34%. Considering an annual depreciation rate of 10%, this would be consistent with a fall of about 1.7% ($\approx -0.34\%/(2 \times 0.10)$) in aggregate investment. Given that the 1 sd monetary shock corresponds to a roughly 25 bp quarterly change in the federal funds rate, as discussed in Footnote 19, this response elasticity is on the higher side, but in line with magnitudes estimated in the literature (e.g., see Cloyne et al. (2023)).

A.2.8 Interest Rate and Debt Responses Conditional on Debt Issuance Proxy

Figure A.9 provides estimates for the heterogeneity in the responses of the average interest rate firms pay on their debt and their total debt level, as predicted by the debt issuance probability $\hat{D}^4_{i,t-1}$, as constructed in Section 2.5. The estimates come from estimating a variation of the baseline specification (1), by replacing the outcome variable to either be the interest rate or the log total debt, and on the right hand side replacing the negative of the liquidity ratio $\ell_{i,t-1}$ with the proxy $\hat{D}^4_{i,t-1}$. I construct a measure of the firm's average interest rate based on the ratio of Compustat's reported *Total Interest and Related Expense* and the one quarter lagged stock of total debt. While this yields an imprecise proxy for the effective borrowing costs of a firm, and data on debt contracts or bonds would provide much more precise estimates of *marginal* financing costs, e.g. as used by Anderson and Cesa-Bianchi (2023), the estimates suggest that in response to a contractionary monetary policy shock, firms that are more likely to issue new debt see their average interest expenses increase by relatively more, and they reduce their total borrowing relative to other firms. In terms of magnitudes, the estimates in Panel A.9a indicate that in response to a 1 sd contractionary monetary shock, i.e. a roughly 25 bp quarterly change the annualized fed funds rate, every 10 pp increase in the debt issuance proxy implies a 4 bp stronger pass through to the firm's average interest rate paid 6 quarters later.

A.3 U.S. Corporate Liquid Asset Portfolio Shares

Table A.1 presents the composition of the U.S. nonfinancial corporate sector's liquid asset portfolio based on the Federal Reserve Board Flow of Funds Accounts data. The shares are computed as the time-averages of the respective shares in each quarter over 1990Q1–2007Q4. In choosing the types of instruments considered among the portfolio of liquid assets, I seek to follow the definition of Compustat's *Cash and Short-Term Investments* as closely as possible.



(a) Average interest rate

(b) Stock of log total debt

Figure A.9: Heterogeneity in responses of average interest rate and stock of log debt conditional on debt issuance probability

Notes: Point estimates and 95% confidence intervals for γ_h from estimating a variation of baseline specification (1), focusing on heterogeneity predicted by the debt issuance probability proxy $\hat{D}^4_{i,t-1}$:

$$\Delta_h y_{i,t+h} = f_{i,h} + d_{n,h,t+h} + \Theta_h' W_{i,t-1} + \gamma_h \hat{D}^4_{i,t-1} \varepsilon^m_t + \Omega_h' \hat{D}^4_{i,t-1} Y_{t-1} + u_{i,h,t+h}$$

where the outcome variable $y_{i,t}$ is either the average interest rate, in Panel (a), or the log stock of firms' total debt, in Panel (b). The average interest rate is measured in annualized basis points. Confidence intervals based on two-way clustered standard errors at firm and SIC 3-digit industry-time levels.

Table A.1: Asset shares in the US nonfinancial corporate sector's liquid assets portfolio

Asset	Share
Checkable deposits and currency	25.5%
Time and savings deposits	25.4%
Money market fund shares	21.3%
Security repurchase agreements	0.6%
Commercial paper	5.4%
Treasury securities	5.6%
Agency- and GSE-backed securities	1.9%
Municipal securities	5.1%
Mutual fund shares	9.2%

Source: Quarterly Flow of Funds Accounts, time-average shares over 1990–2007.

B Model Appendix

B.1 Discussion of Key Assumptions

The following discusses the implications of and rationale behind some of the key assumptions made in the setup of the model in Section 3.

The presence of corporate taxation. Taxes on firms' earnings, with tax-deductible interest payments, introduce a tax advantage of using debt financing. This is a common, and realistic, assumption in models of corporate finance and firm dynamics to incentivize firms to continuously use debt, in contrast to paying it down and becoming net lenders as they mature. This means that firms optimally choose to never "save out" of financial constraints, and perpetually fluctuate between diverse financial positions, occasionally hitting the borrowing constraint, depending on their realized idiosyncratic productivity and debt issuance cost shocks. This allows the model to match realistic features of the cross-sectional distribution of firms, such as their debt issuance behavior and liquid asset positions. The additional presence of exogenous exit and entry of firms simply adds an additional life cycle dimension, but is not necessary for financial frictions to remain relevant in the model's stationary equilibrium.

Fixed debt adjustment costs. The introduction of fixed costs in debt issuance allows the model to generate features of firm-level debt and cash management behavior observed empirically, absent from an analogous model otherwise. For example, as documented by Bazdresch (2013), based on various measures of lumpiness, Compustat firms' debt issuances tend to be concentrated on a small fraction of observations, importantly, even more so than investments in fixed capital. As mentioned above, evidence for at least some non-convexities in the cost of adjusting financial positions has also been documented, for example, based on the observed infrequent rebalancing of firms' capital structures (Leary and Roberts, 2005). In addition, explicit analysis of commercial banks' underwriting spreads of debt issues, e.g. by Kim et al. (2008), has uncovered significant economies of scale, i.e. a negative relationship between issue size and the spreads, suggesting the presence of a fixed cost component. Moreover, the simple correlation between contemporaneous cash accumulation and debt issuance is *positive* in the Compustat data – a basic feature which would be difficult to rationalize with a model in which debt was perfectly liquid, especially if borrowing rates were higher than the returns on cash. Also, importantly for the focus of this paper, non-convex transaction costs in financial adjustment give rise to firms which are at times endogenously disconnected from debt markets. This represents the notion that not all firms are actively responding to fluctuations in corporate debt rates, especially if they have abundant cash reserves and are not planning to borrow in the near future, as documented by Sharpe and Suarez (2021).

In practice, fixed cost components in the act of debt issuance, especially in the case of bond issuance, could arise from underwriting fees paid to the underwriters (e.g., investment or commercial banks) who sell the debt; accounting fees to accountants and auditors who help the company prepare its financial statements; rating agency fees for rating the issues; or legal fees from drafting and reviewing loan agreements or issuance documents. As for bank and other, e.g. syndicated loans, fixed costs could arise from due diligence fees covering the cost of conducting due diligence on the borrower; loan syndication fees (e.g., the upfront fee) charged by the lead arranger for structuring the loan and arranging a group of lenders; or legal fees related to preparing the loan documentation. Paying a long-term loan back early often results in prepayment penalties.[66] More broadly, small fixed cost components which keep firms from continuously adjusting their outstanding debt could arise from internal administrative costs, whereby engaging in the issuance or early repayment of debt could require CFO and financial staff time and effort, e.g. due to gathering and preparing financial information or finding a lender that offers the most beneficial loan terms.

The stochastic nature of the modeled costs captures the idea that otherwise similar firms could have varying opportunities of raising debt at any given point in time due to unmodeled differences in characteristics and the circumstances faced in financial management. The continuous distribution of costs generates smoothness of firms' aggregate policy functions, useful in clearing markets when solving for general equilibrium. The assumption that the adjustment cost can be covered by shareholders ensures that the optimal decision of debt adjustment follows a simple cutoff policy, allowing for computational efficiency. The calibrated average costs are very small in magnitude relative to the raised funds and would thus not induce considerable effects on available funds if financed internally.

Corporate debt as a geometrically decaying fixed coupon. The most common types of debt instruments used by Compustat firms covered by the Capital IQ Capital Structure database are senior bonds and notes.[67] And the most common corporate bonds are noncallable, nonputable, nonconvertible straight bonds with fixed coupons (Edwards et al., 2007). While most non-bank debt has fixed rates, bank debt tends to have floating rates (Ippolito et al., 2018). I model long-term corporate debt as a geometrically decaying coupon as it allows to maintain computational tractablity, as common in the literature. Also, assuming fixed coupon payments which do not respond to changes in market interest rates allows the model to distinguish from the analysis by Ippolito et al. (2018) who emphasize the relevance

[66]Depending on the lender and the specific contract, all the listed fees could either be charged as a fixed amount per issuance, or in other cases as a fraction of the issuance size.

[67]A positive amount outstanding is reported by about two thirds of firm-year observations with non-zero debt between 2002 and 2009, as documented by Colla et al. (2013)

of floating rates in the impact of monetary policy shocks on firms.

I abstract from distinguishing between different maturities of firms' debt. Unsecured, liquid short-term borrowing could be introduced by setting the lower bound on liquid asset holdings to $m' \geq -\bar{m}$ for some $\bar{m} > 0$. This would shift the reference point for the lowest level of (net) liquid asset holdings but not change anything of substance in the economics of the firms' problem. Compustat firms' short-maturity debt outstanding is considerably smaller than their long debt, so a recalibration of the model would retain a prominent role for the latter. To model a notion of credit lines with interest rates different from the returns on cash and long-term debt, one could assume the return on $m' < 0$ to be different (e.g., r^b_{t+1}) from the return r^m_{t+1} on $m' > 0$. Importantly for the main mechanisms under consideration in this paper, note that the majority of credit line facilities tend to feature *variable*-rate loans with fixed spreads (Greenwald et al., 2021). Thus, if one were concerned that the low-liquidity firms in the data held little cash because they had better access to credit lines as liquidity buffers, tapping into credit lines at the time of a monetary shock would expose these low-cash firms to induced borrowing cost fluctuations, much like the debt issuing firms in the model at hand.

