Financial Constraints and Capital-Labor Substitution in Response to Monetary Policy

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Abstract

This paper investigates how firm leverage affects the transmission of monetary policy to labor demand. We find that expansionary monetary policy has a stronger effect on the employment of more leveraged firms but a weaker effect on their capital investment. We interpret these findings using a heterogeneous firm New Keynesian model with two types of wholesale firms facing financing constraints that differ by their leverage and a flexible constant elasticity of substitution (CES) production function of both wholesale and retail firms. In the cross-section, more leveraged firms shift to a less capital-intensive production mode in response to easing monetary policy. On the aggregate, more leverage dampens the response of capital, and thus aggregate demand. As a result, employment response is initially muted but later amplified as firms substitute capital for labor.

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1 Introduction

Since the Great Recession, the Federal Reserve has embarked on a path to normalize monetary policy, raising interest rates towards pre-crisis levels, adjusting the pace according to the economy's performance. These efforts are designed to bolster the Fed's ability to achieve its goals under ''dual mandate", with equal emphasis on both full employment and price stability. [1]

At the same time, the importance of a force that may alter the efficacy of the transmission of the monetary policy–financial frictions–have also grown. A common proxy to those, aggregate leverage—defined as the ratio of nonfincial corporate debt to GDP—has been on a steady upward trajectory, reaching historically high 78%[2]. The quality of this debt has worsened, with BBB-rated bonds, the riskiest slice of investment-grade securities, now making up half of that market. While the literature has mostly focused on the role of financing constraints in transmission to investment, it is less clear what this means for the ability of the Fed to meet its objectives on employment.

This paper addresses this question by examining whether financial frictions dampen or amplify the transmission of monetary policy to firms' employment, in the cross-section as well as on the aggregate, and why. We begin by providing evidence of heterogeneity in firm-level responses to monetary policy, using annual monetary shocks combined with firms' balance sheet information from Compustat. Additionally, we analyze other firm-level variables to explore potential mechanisms behind the role of leverage in shaping labor demand responses. We then employ a New Keynesian model with two types of firms, differing by leverage, to rationalize these findings and investigate whether the cross-sectional results translate into similar effects at the aggregate level.

We find that monetary policy has a stronger impact on labor demand when of firms that are more leveraged, while the effect on capital investment moves in the opposite direction. Interestingly, we observe no significant heterogeneity in sales responses across firms. While consistent findings on labor demand and capital investment separately have been documented in previous studies (see Bahaj et al. 2022 for employment and Ottonello and Winberry 2020 for investment), our analysis uniquely combines these dimensions within a unified setting. Our insight is that firms with higher-than-average leverage shift to a significantly less capital-intensive mode of production following an expansionary monetary shock

1. Chair Jerome H. Powell, "New Economic Challenges and the Fed's Monetary Policy Review," August 2020.

2. According to IMF Global Debt database in 2022.

without affecting their overall output by much. Previous work often focuses on a single aspect—such as investment or employment—when evaluating how financial frictions influence monetary policy transmission. Our study shows that this narrow focus can lead to misleading conclusions about the overall firms' responsiveness, as firms' capital and labor responses may diverge.

We propose that a strong aggregate demand channel can explain our empirical findings. Financial frictions distort the investment response of leveraged firms. However, an expansionary monetary shock raises aggregate demand for the firms output. When unable to increase capital, leveraged firms are forced to hire additional labor instead to meet demand, reducing their capital–labor ratio and amplifying their labor demand response. Our proposed mechanism challenges the conventional view of how financial constraints affect monetary policy transmission, which suggests that firms' capital, labor, and output growth move in the same direction with changes in their borrowing capacity following a monetary policy shift (Jungherr et al. 2022; Ippolito et al. 2018; and González et al. 2024).

In our empirical analysis, we use a panel local projection method to estimate both the immediate and dynamic impacts of monetary shocks, identified through the high-frequency event-study approach. We construct a series of annualized monetary surprises from 1990 to 2007 and merge it with firm-level balance sheet data from Compustat. The dataset includes information on employment, investment, sales, and other characteristics for 5,243 non-financial firms, varying in size from 19 to 115 thousand employees. To assess the variation in response across firms, we interact the monetary policy shock with firm leverage. Following the methodology of Ottonello and Winberry (2020), we concentrate on within-firm changes in leverage, ensuring that long-term differences between firms do not affect our key findings regarding firms' sensitivity to monetary policy. Firm fixed effects are included to control for permanent firm-specific traits, and sector-by-quarter fixed effects are added to account for sectoral responses to aggregate shocks.

To interpret our empirical results and explore their macroeconomic implications, we develop a New Keynesian model with financial frictions and two types of wholesale firms that differ by their leverage. These wholesale firms invest in capital, hire labor, financed through internal funds or external borrowing, and sell their output to retailer firms. Retailer firms, in turn, face price adjustement costs, generating a New Keynesian Phillips curve that links nominal variables to real outcomes. Financial frictions in the model are represented by dividend and collateral constraints, consistent with the literature. To generate variation in leverage, we introduce unanticipated transitory shocks to firms' debt stock. Financial constraints are modeled as occasionally binding and are approximated using penalty functions (Brzoza-Brzezina et al. 2015).