Working capital constraint. The purpose of the working capital constraint (4) is to include empirically relevant firms' cash holding motives to allow the model calibration to more precisely match the corporate liquid asset holdings observed in the data. Namely, in the absence of the working capital constraint, the underlying model with debt adjustment costs features an incentive for firms to accumulate cash and build a liquidity buffer to take advantage of good investment opportunities whenever they arise (in the form of favorable productivity shocks), without fully having to rely on potentially costly, and limited, debt financing. This is a *precautionary motive* for holding cash, documented by an extensive corporate finance literature (Opler et al., 1999). However, even in the absence of precautionary motives, firms hold cash in reality simply to facilitate their day-to-day operations of paying suppliers and workers, while receiving cash from clients – an *operational motive*, also documented to account for a considerable share of firms' cash (Lins et al., 2010). The working capital constraint is a conventional way to introduce this additional motive. Note, importantly, that the presence of the working capital constraint is not instrumental for the model's performance in matching the empirical results of Section 2 on monetary shock responsiveness. The precautionary motive on its own is sufficient to generate a firm distribution where the low-liquidity ones are more likely to issue debt, and respond significantly more negatively to contractionary monetary policy shocks.[68]

[68] As noted in Section 3.2, the strength of the operational motive is governed by the difference $(\nu - \phi_w)$, with ν being the labor share. In the calibration of Section 3.3.1, ϕ_w turns out to be only very slightly below

Non-negative dividends. The assumption that incumbent firms cannot (costlessly) raise equity is a common assumption in the macro-finance literature, ensuring that firms do not easily get around financial constraints. Furthermore, it proxies for the fact documented in empirical corporate finance that the costs related to equity issuances are significantly larger than those for debt issuance, as for example documented by Altinkiliç and Hansen (2000). Also, equity issuance is considerably more infrequent than debt issuance, even for Compustat firms (Bazdresch, 2013). Abstracting from equity issuance (e.g., studied by Jeenas and Lagos (forthcoming)) thus allows to focus the analysis of the paper on the debt financing margin. And nonetheless, any firms paying positive dividends in the model *do* adjust their capital structure to changes in equity financing costs (i.e., the owners' discount rate) by trading off the payment of dividends versus retaining earnings in the firm. Finally, while the empirical analysis in Section 2 is conducted based on Compustat data on publicly listed companies due to data availability considerations, I calibrate the structural model to match features of the whole population of firms in the U.S., adjusting for selection into the Compustat sample. Given that for private firms, new equity issuances are even more costly, this further warrants abstracting from explicitly modeling equity issuance activity.

Pass-through financial intermediary. I employ the concept of a financial intermediary who faces a reserve requirement in order to parsimoniously introduce a difference between the interest rates at which firms can borrow and the returns they earn on their liquid cash holdings (deposits). Empirically, such a spread arises because the corporate sector's liquid asset portfolio contains non-interest-bearing assets (see Appendix A.3), generating a spread between risk-free policy rates and the returns to firms' liquid asset holdings.[69] Moreover, to compare firms' responses to a monetary policy shock in the data and the model, introducing the spread allows to ensure that the firms in the model face similar fluctuations in relevant rates as they do empirically – such as the losses from holding non-interest-bearing assets increasing whenever nominal rates increase.

Capital adjustment costs at both aggregate and individual firm level. The introduction of convex adjustment costs on *aggregate* capital through a capital production sector is common practice in the quantitative business cycle literature. In models with firm financial frictions, it sets in motion the financial accelerator mechanism by inducing a positive relation between the price of capital and aggregate investment (Bernanke et al., 1999). Moreover,

ν, indicating that (4) introduces a quantitatively minor constraint on the firms' problem.

[69] In addition, the fact that firms borrow at interest rates greater or equal to the risk-free (policy) rate can drive another wedge between the cost of borrowing and the return to cash. The current, more conservative baseline specification abstracts from any wedges between the firms' borrowing costs and the risk-free policy rate. One could endogenize such a component of the spread by introducing an additional layer of financial frictions on the intermediary, e.g. following the structures in Bernanke et al. (1999) or Gertler and Kiyotaki (2011).

the aggregate capital adjustment costs also act as a dampening force on the dynamics of aggregate investment, leading to more realistic, smoothed aggregate investment behavior across time. The presence of *firm*-level capital adjustment costs is necessary to generate an explicit role for firms' cash holdings as a state variable, in order to study the relevance of firms' balance sheet liquidity for monetary transmission. In the absence of firm-level capital adjustment costs, capital would be a fully liquid asset. And the sum of a firm's market value of capital and its cash would be a sufficient endogenous state variable (alongside the "illiquid" long-term debt position), not the capital and cash separately.

B.2 Reformulation of Long-Term Debt

This Appendix shows how a long-term debt contract with a nominally fixed geometrically decaying coupon and tax-deductible interest payments, sold at a discount price can be rewritten as one in which the issuer chooses the total real funds raised and thereafter pays the implied one-period real interest rates alongside a pricipal payment.

Let the underlying debt contract on one unit of debt sold in t stipulate that in $t+1$ the firm repays a coupon of c_b nominal units' worth of the final good, γc_b in $t+2$, $\gamma^2 c_b$ in $t+3$, etc. Let q_t^b be the nominal price of a unit of such debt raised in t. If r_t^b is the implicit net nominal one-period return on this long-term debt between periods $t-1$ and t, then it must be that:

$$1 + r_t^b = \frac{\gamma q_t^b + c_b}{q_{t-1}^b} \tag{B.1}$$

Considering a given firm i, let $b_{i,t}^n$ the total number of units of this long-term debt that firm i exits period $t-1$ with. In period t, it is thus obliged to pay a coupon of $c_b b_{i,t}^n$ nominal units.

If the firm chooses not to adjust its debt, then it pays lenders the nominal amount $c_b b_{i,t}^n$, and carries forward the nominal debt outstanding $b_{i,t+1}^n = \gamma b_{i,t}^n$. The payment to lenders can be split into a nominal principal repayment component $\left(q_{t-1}^b - \gamma q_t^b\right) b_{i,t}^n$, and a nominal tax-deductible interest payment component, as the remainder, $\left[c_b - \left(q_{t-1}^b - \gamma q_t^b\right)\right] b_{i,t}^n$.

Defining $b_{i,t} \equiv \frac{q_{t-1}^b b_{i,t}^n}{P_{t-1}}$ as the *real* market value of firm i's debt leaving period $t-1$, these terms can be rewritten in units of the numeraire in t as follows. The real principal repayment component equals $\frac{1}{P_t}\left(q_{t-1}^b - \gamma q_t^b\right) b_{i,t}^n = \frac{P_{t-1}}{P_t}\left(1 - \gamma \frac{q_t^b}{q_{t-1}^b}\right) \frac{q_{t-1}^b b_{i,t}^n}{P_{t-1}} = \left(\frac{1}{\Pi_t} - \gamma_t\right) b_{i,t}$, where $\gamma_t \equiv \gamma \frac{q_t^b / P_t}{q_{t-1}^b / P_{t-1}} = \gamma \frac{q_t^b}{q_{t-1}^b} \frac{1}{\Pi_t}$. And the real tax-deductible interest payment component equals $\frac{1}{P_t}\left[c_b - \left(q_{t-1}^b - \gamma q_t^b\right)\right] b_{i,t}^n = \left[\frac{c_b}{q_{t-1}^b} - \left(1 - \gamma \frac{q_t^b}{q_{t-1}^b}\right)\right] \frac{P_{t-1}}{P_t} \frac{q_{t-1}^b b_{i,t}^n}{P_{t-1}} = \frac{r_t^b}{\Pi_t} b_{i,t}$, where the last equality uses (B.1). Thus, taking into account the tax-deductibility of interest payments, the non-adjusting firm experiences net outflow of real funds of $\left[\frac{1+(1-\tau) r_t^b}{\Pi_t} - \gamma_t\right] b_{i,t}$, and its real market value of debt evolves as $b_{i,t+1} = \frac{q_t^b}{P_t} b_{i,t+1}^n = \frac{q_t^b}{P_t} \gamma b_{i,t}^n = \gamma \frac{q_t^b / P_t}{q_{t-1}^b / P_{t-1}} \frac{q_{t-1}^b b_{i,t}^n}{P_{t-1}} = \gamma_t b_{i,t}$.

The problem of a firm that chooses to adjust its debt is equivalent to making the same principal repayment and tax-deductible interest payment as the non-adjuster, but then repurchasing the remaining debt outstanding $\gamma b_{i,t}^n$ at real cost $\frac{q_t^b}{P_t} \gamma b_{i,t}^n = \gamma_t b_{i,t}$, and being able to freely choose the debt outstanding $b_{i,t+1}^n$ going forward (in real terms $b_{i,t+1} = q_t^b b_{i,t+1}^n / P_t$). This results in the net outflow of real funds of $\left[\frac{1+(1-\tau) r_t^b}{\Pi_t}\right] b_{i,t} - b_{i,t+1}$, with $b_{i,t+1}$ being a choice of the firm.

B.3 Additional Details and Derivations in Baseline Model

B.3.1 Representative Household's Dynamic Problem

The representative infinitely-lived household derives utility from consumption of the final good c^h and supplies labor n^h for the real wage w_t. It saves its wealth in one-period risk-free debt L^h at net nominal return r_{t+1}^f and in one-period shares in firms. I denote the distribution of the household's ownership of the firms' shares using the measure Λ^h. The household also owns the financial intermediary and the capital, retail, and final good producers. The aggregate debt issuance costs, denoted $\Psi_{B,t}$, are rebated lump sum to the household. The Bellman equation for the representative household's lifetime utility is:[70]

$$\mathcal{V}_t^h \left(L^h, \Lambda^h\right) = \max_{c^h, n^h, B^{h\prime}, \Lambda^{h\prime}} \left\{\log(c^h) - \psi n^h + \beta \mathcal{V}_{t+1}^h \left(L^{h\prime}, \Lambda^{h\prime}\right)\right\}$$

$$\text{s.t. } c^h + L^{h\prime} + \int_{\mathbf{S}} \rho_{1,t}(k', m', b', z') \Lambda^{h\prime}(dk', dm', db', dz') \leq$$

$$\leq w_t n^h + \frac{1 + r_t^f}{\Pi_t} L^h + \int_{\mathbf{S}} \rho_{0,t}(k, m, b, z) \Lambda^h(dk, dm, db, dz) + div_t^I + \Xi_t^r + \Psi_{B,t} - T_t$$

$\rho_{0,t}(k, m, b, z)$ is the (*cum dividend*) real price of shares of firms entering period t with state (k, m, b, z), and $\rho_{1,t}(k', m', b', z')$ is the price of new shares of firms which begin the next period with the state (k', m', b', z').[71] div_t^I are the dividends from the financial intermediary. Ξ_t^r are the profits of the retail and capital goods producers and T_t denotes lump sum taxes raised by the government.