In a key departure from the literature, we relax the standard Cobb-Douglas production function and output price symmetry in the wholesale sector. These typical assumptions would imply co-movement in demand for capital and labor, which contradicts our empirical findings. Instead, we adopt a flexible CES structure for the production of both wholesale and retail firms. The parameters suggest upstream substitutability between capital and labor in wholesale production and a downstream preference for product variety in retail production. The first adjustment makes it easier for capital and labor to decouple in response to a monetary shock. The second adjustement propagates the aggregate demand pressure to all wholesale firms. We calibrate the model to match observed investment responses, and show that the model replicates the pattern found in the data for employment.

From our empirical exercise, we find that within the first year following a one standard deviation cut in interest rates, a firm with leverage 1 standard deviation higher (around 37 percentage points) increases employment by 0.55 percentage points more than the average firm. The point estimates remain elevated over the five year horizon, indicating a persistent effect. The effect of leverage on firms' investment responsiveness to monetary policy is similar in magnitude but opposite in sign. The differential response of sales to a monetary policy shock is zero on average over a 5-year horizon and statistically insignificant in every period (with a temporary shift from positive to negative midway through the period).

Our results from the model indicate that the primary effect of leverage in monetary policy transmission to the cross-section of firms is in determining the mode of production rather than in amplifying (or dampening) the response of output as a whole. While more leveraged firms expand production less after monetary policy, the effect is significantly muted compared to the response of capital. This is in line with our empirical evidence on the differential response of firms' sales.

Our findings show that the heterogeneity at the firm level does not translate directly to the aggregate level. We show that leverage plays a key role in distorting the transmission of monetary policy shocks to aggregate investment and prices. More leverage dampens the response of capital and, thus, aggregate demand. As a result, employment response is initially muted but later amplified as firms substitute capital for labor. In addition, the impact of leverage on output and consumption responses to monetary policy is negligible beyond the initial period.

We also compare our model's aggregate output response to a monetary policy shock with the response of a model with the simplified Cobb-Douglas production function and output price symmetry (the 'standard' model). The effect of monetary policy on output is slightly larger but less persistent in the 'standard' model. Additionally, while the state-dependence of responses is similar in shape in both models, leverage has a stronger effect in magnitude in the 'standard' model. Our analysis implies that financial frictions may exert less distortion on monetary policy transmission in an environment characterized by upstream substitutability between capital and labor in wholesale production and downstream preferences for product variety in retail production.

Related literature Our research builds upon several strands of literature that examine the impact of financial frictions and firm heterogeneity on monetary policy transmission. While earlier studies have explored either the investment or employment responses to monetary policy in isolation, we contribute by examining both dimensions within a single framework. By doing so, we highlight the interaction between capital and labor decisions and the role of leverage in shaping firms' responses to monetary policy shocks.

This paper is the first to document that more leveraged firms exhibit a stronger labor demand response to monetary policy in the U.S., using firm-level microdata. Our study adds to the findings of Bahaj et al. (2022), who demonstrate that more leveraged and younger firms in the UK exhibit stronger labor demand responses to monetary policy.[3][4] Unlike Bahaj et al. (2022), our study considers within-firm changes in leverage over time, isolating the impact of leverage from permanent differences in firms' responses, providing a clearer view of how leverage alone amplifies firms' sensitivity to monetary shocks.

In the U.S. context, our research differs from existing studies on employment responses to monetary policy, such as Singh et al. (2023) and Yu (2022). Both Singh et al. (2023) and Yu (2022) document that smaller and younger firms exhibit stronger labor demand reactions to monetary policy. However, our specification offers several advantages. First, we employ a panel local projection method combined with firm-level balance sheet data, capturing both immediate and dynamic impacts of monetary shocks. This contrasts with the approach used by Singh et al. (2023), who utilize state-sector level data from the Quarterly Workforce Indicators dataset, with data grouped by firm characteristics. While detailed firm characteristics such as size and industry are reported, the dataset lacks other balance

3. They use a broad definition of leverage as the ratio of total liabilities to total assets, where liabilities may include accounts payable, pension obligations, income tax liabilities, contingent liabilities, and sales taxes.

4. Age of the firm is measured as the number of years since incorporation.

sheet information. Similarly, Yu (2022) uses firm-level microdata but includes only basic characteristics such as age and size, without key variables like leverage or total assets, making it difficult to account for confounding factors that may influence firms' responses to monetary policy.

Evidence from other countries on employment responses to monetary policy reveals similar patterns of heterogeneity. Jasova et al. (2023) find that smaller and younger firms in Portugal show higher sensitivity in wages, hours, and employment due to limited access to credit, while Madeira and Salazar (2023) observe that the labor market in Chile's primary sector is the least responsive to monetary shocks. These findings further emphasize the role of firm characteristics in shaping labor market responses to monetary policy across different countries.

We contribute to the empirical literature studying the role of financial frictions on firms, with a focus on investment (Ottonello and Winberry 2020; Jeenas 2023; Cloyne et al. 2023;Ippolito et al. 2018). While employment is not the primary focus of this literature, the implicit (or explicit) conclusion is that firms more sensitive to monetary policy in terms of investment also tend to grow more overall. We challenge this conclusion by providing evidence that employment and investment responses diverge, with more leveraged firms increasing labor demand while reducing capital intensity. Additionally, we find no significant heterogeneity in sales responses across firms. We replicate the results in Ottonello and Winberry (2020) using annual Compustat data over the same time period and the same estimation strategy. As we combine this evidence with the findings about employment, we conclude that when more leveraged firms, become less capital intensive in response to expansionary monetary shock.

Finally, our study contributes to the broader literature integrating micro-level heterogeneity within the New Keynesian framework. While previous research has primarily focused on household-level heterogeneity (McKay et al. 2016;Kaplan et al. 2018; Auclert 2019; and Wong 2019), or firm-level heterogeneity (Ottonello and Winberry 2020;Jungherr et al. 2022;Ippolito et al. 2018; Jeenas 2023) and it's impact on investment, our study shifts the focus to labor demand. Building on Jermann and Quadrini (2012) and Drechsel (2023), our model incorporates firm heterogeneity and financial constraints within a New Keynesian framework. The key modifications to the standard New Keynesian framework are flexible CES production functions in wholesale and retail firm sectors, allowing for substitution between capital and labor, rather than assuming fixed co-movement between the two inputs. This flexibility is critical for capturing the heterogeneous responses we observe empirically. Additionally, we model financial frictions as occasionally binding constraints, approximated with penalty functions, which allow for fluctuations in firm's leverage.

Road map Our paper is organized as follows. Section 2 describes the data and empirical specification. Section 3 presents empirical evidence. Section 4 presents the model and calibration. Section 5 uses the model to study the monetary transmission mechanism. Section 6 concludes.

2 Data and Methodology

We use annual firm-level data from Compustat to make inferences about the employment and investment response to monetary policy depending on the firm's leverage.

2.1 Monetary Policy shocks

We follow the high-frequency approach to the identification of monetary policy shocks by Gurkaynak et al. 2005 and Gorodnichenko and Weber 2016.

The shocks are constructed in two steps. Step one takes the raw jumps in the movement in the federal funds rate implied by the current-month federal funds futures contract in a short window of time (from 15 minutes before the announcement to 45 minutes after the announcement) around the Federal Open Market Committee (FOMC) announcements. The purpose of focusing on a narrow window around the FOMC announcement is that one can be reasonably certain that no other news caused the change in the futures rates, while the policy decision is already locked, so the movements in the market could not have caused the policy. Second, following Ottonello and Winberry 2020, we aggregate the high-frequency shocks using a weighted moving average of the shocks, so that an announcement at the end of year t_1 is essentially the same as an announcement at the beginning of year t. We provide a detailed explanation of how we construct the shocks as well as a discussion of alternatives in Section A of the Appendix **??**. Our baseline series begins in January 1990, coinciding with the inception of the Fed Funds futures market, and concludes in December 2007, concentrating on an unbroken spell of conventional monetary policy. We end the sample period before 2008 to avoid the unusual conditions at the onset of the Great Recession and the federal funds rate reaching the zero lower bound, which resulted in little variation in the implied ε_t^m series. We end up with 17 shocks, which are, on average, expansionary. Table 1 presents the summary statistics of the shock. To ease interpretation as well as the comparison across methods, we rescale the shocks to have a standard deviation of one and flip the sign so that an increase in the shock indicates an easing of monetary policy.

Table 1: Summary statistics of monetary policy shocks

	Raw High Frequency	Smoothed Annual	Smoothed, +, sd 1 Annual
Mean	-0.0185	-0.172	0.559
Median	0	-0.113	0.365
S.D.	0.0855	0.309	1
Min	-0.463	-0.843	-1.075
Max	0.152	0.332	2.732
Observations	164	17	17

Notes: Summary statistics of monetary policy shocks for the period 1/1/1990 to 12/31/2007. "High frequency" shocks are estimated using the event study strategy as in Ottonello and Winberry 2020. "Smoothed" shocks are time aggregated to an annual frequency using the weighted average described in Supplemental Materials A. In the last column, shocks have a flipped sign to ease interpretation and are standardized.

To be clear, ε_t^m should be viewed as an imperfect approximation of the annual structural monetary policy shocks, ε_t^f, which are considered fundamental, unexpected innovations that are independent of other structural disturbances. Since ε_t^f is unobservable, following Stock and Watson 2018, ε_t^m can be used as an instrument for policy rate changes in instrumental variable (IV) regressions. However, because this essentially amounts to instrumenting one endogenous variable with a single strong instrument, the resulting estimates are nearly identical (up to a scalar factor) to those obtained by using ε_t^m directly as a measure of monetary policy shocks in ordinary least squares (OLS) regressions. In line with the broader literature, we report the main empirical findings using OLS with ε_t^m.

2.2 Firm Level data

For the firm-level analysis we obtain information on balance sheet and income statements from the annual Compustat database. Compustat offers a long panel of detailed balance-sheet information for U.S. firms, enabling us to utilize within-firm variation and construct key variables of interest. Our main variable of interest is the change in the log of employment $\Delta \log e_{jt}$, where e_{jt} is number of employees of firm j at the end of the period t. Following Ottonello and Winberry 2020, we study the behavior of capital investment, defined as $\Delta \log k_{jt+1}$, where k_{jt+1} is the book value of the tangible capital stock of firm j at the end of period t, constructed using a perpetual inventory method (Section B.1 in the Appendix **??**). We focus on the responsiveness of firms' capital stocks rather than investment rates, as micro-level investment tends to be lumpy and volatile (Doms and Dunne 1998). This irregularity makes it challenging to accurately identify systematic responses in investment rates across firms, particularly over longer time horizons. We also consider sales' response as a proxy for the measure of overall firm output.