[70] For brevity, I leave out purchases of shares in the intermediary or the capital, retail, and final good producers. Given that the household must hold the shares of all firms in equilibrium, I am not explicitly imposing a no-shorting constraint on firm equity.

[71] I follow Khan and Thomas (2013) and use the notation which allows the household to choose its ownership of type (k', m', b', z') firms because the law of large numbers applies and the transition probabilities of z are known.

B.3.2 Financial Intermediary's Dynamic Problem

The representative, perfectly competitive financial intermediary takes in deposits D (at net nominal return r^m_{t+1}), potentially borrows in the one-period risk-free debt market L (at rate r^f_{t+1}), and lends the funds out in the form of purchasing long-term debt B from firms (at effective return r^b_{t+1}). And it faces the statutory reserve requirement requiring at least a fraction $\alpha_r \in [0,1]$ of the deposits to be held as reserves R at the monetary authority, paying a fixed net nominal return of $\bar{r}^r$. The intermediary pays real dividends div^I to the household and faces no other financial constraints apart from the statutory reserve requirement. The intermediary's recursive problem is given by:

$$\mathcal{V}^I_t(B,R,D,L) = \max_{div^I, B', R', D', L'} \left\{ div^I + M_{t+1}\mathcal{V}^I_{t+1}(B',R',D',L') \right\}$$

$$\text{s.t. } div^I \leq \frac{1+r^b_t}{\Pi_t}B + \frac{1+\bar{r}^r}{\Pi_t}R - \frac{1+r^m_t}{\Pi_t}D - \frac{1+r^f_t}{\Pi_t}L - B' - R' + D' + L'$$

$$R' \geq \alpha_r D'$$

$$B', R', D' \geq 0$$

B, R, D and L are the real corporate debt and reserves held, and the real deposits taken in and the real one-period debt borrowed, respectively, by the intermediary at the end of $t-1$. M_{t+1} is the real stochastic discount factor of the representative household as the owner of the intermediary.

Because there are no frictions in financing the intermediary through equity or one-period debt, the intermediary's equilibrium dividends div^I and one-period borrowing L are not uniquely determined. Without loss of generality, I suppose that the intermediary follows a simple financial policy of not acquiring any internal net worth, paying out all its profits (or losses) if any are realized due to unexpected shocks, and financing it's corporate lending activity (over and above reserves and deposits) fully by borrowing in the one-period debt market: $B = D + L - R = (1-\alpha_r)D + L$.

B.3.3 Price Setting and Final Good Production

The final good firm's optimization gives rise to the demand curve, for $j \in [0,1]$:

$$y_{j,t} = \left(\frac{p_{j,t}}{P_t}\right)^{-\varepsilon} Y_t$$

which retailers take as given. The aggregate price index equals $P_t = \left(\int_j p^{1-\varepsilon}_{j,t} dj\right)^{\frac{1}{1-\varepsilon}}$.

The recursive problem of a retailer, with previously set price $p_{j,t-1}$ and value function V_t^P can be written recursively as:

$$V_t^P(p_{j,t-1}) = \max_{p_{j,t},y_{j,t}} \left\{ \frac{1}{P_t} \left[p_{j,t}y_{j,t} - P_t^w y_{j,t} \right] - \frac{\phi_p}{2} \left(\frac{p_{j,t}}{p_{j,t-1}} - \bar{\Pi} \right)^2 Y_t + M_{t+1} V_{t+1}(p_{j,t}) \right\}$$
$$\text{s.t. } y_{j,t} = Y_t \left(\frac{p_{j,t}}{P_t} \right)^{-\varepsilon}$$

By taking the optimality conditions, imposing initial price symmetry $p_{j,t-1} = P_{t-1}, \forall j \in [0,1]$, and defining the markup of the retail goods producers as $\mathcal{M}_t \equiv \frac{P_t}{P_t^w}$, one can derive the standard non-linear New Keynesian Phillips curve as:

$$\left(\Pi_t - \bar{\Pi}\right) \Pi_t = \frac{\varepsilon}{\phi_p} \left[\mathcal{M}_t^{-1} - \frac{\varepsilon - 1}{\varepsilon} \right] + M_{t+1} \left(\Pi_{t+1} - \bar{\Pi}\right) \Pi_{t+1} \frac{Y_{t+1}}{Y_t}$$

Log-linearizing this around the steady state where $M_{SS} = \beta$, $\Pi_{SS} = \bar{\Pi}$, and $\mathcal{M}_{SS} = \frac{\varepsilon}{\varepsilon-1}$, yields the conventional log-linear NKPC that I employ:

$$\hat{\pi}_t = -\kappa_p \log(\mathcal{M}_t / \mathcal{M}_{SS}) + \beta \hat{\pi}_{t+1}$$

where $\hat{\pi}_t \equiv \log(\Pi_t) - \log \Pi_{SS}$, and $\kappa_p \equiv \frac{\varepsilon - 1}{\phi_p \Pi_{SS}^2}$ being the slope of the Phillips curve.

B.3.4 Law of Motion for the Distribution of Firms

Let the equilibrium policies of firms' choices in t be denoted $n_t(k,m,b,z)$, $\hat{\xi}_t(k,m,b,z)$, and $\left\{k_{t+1}^E(k,m,b,z), m_{t+1}^E(k,m,b,z), b_{t+1}^E(k,m,b,z)\right\}_E$, with $E \in \{A,N\}$, denoting the choices of (k', m', b') conditional on adjusting debt or not, respectively. Let the function G denote the cumulative distribution function of ξ. The firms' policy functions then imply a law of motion for the distribution of firms, for all $(\mathcal{A}, z_j) \in \mathcal{S}$:

$$\begin{aligned}
\mu_{t+1}(\mathcal{A}, z_j) =& (1-\eta) \int_{\mathbf{S}} \left\{ G\left(\hat{\xi}_t(k,m,b,z_i)\right) \Gamma_t^A(\mathcal{A},k,m,b,z_i) \right. \\
&+ \left. \left[1 - G\left(\hat{\xi}_t(k,m,b,z_i)\right)\right] \Gamma_t^N(\mathcal{A},k,m,b,z_i) \right\} \pi_{ij} \mu_t(dk,dm,db,dz_i) \\
&+ \eta \pi_j^e \mathbb{1}\left\{(k_0, m_0, 0) \in \mathcal{A}\right\}
\end{aligned} \tag{B.2}$$

where, for $E \in \{A, N\}$:

$$\Gamma_t^E(\mathcal{A},k,m,b,z_i) \equiv \mathbb{1}\left\{ \left(k_{t+1}^E(k,m,b,z_i), m_{t+1}^E(k,m,b,z_i), b_{t+1}^E(k,m,b,z_i) \right) \in \mathcal{A} \right\}$$

B.4 Equilibrium Definition

The perfect foresight equilibrium relevant for the analysis of the model in light of monetary policy shocks ε_t^f can be defined as follows.

Definition 1. *A* perfect foresight fixed price equilibrium *in this economy, given an initial distribution μ_0 of firms over idiosyncratic states, an initial nominal bond price q_{-1}^b, predetermined nominal one-period returns r_0^f, r_0^m, and a path for realizations of the monetary policy shock $\left\{\varepsilon_t^f\right\}_{t=0}^{\infty}$, with given ζ_{-1}^f, is given by the set of functions and quantity and price paths $V_{0,t}(k,m,b,z)$, $n_t(k,m,b,z)$, $\left\{k_{t+1}^E(k,m,b,z), b_{t+1}^E(k,m,b,z), m_{t+1}^E(k,m,b,z)\right\}_{E\in\{A,N\}}$, $\hat{\xi}_t(k,m,b,z)$, c_t^h, n_t^h, L_{t+1}^h, $\Lambda_{t+1}^h(k',m',b',z')$, B_{t+1}, D_{t+1}, R_{t+1}, L_{t+1}, w_t Q_t, I_t, K_t, M_{t+1}, q_t^b, γ_t, r_{t+1}^f, r_{t+1}^b, $\mathcal{M}_t$, Π_t, T_t, $\mu_t(k,m,b,z)$ such that:*

1. *the value function $V_{0,t}$ solves (7)–(8), and n_t, $\hat{\xi}_t$, $\left\{k_{t+1}^E, b_{t+1}^E, m_{t+1}^E\right\}$, for $E\in\{A,N\}$, are the associated policy functions for debt adjusters and non-adjusters, respectively;*

2. *the intermediary earns zero profits in expectation, i.e. (11) and (12) hold, its reserve requirement binds $R_{t+1}=\alpha_r D_{t+1}$, and its corporate lending is financed with one-period borrowing: $L_{t+1}=B_{t+1}-(1-\alpha_r)D_{t+1}$;*

3. *the stochastic discount factor is given by $M_{t+1}=\beta\left(\frac{c_{t+1}^h}{c_t^h}\right)^{-1}$, and it satisfies (9), and the labor supply condition (10) holds;*

4. *r_t^b and γ_t are consistent with long-term debt prices: $1+r_t^b=\frac{c_b+\gamma q_t^b}{q_{t-1}^b}$, $\gamma_t=\gamma\frac{q_t^b}{q_{t-1}^b}\frac{1}{\Pi_t}$;*

5. *the distribution of firms evolves as implied by (B.2);*

6. *the final good market clears:*

$$\begin{aligned}
c_t^h = \int_{\mathbf{S}} \Bigg\{ & z^{1-\nu}k^{\alpha}\left[n_t(k,m,b,z)\right]^{\nu} \\
& -(1-\eta)G\left(\hat{\xi}_t(k,m,b,z)\right)\left[k_{t+1}^A(k,m,b,z)+AC\left(k_{t+1}^A(k,m,b,z),k\right)\left[\Phi'(I_t/K_t)\right]^{-1}\right] \\
& -(1-\eta)\left(1-G\left(\hat{\xi}_t(k,m,b,z)\right)\right)\left[k_{t+1}^N(k,m,b,z)+AC\left(k_{t+1}^N(k,m,b,z),k\right)\left[\Phi'(I_t/K_t)\right]^{-1}\right] \\
& +(1-\eta)(1-\delta)k+\eta\left[(1-\delta)k-k_0\right]\Bigg\}\mu_t(dk,dm,db,dz)
\end{aligned}$$

   with $AC(k',k)\equiv\frac{\kappa}{2}\left(\frac{k'}{k}-1\right)^2$;