The main explanatory variable we examine is leverage ℓ_{jt}. More specifically, we measure leverage as a firm's debt-to-asset ratio: a share of the sum of short term and long term debt and in the overall book value of assets. Finally we collect a range of firm-level variables to use as potential controls, including the share of current assets. A shortcoming of Compustat is that it excludes privately held firms and that employment is only available on an annual frequency.

To ensure our results are not influenced by outliers, we winsorize our sample at the top and bottom 0.5% of observations for investment rate, sales growth of more than a 100% or less than a -100%, and leverage is over 1000% . Additional details on sample selection and variable construction are provided in Appendix **??**, specifically in Sections B.2 and B.3.

In the baseline analysis, we merge monetary policy shocks to the firm-level data on a calendar year basis (regardless of the fiscal-year definition each firm adopts)[5]. The resulting underlying unbalanced panel contains 59,111 firm-year observations. Table 2 presents basic summary statistics of the sample used in our analysis. Compustat contains only publicly traded firms, thus the median size of the firm in the sample is large, about \$ 152 million (in 2017 dollars). The average firm has 700 employees. The right-skewed size distribution of firms motivates the usage of log assets as the relevant measure of size in regressions. The mean leverage ratio is approximately 27% and exhibits considerable variation in the cross-section, with a standard deviation of 37.2%.

Larger firms, both by size, sales and employment, tend to have slightly higher leverage. Meanwhile, capital, labor, and capital-labor ratio growth rates are negatively correlated with leverage. 14% of firms in our sample do not hold any debt.

5. As a robustness exercise, we aggregate monetary policy shocks based on fiscal years and merge them to the firm dataset on a fiscal year basis. While potentially being more precise, this specification differs from the baseline by having the monetary policy shock ε_t^m varying across firms. The results are comparable.

Table 2: Summary statistics of the firm-level variables in the Compustat sample

	Mean	Median	S.D.	Observations	Corr with leverage
ℓ_{jt}	0.27	0.20	0.37	59,111	
$\Delta \log k_{jt+1}$	0.00	-0.01	0.31	59,111	-0.1046
$\Delta \log e_{jt}$	-0.01	0.00	0.33	57,128	-0.0625
$\Delta \log \frac{k_{jt}}{e_{jt}}$	0.03	0.00	0.41	57,128	-0.0266
$\Delta \log \text{sales}_{jt}$	0.01	0.03	0.38	58,919	-0.0585
Size (mill)	2293.03	152.01	13004.91	59,069	0.0134
Employment	7926.32	700.00	38535.81	57,724	0.0021
Sales (mill)	2134.77	169.28	10984.14	59,030	0.0014

Notes: Summary statistics of firm-level variables for the period 1990-2007. Leverage is measured as total debt to asset, $\Delta \log k_{jt+1}$ is the annual growth in the capital stock, $\Delta \log e_{jt}$ the annual growth in the number of employees, $\Delta \log \frac{k_{jt}}{e_{jt}}$ the annual growth in capital-labor ratio

2.3 Empirical framework

Our empirical analysis aims to test whether monetary policy's effect on a firm's employment is muted, amplified, or unaffected by firm's leverage. Additionally, we examine other firm-level variables, such as capital and sales, to assess whether the effects of monetary policy on these variables align with the observed labor demand responses.

We approach this by estimating heterogenous local projections à la Jordà 2005 to capture the dynamic effect of moentary policy. Specifically, we regress the cumulative change in a variable of interest $\Delta_h \log y_{j,t+h} (\equiv \log y_{j,t+h} - \log y_{j,t-1})$ over a given horizon $h \geq 0$ on interaction terms between firms' leverage at the end of period $t-1$ and the monetary policy shock at time t, while controlling for various firm-level characteristics. This allows us to assess the role of the leverage ratio (denoted as $\ell_{j,t-1}$) in shaping firms' responses, both on its own and in combination with other characteristics highlighted in the literature.

We estimate variants of the baseline empirical specification

$$\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h (\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h' (\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}]) Y_{t-1} + \epsilon_{j,h,t+h}, \quad (1)$$

where $y_{j,t}$ is firms' employment, capital, capital-labor ratio or sales, $h = 0, 1, \ldots, H$ denotes the horizon at which the relative effect is being estimated, j stands for a firm, and t for a year. $\alpha_{j,h}$ denotes firm j's fixed effect in it's cumulative $h+1-$ year $y_j -$ growth. $\alpha_{s,t,h}$

is a sector s by year t fixed effect for $h+1$-year growth[6]. $\ell_{j,t-1}$ is the firm's leverage ratio (debt-to-asset ratio), $\mathbb{E}_j[\ell_{j,t}]$ the average value of $\ell_{j,t}$ for a given firm j over the sample. $Z_{j,t-1}$ 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 annual monetary policy shock as described in Section .

The main coefficient of interest β^h measures how the semi-elasticity of net hiring in response to a monetary policy shock depends on firms' leverage. For clarity, we scale β^h by 100 to express the results in percentage points. The shock variable, ε_t^m, is standardized by its sample standard deviation, which is approximately 0.309 units, where a positive ε_t^m corresponds to a decrease in the federal funds rate. We also standardize firms' demeaned leverage, $\ell_{j,t-1} - \mathbb{E}j[\ell j, t]$, so that the units represent standard deviations within the sample. As a result $100 \cdot \beta^h$ represents the percentage point difference after h years in the response of net hiring to a 1 standard deviation easing of monetary policy when the firm's prior leverage is 1 standard deviation higher. Positive estimates of β^h would indicate that the increase (decrease) in net hiring prompted by a monetary expansion (contraction) is amplified by firms' leverage.

Our baseline firm controls $Z_{j,t-1}$ include standardized leverage $\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}]$, total assets, sales growth, current assets as a share of total assets, all measured at the end of year $t-1$ to ensure exogeneity with respect to the shock ε_t^m. The extra controls in addition to $\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}]$ potentially capture heterogeneity across units that could correlate with their leverage as well as their sensitivity to monetary policy shock. The vector Y_{t-1}, which includes past GDP growth and/or unemployment rate, accounts for potential differences in cyclical sensitivities across units that are not driven by the monetary policy shocks. Since the primary objective is to assess differences in firms' responses to monetary shocks based on their leverage ratios, incorporating sector-time fixed effects, $\alpha_{s,t,h}$, provides a flexible approach to controlling for aggregate time variation. However, this precludes us from measuring the baseline effect of ε_t^m on net hiring or other variables.

We adopt an approach from Ottonello and Winberry 2020 and focus on within-firm variation in leverage, $\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}]$, to ensure that permanent differences across firms do not influence our main results on firms' responsiveness, since firms in the data may be ex-ante heterogeneous in how they react to monetary policy in a way that correlates with their average leverage ratio. For instance, firms in riskier markets may consistently carry higher leverage, making them more exposed to interest rate fluctuations. By demeaning the leverage

6. The sectors s we consider, based on SIC codes, are: agriculture, forestry, and fishing; mining; construction; manufacturing; transportation communications, electric, gas, and sanitary services; wholesale trade; retail trade; and services. We do not include finance, insurance, and real estate, and utilities

within firms our estimates capture how a firm's response to monetary policy varies when it has higher or lower leverage than its typical level. We leave the analysis with the level of ℓ_{jt} as a robustness exercise in Appendix E.3.

Throughout the analysis, we cluster standard errors in two dimensions, by j and by t, to account for intra-unit and intra-time correlations.

We also apply this specification to a panel of sector-quarter data, where j stands for a sector aggregate financial positions by sector (see Appendix D).

3 Empirical results

In this section, we demonstrate that more leveraged firms exhibit a stronger labor demand response to monetary policy. Prior research does not provide a straightforward explanation for how leverage affects the transmission of monetary policy to labor demand, since labor cannot serve as collateral. In contrast, the relationship between leverage and capital is more intuitive, with capital frequently acting as a key source of corporate collateral.

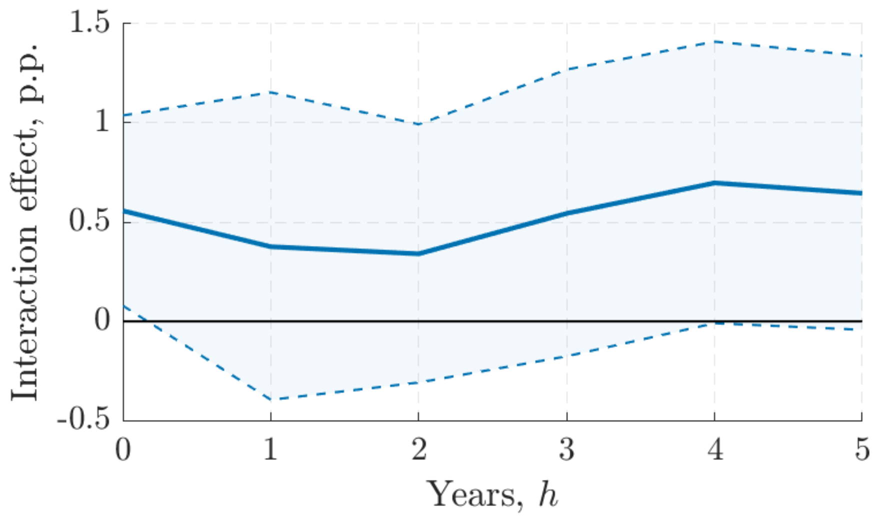
Next, we study the behavior of other firm-level variables to shed light on possible mechanisms behind the amplifying role of leverage in the response of labor demand. We show that in contrast to employment, the response of investment to monetary policy is muted for highly leveraged firms (as in Ottonello and Winberry 2020). Our results are puzzling, revealing that expansionary monetary policy creates a wedge in capital intensity between more and less leveraged firms. Overall, we find no evidence of heterogeneous effects on sales.

3.1 Employment response to Monetary policy

Figure 1 presents the main result of the empirical analysis, showing scaled point estimates for β^h with 90% confidence intervals from the baseline specification (1). The positive estimates show that firms with higher leverage at the time of an expansionary monetary shock increase their employment relative more compared to the baseline. The effect is significant at the 95% level at the time of the shock, becomes insignificant between years 1 and 3, and returns to significance in year 4.

Within the first year following a one standard deviation cut in interest rates, a firm with leverage 1 standard deviation higher (around 37 percentage points) increases employment by 0.55 percentage points more than the average firm. Despite large standard errors, the point estimates remain high over the five year horizon, indicating a persistent effect. The large standard errors may be due to the small number of monetary shocks in the sample—only 17—forced by Compustat data providing employment information only on an annual basis.