7. *Q_t satisfies the capital producer's optimality condition (13), with $K_t=\int_{\mathbf{S}} k\mu_t(dk,dm,db,dz)$, and I_t implicitly determined by $K_{t+1}=\Phi\left(\frac{I_t}{K_t}\right)K_t+(1-\delta)K_t$;*

8. *the labor market clears:* $n_t^h = \int_{\mathbf{S}} n_t(k,m,b,z)\mu_t(dk,dm,db,dz)$;

9. *the equity market clears:* $\Lambda_{t+1}^h(k',m',b',z') = \mu_{t+1}(k',m',b',z')$ *for each* $(k',m',b',z') \in \mathbf{S}$;

10. *the long-term debt market clears:*

$$B_{t+1} = (1-\eta)\int_{\mathbf{S}} \{G\left(\hat{\xi}_t(k,m,b,z)\right) b_{t+1}^A(k,m,b,z) + \left[1 - G\left(\hat{\xi}_t(k,m,b,z)\right)\right] b_{t+1}^N(k,m,b,z)\}\mu_t(dk,dm,db,dz)$$

11. *the deposits market clears:*

$$D_{t+1} = (1-\eta)\int_{\mathbf{S}} \left\{G\left(\hat{\xi}_t(k,m,b,z)\right) m_{t+1}^A(k,m,b,z) + \left[1 - G\left(\hat{\xi}_t(k,m,b,z)\right)\right] m_{t+1}^N(k,m,b,z)\right\}\mu_t(dk,dm,db,dz) + \eta m_0$$

12. *the Taylor rule* (5), *the New Keynesian Phillips curve* (14), *and the government's budget constraint* (6) *are satisfied, with* $\mathcal{P}_t = \int_{\mathbf{S}} \Big\{\mathcal{M}_t^{-1} z^{1-\nu} k^{\alpha} \left[n_t(k,m,b,z)\right]^{\nu} - w_t n_t(k,m,b,z) - Q_t \delta k + \frac{r_t^m}{\Pi_t} m - \frac{r_t^b}{\Pi_t} b\Big\}\mu_t(dk,dm,db,dz)$, *and* $\zeta_t^f = \rho_f \zeta_{t-1}^f + \varepsilon_t^f$;

13. *the one-period debt market clears by Walras' law:* $L^h = L$.

It is also useful to clarify how the interest rates r_t^f, r_t^b, r_t^m, and the debt price q_t^b are determined along the perfect foresight equilibrium path and in response to any unexpected shocks. Along the perfect foresight equilibrium path, these values are exactly determined as a solution to the equilibrium conditions, as described in the above equilibrium definition.

If at time $t+1$ any unexpected shocks are realized, agents' optimal behavior and the government policies going forward dictate new equilibrium paths for r_{t+j+1}^f, r_{t+j+1}^m, r_{t+j}^b, and q_{t+j}^b for $j \geq 1$, among all other equilibrium outcomes. Yet, r_{t+1}^f, r_{t+1}^m, and q_t^b are predetermined. The latter implies that the impact response of q_{t+1}^b generates a response in r_{t+1}^b and the return on holding long-term debt is not fixed in response to any aggregate shocks. For example, a monetary policy announcement at time $t+1$ which increases real rates going forward induces a drop in q_{t+1}^b and r_{t+1}^b, generating losses for the intermediary holding the long-term debt.

B.5 Details on Calibrated Model Steady state

B.5.1 Calibration and Summary

As stated in Section 3.3.1, I determine α_r and $\bar{r}^r$ by targeting a steady state nominal return on firm's cash (i.e., deposits in the intermediary) r^m_{SS}, relative to r^f_{SS}, and its relative exposure to fluctuations in r^f_{t+1}, i.e., $\frac{\partial r^m_{t+1}}{\partial r^f_{t+1}} = 1 - \alpha_r$. I derive the r^m_{SS} target using the Flow of Funds Accounts data on the U.S. nonfinancial corporate sector's aggregate balance sheet to construct a representative liquid asset portfolio. I assume that all components of the liquid asset portfolio earn the implicit policy rate r^f_t, except *Checkable deposits and currency* to which I impose a zero nominal return. Time-averaged over the 1990Q1–2007Q4 period, checkable deposits and currency accounted for approximately 25.5% of the aggregate corporate sector's liquid portfolio.[72] Thus, I target $r^m_{SS} = (1 - 0.255) \times r^f_{SS}$.

Similarly, to target the exposure of r^m_{t+1} to fluctuations in r^f_{t+1}, I also employ the U.S. nonfinancial corporate sector's liquid asset portfolio shares. I assume that the shares are constant in response to any aggregate fluctuations. Following the facts documented by Drechsler et al. (2017) on the responsiveness of bank deposit rates to changes in monetary policy, I suppose that the exposure of the return on *Time and savings deposits* to changes in the policy rate is 0.5. As in the calibration of the steady state rate r^m_{SS} above, I consider checkable deposits and currency as earning a zero nominal return and all remaining components of the liquid assets portfolio earning the implicit policy rate. All in all, combining the portfolio shares of checkable deposits and currency of 25.5%, and the time and savings deposits share of 25.4%, I infer: $1 - \alpha_r = 0.254 \times 0.5 + (1 - 0.255 - 0.254) \times 1 = 0.618$. Thus an increase of 1 bp in the policy rate r^f_{t+1} corresponds to a 0.618 bp increase in r^m_{t+1} in the model.

The exact parameter values used in the baseline calibration of the model and their corresponding targets and sources are reported in Table B.1.

B.5.2 Untargeted Moments of Firm Dynamics

This Appendix shows how the calibrated model of Section 3 generates a subsample of public firms which matches various untargeted features of the Compustat sample in Section 2, as summarized in Table B.2.

First, it does a good job at generating a distribution of liquidity ratios similar to the data. The cross-sectional standard deviation of liquidity ratios in the model is 0.129, whereas in Compustat, the average within industry-time cell standard deviation is 0.147 at the SIC3-digit level (weighted by number of observations per cell). Also, the model captures well

[72] The complete decomposition of the nonfinancial corporate sector's average liquid asset portfolio for the 1990Q1–2007Q4 period can be seen in Table A.1 of Appendix A.3.

Table B.1: Calibrated parameter values and calibration targets

Externally calibrated				
Parameter	Value	Target / Source		
β	$1.02^{-1/4}$	2% annual real risk-free rate		
$\bar{\Pi}$	$1.02^{-1/4}$	2% annual inflation rate		
$(\alpha_r, \bar{r})$	$(0.382,\ 33.1\times 10^{-4})$	$r^m_{SS}/r^f_{SS} = 0.745$, $\partial r^m_{t+1}/\partial r^f_{t+1} = 0.618$, FOFA		
$(\delta,\ \rho_z)$	(0.025, 0.90)	Conventional, e.g. Ottonello and Winberry (2020)		
ν	0.64	Labor share $\approx 58\%$, Karabarbounis and Neiman (2013)		
α	0.23	DRS of 0.87, Clementi and Palazzo (2016)		
γ	1-1/16	4 year debt maturity		
η	0.022	BDS exit rate		
τ	0.20	Nikolov and Whited (2014)		
$(\epsilon,\ \kappa_p,\ \phi_\pi,\ \rho_f)$	(10, 0.1, 1.25, 0.61)	Kaplan et al. (2018)		
Internally calibrated				
Parameter	Value	Moment	Data	Model
θ	0.422	Aggregate Debt/Assets	0.297*	0.304
ϕ_w	0.622	Aggregate Cash/Assets	0.065*	0.062
σ_ϵ	0.245	acor(i_a/k)	0.33*	0.33
κ	0.158	$\sigma(i_a/k)$	0.315*	0.310
$\bar{\xi}$	0.0615	freq$(D=1)$	0.251*	0.252
k_0	1.84	$\mathbb{E}[i_a/k]$	0.26	0.26
z_0	-0.24	$\mathbb{E}[n_0]/\mathbb{E}[n]$	0.255	0.254
m_0	0.0090	Entrants' "operational cash needs"	–	–
ψ	0.708	$w_{SS} = 1$ normalization	–	–

Notes: D refers to a binary indicator variable for whether a firm issued long-term debt in a given quarter. i_a refers to annual investment. ""*" refers to moments derived from Compustat in the data, and from firms older than 5 years in the model. Targets for *Aggregate Debt/Assets*, *Aggregate Cash/Assets*, and *freq*$(D=1)$ computed from the Compustat sample used as the basis of the empirical work of Section 2, prior to dropping firms observed for less than 40 quarters, i.e. Step 6. from Appendix A.1.1 – aggregation done by quarter, then medians of aggregates across time. Targets for acor(i_a/k) and $\sigma(i_a/k)$ from Bai et al. (2022).

the weak negative cross-sectional correlation between log firm size and liquidity ratios, with values of -0.228 in the model and -0.145 in the data, again within industry-time cells (or -0.255 across industries, within time cells, as seen in Table 1). The correlation between liquidity ratios and 4-quarter-ahead investment rates is slightly positive in both the model and data, illustrative of the idea that firms acquire liquidity buffers in preparation of future investment opportunities (and these buffers then allow them to engage in future investment). The model also captures well the strong negative cross-sectional relationship between firms' liquidity and leverage ratios: Compustat firms with above and below-median liquidity have average leverage ratios of 0.159 and 0.337, respectively, whereas the corresponding numbers in the model are 0.205 and 0.349. In the Compustat sample, a share of about 1.3% firm-quarters feature liquidity ratios of exactly zero, and 3.1% of them have ratios below 0.001. In the model, the respective shares are about 4.9% and 6.1%.