Figure 1: Dynamics of heterogeneous net hiring responses to monetary policy



Notes: This figure displays the dynamic interaction coefficient β^h between leverage and monetary policy shocks over a five-year horizon $h = \overline{0,5}$. The dependent variable $y_{j,t+h}$ is employment. Estimates are obtained from the specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma'_h Z_{j,t-1} + \Omega'_h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, where all variables are defined in the main text, Section 2.3. The figure plots point estimates and 90% confidence intervals, constructed using standard errors clustered at both the firm and time levels. All estimates are scaled to percentage point units.

These findings are also consistent with suggestive evidence at from a quarter-industry panel (NAICS 3-digit), which we present in Section D.2 in the Appendix D.

Table 3 presents the results from estimating the baseline specification (1) at a time horizon of $h = 0$, which captures the immediate effect within the year of the monetary shock.

In Columns 1 and 2, we omit firm-level control variables, while Column 1 also excludes the interaction between past GDP and past leverage. Column 4 presents results using non-demeaned leverage, and the final column restricts the sample to firms with at least 10 years of investment data, a sample restriction similar to that of Ottonello and Winberry 2020. As we incorporate additional controls, the precision of our estimates improves, likely because the controls account for heterogeneity across firms, which may be correlated with both their leverage and their sensitivity to monetary policy shocks, thus reducing noise in our estimates. The point estimates remain within a similar order of magnitude.

Our findings indicate that more leveraged firms respond more strongly to monetary

Table 3: Heterogeneous net hiring responses to monetary policy

	(1)	(2)	(3)	(4)	(5)
leverage × ffr shock	0.00373	0.00396	0.00550**		0.00511*
	(0.00248)	(0.00245)	(0.00258)		(0.00267)
leverage (with mean) × ffr shock				0.00438**	
				(0.00179)	
Observations	51303	51303	49940	49940	42221
R^2	0.247	0.247	0.261	0.261	0.222
Firm controls	no	no	yes	yes	yes
Interaction of leverage with L.GDP	no	yes	yes	yes	yes
Time sector FE	yes	yes	yes	yes	yes
Time clustering	yes	yes	yes	yes	yes
Spell of at least 10 years					yes
p-value on main coefficient	0.15	0.13	0.05	0.03	0.07

Note: Results from estimating variants of the baseline specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, for $h = 0$. The dependent variable $y_{j,t+h}$ is employment. Point estimates and standard errors are reported in log units. Columns 1 and 2 omit the firm-level control variables. Column 1 omits the interaction of past GDP with past leverage. Column 4 reports the result for non-demeaned leverage. The last column restricts the sample to spells of at least 10 years of data on investment (a sample restriction adopted by Ottonello and Winberry 2020). Standard errors in parentheses are clustered two ways, on firm and year. The last row of the table reports the p-value on the main effect of interest.

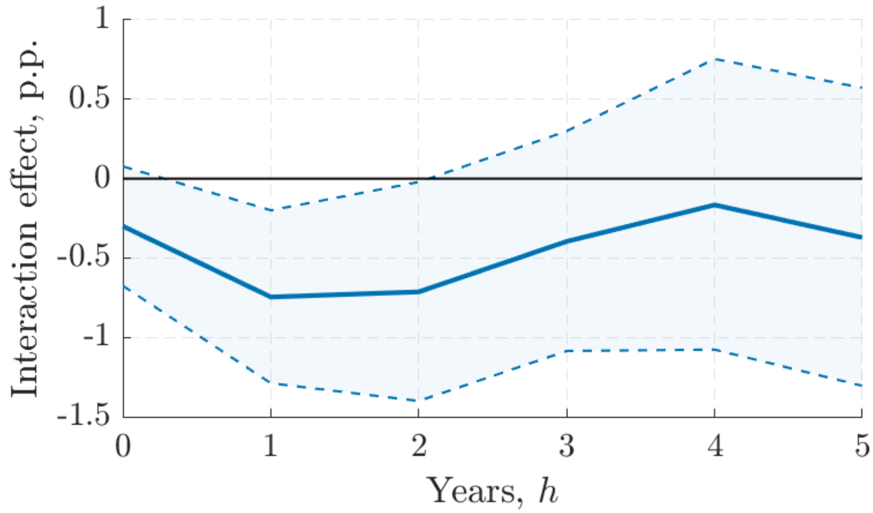
shocks[7]. The most common theoretical explanation for the heightened sensitivity of more leveraged firms to monetary policy is the financial accelerator mechanism, where high leverage is interpreted as a proxy of being financially constrained. Expansionary monetary policy, by raising asset prices, current period revenue and the value of collateral, eases financial constraints. This enables firms that were previously constrained to respond more flexibly to shocks. However, if this financial accelerator effect was driving our results (i.e. expanding firms' borrowing capacity would free the leveraged firm to respond more to the demand shock), we should observe a comparable heterogeneity in the response of firms' investment to expansionary monetary shocks. This reasoning motivates our next subsection, which investigates the heterogeneous response of firms' investment to monetary policy, conditional on leverage.

7. Our baseline specification yields results that are consistent with the findings of Bahaj et al. 2022, who show that employment at younger, more-leveraged firms is the most sensitive to monetary policy shocks, based on micro-data from private and public UK firms.

3.2 Investment response to Monetary policy

Figure 2 shows the point estimates of β^h, along with 90% confidence intervals, derived from the baseline specification (1) with firm investment as the dependent variable. The point estimate differences turn negative at the time of the shock (Table A2 in Appendix C) and become statistically significant at the 95% level one year later.