Table B.2: Model fit along untargeted moments for public firm dynamics

Moment	Data	Model
$\sigma(\ell)$	0.147	0.129
$\text{cor}(\ell, \log(\text{size}))$	-0.145	-0.228
$\text{cor}(\ell, (i/k)_{+4})$	0.132	0.125
$\mathbb{E}[b \vert \text{high } \ell]$	0.159	0.205
$\mathbb{E}[b \vert \text{low } \ell]$	0.337	0.349
$\text{freq}(\ell = 0)$	0.013	0.049
$\text{freq}(\ell < 0.001)$	0.031	0.061
$\text{skew}(\log(k))$	0.055	0.014
$\text{freq}(D = 1 \vert \text{small})$	0.233	0.222
$\text{freq}(D = 1 \vert \text{large})$	0.287	0.282
$\text{freq}(div_a > 0)$	0.349	0.343

Notes: $(i/k)_{+4}$ refers to the 4-quarter-ahead quarterly investment rate, b to the leverage ratio. D refers to a binary indicator variable for whether a firm issued long-term debt in a given quarter. *"high ℓ"* refers to firms with liquidity ratio above the median public firm, *"low ℓ"* to those below the median. *"large"* refers to firms with total assets above the median public firm, *"small"* to those below the median. div_a refers to annual dividends. Model moments computed based on stationary distribution, with "public" firms being those older than 5 years.

The "public" firm capital stock distribution exhibits similar right-skewedness as the Compustat data, with a cross-sectional skewness of $\log(k)$ of 0.014, compared to an empirical average within industry-time cell skewness of 0.055. The model's positive unconditional cross-sectional relationship between firm size and debt issuance frequency is also in line with the data: for firms in the bottom and top halves of the size distribution, the probabilities of debt issuance are 0.222 and 0.282, respectively. The corresponding frequencies in the data are 0.233 and 0.287, respectively, conditioning again on time-industry splitting of firms into large and small. Also, the model matches the frequency of public firms paying dividends, with positive dividends paid in 34.9% of the firm-years in the Compustat sample of Section 2, and in 34.3% of public firm-years in the stationary distribution of the model.

B.5.3 Public vs. Private Firms in Model and Data

For comparability with empirical moments based on Compustat public firms' data, I approximate model firm selection into the sample of public firms based on firm age. Following Wilmer Cutler Pickering Hale and Dorr LLP (2017), the median IPO age of firms during the relevant sample period ranges from 2.8 to 6.8 years during 1996–2007. I thus follow a relatively conservative cutoff of older than 5 years to determine "public" firms in the data. Appendices B.5.1 and B.5.2 above illustrate how the resulting model-based subsample of public firms matches various targeted and untargeted moments from Compustat.

In addition to this, Table B.3 below shows that the chosen approach generates an implied selection of model firms into public status, as compared to the remaining firms, in line with the data along several relevant dimensions. Namely, the average public firm is approximately 13 years older than the average private firm, both in the model and in U.S. data. The share of aggregate investment accounted for by public firms is about 45.5% in U.S. data, wherereas in the model it is 44.8%. And finally, the average liquidity ratio is noticeably higher among U.S. public firms compared to private ones. This is also the case in the model, although to a slightly smaller extent quantitatively.

Table B.3: Comparison of public and private firms in model and data

Moment	Data	Model	Source
$\mathbb{E}[\text{age}\vert\text{public}] - \mathbb{E}[\text{age}\vert\text{private}]$	13 years	13.8 years	Dinlersoz et al. (2019)
I^{pub}/I	0.455	0.448	Asker et al. (2011)
$\mathbb{E}[\ell\vert\text{public}] - \mathbb{E}[\ell\vert\text{private}]$	0.073	0.048	Asker et al. (2011)

Notes: I^{pub}/I refers to the share of aggregate investment accounted for by public firms. Model moments computed based on stationary distribution, with "public" firms being those older than 5 years.

B.5.4 Firm Life Cycle

Figure B.1 plots the life cycle dynamics of the average firm in the model from birth until the age of 30 years. Entrants are born with initial capital k_0 and zero debt. They have a low level of initial cash m_0, corresponding to the "operational cash needs" at $(k = k_0, z = 1)$, as governed by the calibrated ϕ_w relative to the labor share ν. Although the entrants' average idiosyncratic TFP levels are below the unconditional mean of $z = 1$, their capital stocks are below optimal, inducing strong incentives to invest and expand their capital stock. To do so, firms pay the debt issuance cost and lever up.[73] Because of the adjustment costs on capital, firms do not immediately spend all of the raised funds on investment but rather build up and then draw down a cash buffer, allowing them to continue growing while economizing on further debt issuance costs. The strength of the incentives for young firms to expand is illustrated by the fact that almost no firms pay dividends during the first few years of life.

As firms mature and grow, approaching their optimal capital stocks as dictated by their z realizations, they delever slightly. But the average firm does not fully pay back its debt. Instead, the average leverage converges to a level of approximately 0.20 while firms trade off the benefits from the tax advantage of debt against the cost of being close to the borrowing constraint and having little "financial capacity" to borrow and expand whenever good investment opportunities (high z draws) arise. At the same time, firms accumulate a liquidity buffer to facilitate such investment expansions in case debt is costly to issue. These incentives give rise to a world where mature firms continuously issue debt while managing their liquid asset holdings, unlike models in which mature firms grow out of financial constraints and do not borrow at all.

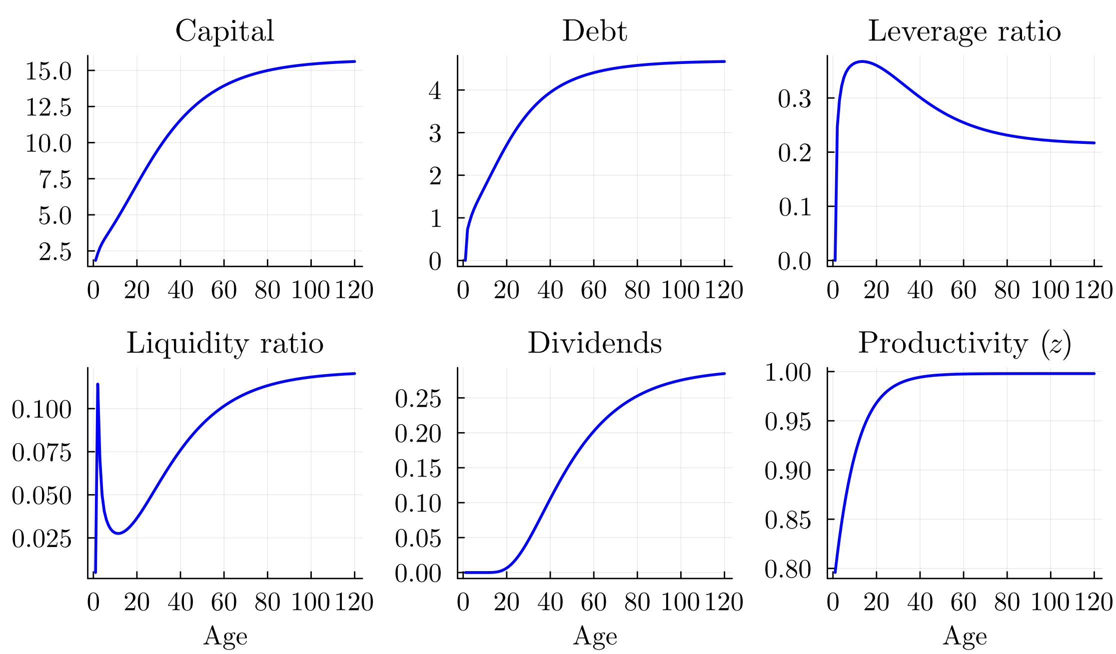


Figure B.1: Average firm life cycle in the model

Notes: Average capital stock, debt, leverage and liquidity ratios, dividends, and idiosyncratic TFP conditional on age in stationary equilibrium. Leverage and liquidity as ratios, other variables in levels. Horizontal axis: firm age in quarters.

[73] In the quarter of birth, about 70% of firms issue debt. In the second quarter of life, about 40% do so.

B.6 Replicating Empirical Panel Regressions in the Model

This Appendix provides details on how I identify and estimate γ_h from model simulated data in order to replicate the empirical estimation of (1) in Section 2. As discussed in Section 3.3.1 I approximate the selection of firms into Compustat and becoming public based on firms' age in the model. Thus, the model experiments are conducted based on a representative sample from the distribution of firms, conditioning on them being at least 5 years old. To ensure that the results of the model experiment are not affected by sampling variation, I consider a large model sample of 50,000 firms to retrieve the model estimates for γ_h.

In the following, I discuss how one can utilize the option of computing counterfactuals with and without realized monetary policy shocks in identifying and estimating γ_h from model simulated data. The key empirical regression specification to be estimated at horizon h, given a monetary policy shock at t, has the following structure:[74]

$$\log(k_{i,t+h}) - \log(k_{i,t-1}) = f_{i,h} + d_{h,t+h} + \Theta_h' W_{i,t-1} - \gamma_h \ell_{i,t-1}\varepsilon_t^m - \Omega_h' \ell_{i,t-1} Y_{t-1} + u_{i,h,t+h} \quad \text{(B.3)}$$

Under the scenario of a "one unit" monetary policy shock occurring at time t, $\varepsilon_t^m = 1$, (B.3) becomes:

$$\log(k_{i,t+h}^{\varepsilon}) - \log(k_{i,t-1}) = f_{i,h} + d_{h,t+h}^{\varepsilon} + \Theta_h' W_{i,t-1} - \gamma_h \ell_{i,t-1} - \Omega_h' \ell_{i,t-1} Y_{t-1} + u_{i,h,t+h}^{\varepsilon} \quad \text{(B.4)}$$

where $k_{i,t+h}^{\varepsilon}$ is firm i's capital stock at the end of period $t+h$ in the scenario of the one unit monetary policy shock, $d_{h,t+h}^{\varepsilon}$ captures the aggregate fluctuations in capital accumulation induced by the shock, and $u_{i,t+h}^{\varepsilon}$ reflects any idiosyncratic variation in capital accumulation not explained by firm fixed effects or controls. In the absence of a monetary policy shock in the same quarter t, $\varepsilon_t^m = 0$, and (B.3) reads:

$$\log(k_{i,t+h}^{SS}) - \log(k_{i,t-1}) = f_{i,h} + d_{h,t+h}^{SS} + \Theta_h' W_{i,t-1} - \Omega_h' \ell_{i,t-1} Y_{t-1} + u_{i,h,t+h}^{SS} \quad \text{(B.5)}$$

I denote the outcomes in the absence of the shock with the "SS" label because in the experiment, I consider unexpected monetary policy announcements which hit the economy in the stationary equilibrium. Taking the difference between (B.4) and (B.5), one gets:

$$\log(k_{i,t+h}^{\varepsilon}) - \log(k_{i,t+h}^{SS}) = \hat{d}_{h,t+h} - \gamma_h \ell_{i,t-1} + \hat{u}_{i,t+h} \quad \text{(B.6)}$$

where $\hat{d}_{h,t+h} \equiv d_{h,t+h}^{\varepsilon} - d_{h,t+h}^{SS}$ and $\hat{u}_{i,t+h} \equiv u_{i,t+h}^{\varepsilon} - u_{i,t+h}^{SS}$. (B.7) has the natural implication that one can identify and estimate γ_h in the model by simply comparing each firm's capital

[74] I am omitting the indication of industry-time fixed effects as there is no industry dimension in the model.

stock h quarters after the monetary policy shock under the shock scenario to that under the counterfactual no-shock scenario, and regressing these differences on the financial conditioning variable of interest. In general, given controls $Z_{i,t-1}$ that could be interacted with the monetary shock, as in (2), one should estimate:

$$\log(k^{\varepsilon}_{i,t+h}) - \log(k^{SS}_{i,t+h}) = \hat{d}_{h,t+h} + \psi'_h Z_{i,t-1} - \gamma_h \ell_{i,t-1} + \hat{u}_{i,t+h} \tag{B.7}$$

Finally, note that following the discussion at the beginning of Section 4.2.2, I scale the estimated model-based coefficients γ_h so that they correspond to the effect of a monetary shock ε^f_t which induces an unexpected annualized 25 bp quarterly change in the observed equilibrium policy rate r^f_{t+1}, in line with the empirical estimation of specification (15).

B.7 Model Regression Estimates with Demeaned Explanatory Variables

Figure B.2 presents the estimates for the key regression coefficients of interest, γ_h, estimated based on data generated by the model of Section 3 when employing observed within-firm variation in the liquid asset ratios. And it compares the coefficients to the estimates when not demeaning the liquid asset ratios, corresponding to the model coefficients of interest studied in Section 4.2.2. The median firm in the Compustat sample that I employ in the estimations of Section 2 is observed for 59 quarters. I compute the firms' average liquid asset ratios in the model based on samples of 60 quarters. Given that variation in firms' liquid asset ratios is also generated by other idiosyncratic and aggregate shocks in the data not present in the model, I consider this to be a conservatively long sample period.

The results show that the estimates for γ_h based on the within-firm demeaned measures of liquid asset ratios are noticeably biased towards zero in comparison to the coefficients of interest, based on the non-demeaned ratios. The model can thus explain why the main results on response heterogeneity being predicted by within-firm demeaned liquidity ratios become weaker, as seen in Figure A.5, in comparison to the results from the non-demeaned specification, seen in Figure 1. In the model, firms' liquid asset holdings exhibit nontrivial persistent differences due to life cycle dynamics and the fact that the realized persistent idiosyncratic productivity levels can dictate significantly different optimal liquid asset holdings for firms within the same age cohort. For example, old financially unconstrained firms with low productivity z hold large buffer stocks of liquid assets to finance investment spurts whenever good productivity draws arrive, whereas mature high-productivity firms have no need for such buffers.

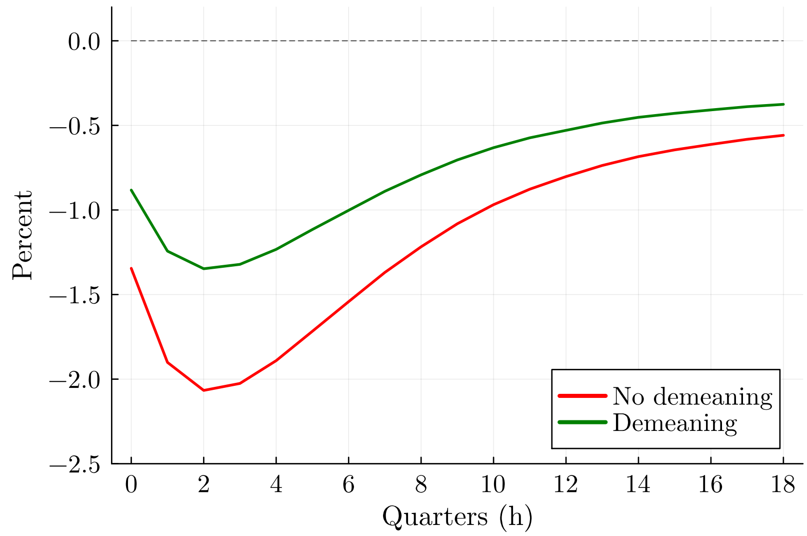


Figure B.2: Coefficient estimates for heterogeneity in responses of capital accumulation based on within-firm demeaned and non-demeaned measures of liquid asset ratios

Notes: Point estimates for γ_h, from estimating (B.6), with either $\ell_{i,t}$ ("No demeaning") or $\ell_{i,t-1} - \bar{\ell}_i$ ("Demeaning") as the main explanatory variable. $\bar{\ell}_i$ is the sample mean of $\ell_{i,t}$ when simulating the firm for 60 quarters in steady state. Estimated on model simulated data on a sample of 50,000 firms, drawn from the stationary distribution, conditioning on the firms being at least 5 years old.

B.8 Analysis of a Simplified Problem of the Firm

In this Appendix, I provide a more detailed theoretical analysis of the key channels of monetary transmission at play in the model of Section 3. To simplify the analysis, I focus on a "two-period" special case, i.e., the period t problem of a firm which knows with certainty that it will have to exit after production in period $t+1$.[75] Moreover, I assume that there are no capital adjustment costs ($\kappa = 0$) and no corporate taxation ($\tau = 0$), and the firm's productivity is fixed at a constant z, treating it as a parameter for brevity here.[76]

B.8.1 General Problem and Optimality Conditions

Following equation (7), the value function of the firm in $t+1$ is:

$$V_{0,t+1}(k, m, b, z) = \Upsilon_{t+1}(k, m) + (1-\delta)Q_{t+1}k + \frac{1 + r^m_{t+1}}{\Pi_{t+1}}m - \frac{1 + r^b_{t+1}}{\Pi_{t+1}}b \qquad \text{(B.8)}$$

[75]Or, equivalently, the problem of an entrant with arbitrary state (k, m, b, z), under the parameterization $\eta = 1$.

[76]In the presence of taxation ($\tau > 0$) in this two-period problem, all debt adjusting firms would necessarily want to borrow up to the borrowing constraint (unlike in the general version of the model) precluding the analysis of interior choices of debt and of monetary transmission through the "direct" effects of r^b_{t+1}.

And following equation (8), the firm's problem in period t is:

$$V_{1,t}(k,m,b,z,\xi) = \max_{div,k',m',b'} \left\{ div - \xi \mathbb{1}_{[b' \neq \gamma_t b]} + M_{t+1} V_{0,t+1}\left(k',m',b',z\right) \right\} \tag{B.9}$$

$$\text{s.t.} \quad 0 \leq div \leq \Upsilon_t(k,m) - \frac{1+r_t^b}{\Pi_t} b + b' + \frac{1+r_t^m}{\Pi_t} m - m' + Q_t[(1-\delta)k - k']$$

$$0 \leq \frac{1+r_{t+1}^b}{\Pi_{t+1}} b' \leq \theta Q_{t+1} k'; \quad m' \geq 0$$

The earnings function $\Upsilon_t(k,m)$ is defined, as in Section 3, dropping the fixed z as an argument, as:

$$\Upsilon_t(k,m) \equiv \max_n \left[\mathcal{M}_t^{-1} z^{1-\nu} k^\alpha n^\nu - w_t n\right]$$

$$\text{s.t.} \;\; w_t n \leq \frac{m}{\Pi_t} + \phi_w \mathcal{M}_t^{-1} z^{1-\nu} k^\alpha n^\nu$$

Using the derivatives of $V_{0,t+1}$ one gets the first order optimality conditions in t:

$$(k'): \quad \lambda = M_{t+1} \frac{\Upsilon_{t+1}^k(k',m') + (1-\delta) Q_{t+1}}{Q_t} + \theta \frac{Q_{t+1}}{Q_t} \zeta \tag{B.10}$$

$$(m'): \quad \lambda = M_{t+1} \left[\Upsilon_{t+1}^m(k',m') + \frac{1+r_{t+1}^m}{\Pi_{t+1}}\right] + \mu^m \tag{B.11}$$

$$(b'): \quad \lambda = M_{t+1} \frac{1+r_{t+1}^b}{\Pi_{t+1}} - \mu_t^b + \frac{1+r_{t+1}^b}{\Pi_{t+1}} \zeta \tag{B.12}$$

$$(div): \quad \lambda = 1 + \mu^{div} \tag{B.13}$$

where $\Upsilon_t^x(\cdot) \equiv \frac{\partial \Upsilon_t(\cdot)}{\partial x}$, λ is the Lagrange multiplier on the budget constraint in t, ζ is the Lagrange multiplier on the borrowing constraint, and μ^x are the Lagrange multipliers on the constraints $x' \geq 0$, with $x' \in \{m', b', div\}$.

B.8.2 Direct Transmission through Interest Rates

In order to first provide a simple illustration of the direct effects of monetary transmission through the interest rates r_{t+1}^m and r_{t+1}^f (and implicitly, also the firm owner's discount rate $r_{t+1}^f = \Pi_{t+1} M_{t+1}^{-1} - 1$) induced by a monetary shock announced in t, I focus on the cases where the firm's choices of m' and b' are interior.[77] I will discuss the firm's decisions conditional on

[77] In the cases where m' and b' are at their respective binding constraints and investment in k' is determined mechanically by the firm's budget constraint, discussed in Appendix B.8.3 below, monetary policy operates first and foremost through indirect general equilibrium effects affecting operating revenues $\Upsilon_t(k,m)$ and capital prices Q_t.

paying the debt adjustment cost ξ, and not doing so, in turn.