Figure 2: Dynamics of heterogeneous investment responses to monetary policy



Notes: This figure displays the dynamic interaction coefficient β^h between leverage and monetary policy shocks over a five-year horizon $h = \overline{0,5}$. The dependent variable $y_{j,t+h}$ is physical capital. Estimates are obtained from the specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, where all variables are defined in the main text, Section 2.3. The figure plots point estimates and 90% confidence intervals, constructed using standard errors clustered at both the firm and time levels. All estimates are scaled to percentage point units.

In contrast to our analysis of employment, the behavior of investment suggests that more leveraged firms are less responsive to monetary policy. These results replicate those of Ottonello and Winberry 2020[8]. Ottonello and Winberry 2020 argue that after a positive monetary shock raises investment demand across the board, leveraged firms respond less than they would want as they bump against their financial constraints. While the financial accelerator channel is present and pushes in the opposite direction, it is dominated by the direct effect of constraints. Overall, the behavior of investment is inconsistent with the hypothesis that leverage amplifies the response of employment through the financial accelerator channel.

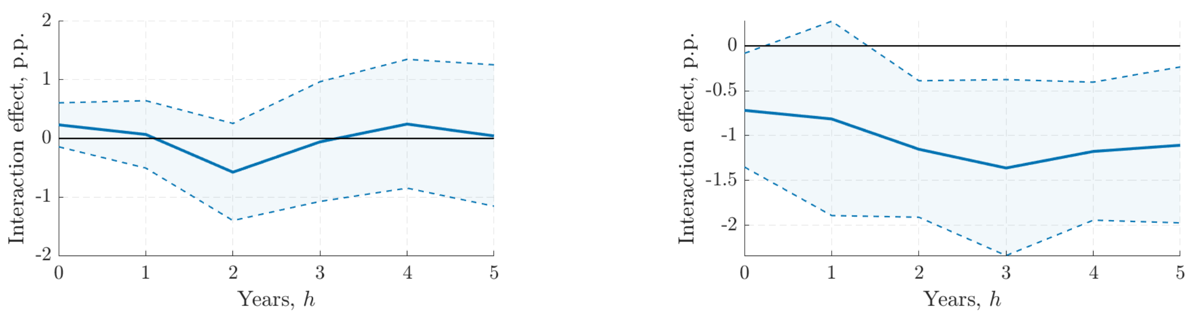
8. They use quarterly Compustat data over the same time period and the same estimation strategy.

Aligned with the response of aggregate economic activity, as estimated by Gertler and Karadi 2015, differences in fixed capital accumulation take time to materialize. The largest differences, observed between one and two years after the shock, indicate that a 37 percentage points higher leverage ratio predicts approximately 0.55 percentage points lower cumulative capital growth following a one standard deviation monetary policy shock. Afterward, the differences begin to gradually dissipate.[9] The analysis of investment on the sector level is consistent with the firm-level heterogeneity (see Appendix D.2)

3.3 Additional analysis for sales and capital-labor ratio

Figure 3 (a) presents the results of the baseline analysis, where we use the log-change in the firm's sales as the a proxy for the firm's total output. The differential response of sales to a monetary policy shock is zero on average over a 5-year horizon, with a temporary shift from positive to negative midway through the period. This suggests that leverage actually does not significantly impact whether a firm grows more or less overall after a monetary policy shock. Instead, heterogeneity in leverage is primarily affecting the firms' mode of production.

Figure 3: Dynamics of heterogeneous sales' and capital-labor ratio's responses to monetary policy



(a) Sales (b) Capital-Labor ratio

Notes: This figure displays the dynamic interaction coefficient β^h between leverage and monetary policy shocks over a five-year horizon $h = \overline{0,5}$. The dependent variable $y_{j,t+h}$ for panel (a) is sales, for panel (b) – Capital-Labor ratio. Estimates are obtained from the specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma'_h Z_{j,t-1} + \Omega'_h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, where all variables are defined in the main text, Section 2.3. The figure plots point estimates and 90% confidence intervals, constructed using standard errors clustered at both the firm and time levels. All estimates are scaled to percentage point units.

Figure 3 (b) illustrates this clearly. Within the first year following a one standard deviation

9. The magnitude of this effect aligns with the findings of Durante et al. 2022, though it is opposite in sign. They use annual firm-level data from four European countries.

cut in interest rates, a firm with leverage 1 standard deviation higher (about 37 percentage points) reduces its capital intensity (capital-labor ratio) by 0.7 percentage points. This effect persists and reaches a maximum decline of 1.5 percentage points three years after the shock. Notably, the capital-labor ratio does not recover within the 5-year period. The immediate effects on firms' sales and capital-labor ratios are reported in Tables A3 and A4, respectively, in Appendix C.

3.4 Robustness

Appendix E.3 presents three sets of additional empirical results that serve as robustness checks for our main findings. The first set addresses alternative definitions of monetary policy shocks. Table A7 shows that the results remain robust when controlling for the information channel of monetary policy, using Greenbook forecast revisions following Miranda-Agrippino and Ricco 2021. Additional specifications using alternative monetary policy shock series yield similar conclusions and are discussed in the same Section E.1.

The second set examines robustness with respect to firm-level heterogeneity. These specifications allow the monetary policy shock to interact with other firm characteristics such as size, sales growth, and the share of current assets in total assets (see Tables in Section E.2).

The third set of results connects our analysis to existing literature. We demonstrate that our findings remain consistent when using alternative measures of firms' financial positions—such as distance to default (as in Ottonello and Winberry (2020), Figure A1), firm liquidity (as in Jeenas (2023), Figure A2), and firm age (as in Cloyne et al. (2023), Figure A4).