Adjuster. Considering the solution for a firm that pays the debt adjustment cost ξ, an interior choice for b' (i.e., $\zeta = 0$), in combination with $r^f_{t+1} = r^b_{t+1}$, implies that $\lambda = 1$ and $\mu^d = 0$, and thus the firm's solution for div must also be interior. The optimal choice of (k', m') for this firm is determined by the following system of equations:[78]

$$\frac{\Upsilon^k_{t+1}(k', m') + (1-\delta)Q_{t+1}}{Q_t} = \frac{1 + r^b_{t+1}}{\Pi_{t+1}} \tag{B.14}$$

$$\Upsilon^m_{t+1}(k', m') = \frac{r^b_{t+1} - r^m_{t+1}}{\Pi_{t+1}} \tag{B.15}$$

Note that since $r^b_{t+1} > r^m_{t+1}$ in the equilibria considered, $m' > 0$ necessarily means that $\Upsilon^m_{t+1}(k', m') > 0$ and thus, the firm's working capital constraint in $t+1$ must be binding at the margin. Differentiating (B.14)–(B.15) implies:

$$\begin{bmatrix} \Upsilon^{kk}_{t+1}/Q_t & \Upsilon^{mk}_{t+1}/Q_t \\ \Upsilon^{mk}_{t+1} & \Upsilon^{mm}_{t+1} \end{bmatrix} \begin{bmatrix} dk' \\ dm' \end{bmatrix} = \begin{bmatrix} 1/\Pi_{t+1} & 0 \\ 1/\Pi_{t+1} & -1/\Pi_{t+1} \end{bmatrix} \begin{bmatrix} dr^b_{t+1} \\ dr^m_{t+1} \end{bmatrix} \tag{B.16}$$

where, for brevity, $\Upsilon^{xy}_{t+1} \equiv \frac{\partial^2 \Upsilon_t(k,m)}{\partial x \partial y}$. Denoting $\Omega_{t+1} \equiv Q_t \Pi^{-1}_{t+1} \left[\Upsilon^{kk}_{t+1}\Upsilon^{mm}_{t+1} - (\Upsilon^{mk}_{t+1})^2\right]^{-1}$, one can derive and quantify at the baseline model's calibration that:[79]

$$\frac{dk'}{dr^m_{t+1}} = \Omega_{t+1}\frac{\Upsilon^{mk}_{t+1}}{Q_t} > 0$$

$$\frac{dm'}{dr^m_{t+1}} = -\Omega_{t+1}\frac{\Upsilon^{kk}_{t+1}}{Q_t} > 0$$

[78] $div - b'$ adjusts to satisfy the firm's budget constraint at equality, with the exact values of (div, b') being indeterminate due to the fact that $M_{t+1}\frac{\Pi_{t+1}}{1+r^b_{t+1}} = 1$ in equilibrium.

[79] More precisely, defining $\bar{n}_t(k,m)$ as the amount of labor that satisfies the working capital constraint at equality in t, given (k,m), and $y_t(k,n) \equiv \mathcal{M}_t^{-1} z^{1-\nu} k^\alpha n^\nu$, with $y^x_t(k,n) \equiv \frac{\partial y_t(k,n)}{\partial x}$ and $y^{xs}_t(k,n) \equiv \frac{\partial^2 y_t(k,n)}{\partial x \partial s}$, one can derive that for m' low enough such that the working capital constraint in $t+1$ is binding, we have: $\Upsilon^k_{t+1}(k', m') = y^k_{t+1}(k, \bar{n}_{t+1}(k', m'))\left[1 + \phi_w \frac{y^n_{t+1}(k', \bar{n}_{t+1}(k', m')) - w_{t+1}}{w_{t+1} - \phi_w y^n_{t+1}(k', \bar{n}_{t+1}(k', m'))}\right] > 0$, $\Upsilon^m_{t+1}(k', m') = \Pi^{-1}_{t+1}\frac{y^n_{t+1}(k', \bar{n}_{t+1}(k', m')) - w_{t+1}}{w_{t+1} - \phi_w y^n_{t+1}(k', \bar{n}_{t+1}(k', m'))} > 0$, $\Upsilon^{mm}_{t+1}(k', m') = \Pi^{-1}_{t+1}\frac{\partial \bar{n}_{t+1}(k', m')}{\partial m'}\frac{w_{t+1}(1-\phi_w)y^{nn}_{t+1}(k', \bar{n}_{t+1}(k', m'))}{\left[w_{t+1} - \phi_w y^n_{t+1}(k', \bar{n}_{t+1}(k', m'))\right]^2} < 0$, $\Upsilon^{mk}_{t+1}(k', m') = \frac{w_{t+1}(1-\phi_w)}{\left[w_{t+1} - \phi_w y^n_{t+1}(k', \bar{n}_{t+1}(k', m'))\right]^2}\left[\frac{\partial \bar{n}_{t+1}(k', m')}{\partial k'} y^{nn}_{t+1}(k', \bar{n}_{t+1}(k', m')) + y^{nk}_{t+1}(k', \bar{n}_{t+1}(k', m'))\right] > 0$, with $\frac{\partial \bar{n}_{t+1}(k', m')}{\partial k'} = \frac{\phi_w y^k_{t+1}(k', \bar{n}_{t+1}(k', m'))}{w_{t+1} - \phi_w y^n_{t+1}(k', \bar{n}_{t+1}(k', m'))} > 0$ and $\frac{\partial \bar{n}_{t+1}(k', m')}{\partial m'} = \frac{\Pi^{-1}_{t+1}}{w_{t+1} - \phi_w y^n_{t+1}(k', \bar{n}_{t+1}(k', m'))} > 0$. Finally, the algebraic form for $\Upsilon^{kk}_{t+1}(k', m')$, when the working capital constraint is binding, is more involved, but can be computationally signed to be strictly negative at the calibrated model parameters. Also, I have verified computationally that $\Upsilon^{kk}_{t+1}\Upsilon^{mm}_{t+1} - (\Upsilon^{mk}_{t+1})^2 > 0$, and thus $\Omega_{t+1} > 0$.

$$\frac{dk'}{dr^b_{t+1}} = \Omega_{t+1}\left(\Upsilon^{mm}_{t+1} - \frac{\Upsilon^{mk}_{t+1}}{Q_t}\right) < 0$$
$$\frac{dm'}{dr^b_{t+1}} = \Omega_{t+1}\left(-\Upsilon^{mk}_{t+1} + \frac{\Upsilon^{kk}_{t+1}}{Q_t}\right) < 0$$

Even though the complementarities between cash and investment due to the working capital constraint ($\Upsilon^{mk}_{t+1} > 0$) imply that an isolated increase in r^m_{t+1}, keeping r^b_{t+1} fixed, leads to higher cash holdings m' and thus higher k', the overall effect of a contractionary monetary shock on k' is negative. To see this, note that if it were the case that monetary shocks ε^f_t did not move the spread $r^b_{t+1} - r^m_{t+1}$, that is, $\frac{dr^m_{t+1}}{d\varepsilon^f_t} = \frac{dr^b_{t+1}}{d\varepsilon^f_t}$, then the effect on k' would be: $\frac{dk'}{d\varepsilon^f_t} = \left(\frac{dk'}{dr^b_{t+1}} + \frac{dk'}{dr^m_{t+1}}\right)\frac{dr^b_{t+1}}{d\varepsilon^f_t} = \Omega_{t+1}\Upsilon^{mm}_{t+1}\frac{dr^b_{t+1}}{d\varepsilon^f_t} = Q_t\Pi^{-1}_{t+1}\left[\Upsilon^{kk}_{t+1} - (\Upsilon^{mk}_{t+1})^2/\Upsilon^{mm}_{t+1}\right]^{-1}\frac{dr^b_{t+1}}{d\varepsilon^f_t} < 0$. Yet since $\frac{dr^m_{t+1}}{d\varepsilon^f_t} < \frac{dr^b_{t+1}}{d\varepsilon^f_t}$ in the quantitative applications in the model, the direct effect of a monetary shock on a debt adjuster's k' is even more negative than this.

Non-adjuster. For the case of a firm that does not pay the debt adjustment cost ξ, I will focus on the situation in which the non-negativity constraint on $div \geq 0$ is binding.[80] Then, the optimal choice of (k', m') is determined by:

$$\frac{\Upsilon^k_{t+1}(k', m') + (1-\delta)Q_{t+1}}{Q_t} = \Upsilon^m_{t+1}(k', m') + \frac{1 + r^m_{t+1}}{\Pi_{t+1}} \tag{B.17}$$
$$Q_t k' + m' = \Upsilon_t(k, m) - \frac{c_b}{\Pi_t q^b_{t-1}} b + \frac{1 + r^m_t}{\Pi_t} m + Q_t(1-\delta)k \tag{B.18}$$

where I have used the fact that in budget constraint (B.18), $\left(\frac{1+r^b_t}{\Pi_t} - \gamma_t\right) b = \frac{c_b}{\Pi_t q^b_{t-1}} b$ following the discussion in Appendix B.2, with $\frac{c_b}{q^b_{t-1}} b$ being the pre-determined nominal coupon payments that the non-adjusting firm incurs. Since the right hand side of (B.18) is (directly) unaffected by the changes in r^m_{t+1} and r^b_{t+1}, we have that $Q_t dk' + dm' = 0$. Using this together

[80] If the choice of a non-debt-adjuster's dividends $div > 0$ were interior, fluctuations in the owner's discount rate r^f_{t+1}, which in the equilibrium of the benchmark model in this paper is equal to the cost of borrowing r^b_{t+1}, would imply similar direct effects of $r^b_{t+1} = r^f_{t+1}$ and r^m_{t+1} on the non-adjuster's (k', m') as discussed for the adjuster above. However, in the baseline calibration of the model, about 8.6% of all firms in the population pay dividends in any given quarter, suggesting that firms for which this scenario applies form a small minority.

with differentiating (B.17), we have:

$$\frac{dk'}{dr^m_{t+1}} = \frac{Q_t\Pi^{-1}_{t+1}}{\Upsilon^{kk}_{t+1} + \Upsilon^{mm}_{t+1}Q_t^2 - 2\Upsilon^{mk}_{t+1}Q_t} < 0$$
$$\frac{dm'}{dr^m_{t+1}} = -\frac{Q_t^2\Pi^{-1}_{t+1}}{\Upsilon^{kk}_{t+1} + \Upsilon^{mm}_{t+1}Q_t^2 - 2\Upsilon^{mk}_{t+1}Q_t} > 0$$
$$\frac{dk'}{dr^b_{t+1}} = \frac{dm'}{dr^b_{t+1}} = 0$$

And thus, as discussed throughout the paper, the non-debt-adjusting firm is shielded from the direct effect of movements in borrowing rates r^b_{t+1} and tends to adjust capital as dictated by the less responsive r^m_{t+1}.

To clearly illustrate that the induced transmission for the non-adjuster is indeed weaker, note that following the discussion above, the full effect of monetary policy shock ε^f_t-induced changes in r^b_{t+1} and r^m_{t+1} on the adjuster's k' necessarily satisfies:

$$\begin{aligned}\frac{dk'}{d\varepsilon^f_t} = \frac{dk'}{dr^b_{t+1}}\frac{dr^b_{t+1}}{\varepsilon^f_t} + \frac{dk'}{dr^m_{t+1}}\frac{dr^m_{t+1}}{\varepsilon^f_t} &< \left[\frac{dk'}{dr^b_{t+1}} + \frac{dk'}{dr^m_{t+1}}\right]\frac{dr^b_{t+1}}{\varepsilon^f_t} \\ &= Q_t\Pi^{-1}_{t+1}\left[\Upsilon^{kk}_{t+1} - (\Upsilon^{mk}_{t+1})^2/\Upsilon^{mm}_{t+1}\right]^{-1}\frac{dr^b_{t+1}}{\varepsilon^f_t} \\ &< \frac{Q_t\Pi^{-1}_{t+1}}{\Upsilon^{kk}_{t+1}}\frac{dr^b_{t+1}}{\varepsilon^f_t} \end{aligned} \tag{B.19}$$

where the last inequality follows from the fact that $\Upsilon^{kk}_{t+1} < 0$, $(\Upsilon^{mk}_{t+1})^2/\Upsilon^{mm}_{t+1} < 0$, and $\Upsilon^{kk}_{t+1} - (\Upsilon^{mk}_{t+1})^2/\Upsilon^{mm}_{t+1} < 0$. At the same time, for the effects on the non-adjuster we have that:

$$\frac{dk'}{d\varepsilon^f_t} = \frac{dk'}{dr^m_{t+1}}\frac{dr^m_{t+1}}{\varepsilon^f_t} = \frac{Q_t\Pi^{-1}_{t+1}}{\Upsilon^{kk}_{t+1} + \Upsilon^{mm}_{t+1}Q_t^2 - 2\Upsilon^{mk}_{t+1}Q_t}\frac{dr^m_{t+1}}{\varepsilon^f_t} > \frac{Q_t\Pi^{-1}_{t+1}}{\Upsilon^{kk}_{t+1}}\frac{dr^m_{t+1}}{\varepsilon^f_t} \tag{B.20}$$

where the last inequality follows from the fact that $\Upsilon^{kk}_{t+1} < 0$, $\Upsilon^{mm}_{t+1} < 0$, and $\Upsilon^{mk}_{t+1} > 0$. Since $\frac{dr^b_{t+1}}{\varepsilon^f_t} > \frac{dr^m_{t+1}}{\varepsilon^f_t}$, (B.19) and (B.20) clearly establish the stronger direct transmission of monetary shocks on a debt adjuster's capital investment, relative to the case where they were not adjusting debt.

Finally, note also that the preceding analysis focused on the direct effects of monetary policy through r^m_{t+1} and r^b_{t+1} on the non-adjuster, assuming that capital prices and the right hand side of budget constraint (B.18) remain unchanged. As discussed below in Appendix B.8.3, the general equilibrium effects of a monetary contraction also influence a firm's available resources by decreasing operating profits $\Upsilon_t(k, m)$ and capital prices Q_t. However, the average firm's financial positions in the calibrated model imply that a drop in capital prices would on average *increase* the non-adjusting firm's ability to acquire k', in the limiting case of $m' \approx 0$, thanks to capital becoming cheaper, further illustrating the weaker sensitivity of non-adjusters to monetary shocks, as compared to debt adjusters.

B.8.3 Balance Sheet Effect through Capital Prices

In the following I discuss the strength of the balance sheet effect of monetary transmission, i.e. the idea that changes in asset prices and operating profits caused by monetary policy in general equilibrium affect the investment ability of a firm by directly influencing its available financial resources. More precisely, to focus on the channel in its most prominent form, I consider the case where the constraints $m' \geq 0$ and $div \geq 0$ bind (i.e., $\mu^m > 0$ and $\mu^{div} > 0$) and the debt adjuster's borrowing constraint binds ($\zeta > 0$), so that the budget constraint directly maps a firm's currently available financial resources into its investment in k'. And I examine the elasticity of k' with respect to changes in the capital price Q_t, keeping all other prices fixed.[81]

Adjuster. When $m' = div = 0$ and the borrowing constraint binds, the debt adjuster's budget constraint implies:

$$k' = \frac{1}{Q_t} \frac{1}{1 - \frac{\Pi_{t+1}}{1+r_{t+1}^b} \theta \frac{Q_{t+1}}{Q_t}} \left[\Upsilon_t(k, m) - \frac{1 + r_t^b}{\Pi_t} b + \frac{1 + r_t^m}{\Pi_t} m + Q_t(1 - \delta)k \right] \tag{B.21}$$

Let us, for simplicity, focus on the case of persistent shocks, so that Q_{t+1} and Q_t move approximately proportionally (i.e, $\frac{d \log Q_{t+1}}{d \log Q_t} \approx 1$). Defining $\mathcal{Y}_t^A(k, m, b) \equiv \Upsilon_t(k, m) - \frac{1+r_t^b}{\Pi_t} b + \frac{1+r_t^m}{\Pi_t} m$ as a measure of the effective net financial position of the firm, one can then write:

$$\frac{d \log k'}{d \log Q_t} = -1 + \frac{Q_t(1 - \delta)k}{\mathcal{Y}_t^A(k, m, b) + Q_t(1 - \delta)k} = \frac{\mathcal{B}_t^A(k, m, b)}{1 - \mathcal{B}_t^A(k, m, b)} \tag{B.22}$$

where $\mathcal{B}_t^A(k, m, b) \equiv \frac{-\mathcal{Y}_t^A(k,m,b)}{Q_t(1-\delta)k}$ is a form of the firm's effective net leverage position. (B.22) captures the conventional mechanical force that the more levered a firm is, the stronger is the elasticity of its available funds $\mathcal{Y}_t^A(k, m, b) + Q_t(1 - \delta)k$ (here also equal to its net worth) with respect to asset prices Q_t. Since the firm is assumed to use all available funds to acquire

[81] In general, the balance sheet effect works by monetary policy affecting a firm's available financial resources also through other forces, e.g, in the scope of this model also by moving operating profits $\Upsilon_t(k, m)$. But in practice, the value of the firm's undepreciated stock of capital $Q_t(1 - \delta)k$ forms a considerably larger part of the firm's currently available funds. And thus, in relative terms, fluctuations in the value of capital play a more significant role in determining the firm's available funds in the aftermath of a monetary shock, as compared to the fluctuations in operating profits.

capital k', this translates into a direct positive effect of $\mathcal{B}_t^A(k,m,b)$ on $\frac{d\log k'}{d\log Q_t}$.

Non-adjuster. When $m' = div = 0$, the non-debt-adjuster's budget constraint implies:

$$k' = \frac{1}{Q_t}\left[\Upsilon_t(k,m) - \frac{c_b}{\Pi_t q_{t-1}^b}b + \frac{1+r_t^m}{\Pi_t}m + Q_t(1-\delta)k\right] \tag{B.23}$$

Analogously as above, defining $\mathcal{Y}_t^N(k,m,b) \equiv \Upsilon_t(k,m) - \frac{c_b}{\Pi_t q_{t-1}^b}b + \frac{1+r_t^m}{\Pi_t}m$ as a measure of the effective *liquid* net financial position of the firm, and $\mathcal{B}_t^N(k,m,b) \equiv \frac{-\mathcal{Y}_t^N(k,m,b)}{Q_t(1-\delta)k}$ as the corresponding liquid net leverage position, one can write:

$$\frac{d\log k'}{d\log Q_t} = -1 + \frac{Q_t(1-\delta)k}{\mathcal{Y}_t^N(k,m,b) + Q_t(1-\delta)k} = \frac{\mathcal{B}_t^N(k,m,b)}{1-\mathcal{B}_t^N(k,m,b)} \tag{B.24}$$

The resulting positive effect of $\mathcal{B}_t^N(k,m,b)$ on $\frac{\partial\log k'}{\partial\log Q_t}$ for the non-adjuster reflects analogous mechanics as above: the higher the effective net leverage position, the more elastic are the available funds to changes in asset prices. However, the key difference between the non-adjuster's and the adjuster's cases is that the former is assumed to use all its available *liquid* funds on hand $\mathcal{Y}_t^N(k,m,b) + Q_t(1-\delta)k$ in acquiring capital k', whereas the latter does so by levering the whole net worth $\mathcal{Y}_t^A(k,m,b) + Q_t(1-\delta)k$. And since, all else equal, the only difference between the firm's liquid funds on hand and its net worth is the value of the firm's long-term debt left outstanding ($\mathcal{Y}_t^N - \mathcal{Y}_t^A = \gamma_t b$) the relevant effective leverage of the debt adjuster is higher ($\mathcal{B}_t^A(k,m,b) - \mathcal{B}_t^N(k,m,b) = \frac{\gamma_t}{Q_t(1-\delta)}\frac{b}{k}$), leading to a higher elasticity of investment to asset prices for the debt adjuster whenever long-term debt b is positive. To provide an illustrative back-of-the-envelope calculation of the relevant magnitudes, evaluated at the mean $\frac{b}{k} \approx 0.31$ in the steady state of the calibrated model of Section 3, one gets $\mathcal{B}_{SS}^A - \mathcal{B}_{SS}^N = \frac{\gamma_{SS}}{(1-\delta)} \times \text{mean}(\frac{b}{k}) \approx 0.296$. And the implied elasticities, evaluated at the cross-sectional mean financial positions, yield $\frac{\partial\log k'}{\partial\log Q_t} = \frac{\mathcal{B}_{SS}^A}{1-\mathcal{B}_{SS}^A} \approx 0.204$ and $\frac{\partial\log k'}{\partial\log Q_t} = \frac{\mathcal{B}_{SS}^N}{1-\mathcal{B}_{SS}^N} \approx -0.113$ for the adjuster and non-adjuster, respectively.