4 Model

In this section, we build a mode that allows us to explain the empirical patterns observed in Section 3 of Chapter 1. We consider a New Keynesian model with two types of firms that face dividend and collateral constraints and are hit by idiosyncratic shocks of opposite signs to their debt at the beginning of the period. The model comprises three parts: a production block that captures firms' heterogeneous responses to monetary policy, a New Keynesian block that produces the Phillips curve, and a representative household block that completes the framework.

4.1 Production block

A continuum of size 1 of wholesale firms produces intermediate goods. Within the continuum are two types of firms, $j \in A, B$. Firms with $j = A$ are hit with v_t, an unanticipated transitory shock to their debt stock, while $j = B$ denotes firms that are hit with $-v_t$[10]. The measure of type-A firms is 0.5. All intermediate producers operate the technology $y_t^j(i) = f(k_t^j(i), n_t^j(i))$, where is $k_t^j(i)$ the input of pre-determined capital, $n_t^j(i)$ the input of labor. We will discuss a choice of production function later in the paper.

In period t firms sell the intermediate good at nominal price P_t^j, while P_t is the nominal price of the final good, taking both as given. The firm's revenue in real terms is defined as

$$p_t^j f(k_t^j(i), n_t^j(i)),$$

where $p_t^j = \frac{P_t^j}{P_t}$ is the real price of the intermediate good of type-j firm.

Firms can borrow using one-term debt contracts, up to a constraint. Specifically, a firm 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. Firms are unable to issue equity and must pay a certain amount of dividends to their shareholders. Specifically, the minimum amount of dividends paid to shareholders has to be at least a fraction ω of the payout target (steady-state level of $d_t^j(i)$). Interest payments are tax-deductible, introducing a tax advantage of debt.

The decision problem of a firm is to pick a dividend $d_t^j(i)$, capital $k_{t+1}^j(i)$, labor $n_t^j(i)$ and debt $b_{t+1}^j(i)$ sequences to maximize the expected stream of dividends, discounted at its owner's discount factor $m_{t,t+1}$. State variables are $k_t^j(i)$ and $b_t^j(i)$(endogenous), and v_t^j (exogenous).

$$\max_{d_t^j(i), n_t^j(i), k_{t+1}^j(i), b_{t+1}^j(i)} \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t} d_t^j(i) \tag{2}$$

10. Mechanically, the shock to debt stock allows us to generate heterogeneity in leverage.

subject to

$$\begin{aligned}
d_t^j(i) = {} & p_t^j y(k_t^j(i), n_t^j(i)) - w_t n_t^j(i) - Q_t[k_{t+1}^j(i) - (1-\delta)k_t^j(i)] \\
& - \frac{(1+v_t^j)b_t^j(i)}{1+\pi_t} + \frac{b_{t+1}^j(i)}{R_t} && (3) \\
& \omega\bar{d} \leq d_t^j(i) && (4) \\
& b_{t+1}^j(i) \leq \theta \mathbb{E}_t Q_{t+1}(1-\delta)k_{t+1}^j(i) && (5) \\
& y_t^j(i) = f(k_t^j(i), n_t^j(i)) && (6) \\
& R_t = 1 + (1-\tau)r_t^n, && (7)
\end{aligned}$$

where $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is inflation rate, and r_t^n - the nominal one-period risk-free rate, w_t is the real wage and Q_t is the real price of a unit of capital (all common across firms). A firm's capital depreciates at rate $\delta \in (0,1)$.

4.2 New Keynesian block

Retail firms and Final Good Producer There is a unit mass of retail firms, each with a constant returns to scale production function that transforms bundled wholesale goods into intermediate retail goods:

$$y_t(k) = g(x_t^A, x_t^B)$$

with x_t^A, x_t^B the amount of intermediate goods from wholesale producers employed as input by retailer k in period t. The retailers purchase from the two types of production firms operating in a competitive market for the nominal prices P_t^A, P_t^B, and sell their production for price $p_t(k)$. They operate in a monopolistic competition and take the demand curve for their retail good as a function of $p_t(k)$ as given. In setting their prices, the retailers face Rotemberg (1982) adjustment costs $\frac{\varphi_p}{2}\left(\frac{p_t(k)}{p_{t-1}(k)} - \overline{pi}\right)^2 y_t$, Here, $\overline{\pi} > 0$ 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.

The assumption of constant returns to scale ensures that the choice can be separated into cost minimizing combination of inputs and a profit maximization choice of output and price. Thus we can write the real profit of the retailer as

$$\frac{p_t(k)}{P_t} y_t(k) - mc(p_t^A, p_t^B) y_t(k),$$

where $mc(p_t^A, p_t^B)$ is marginal cost of retail goods production.

The final good is produced by a perfectly competitive final 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 η

$$y_t = \left(\int y_t(k)^{\frac{1}{\eta}} \, dk \right)^{\eta}, \tag{8}$$

η defines nominal price markup.

Optimization by the final goods producers gives rise to the demand for retail good $k \in [0, 1]$, of

$$y_t(k) = \left(\frac{p_t(k)}{P_t} \right)^{-\frac{\eta}{1-\eta}} y_t.$$

The combination of the isoelastic demand curve, the quadratic price adjustment costs, linear production function of retailers and initial price symmetry gives rise to a New Keynesian Phillips Curve, with $\hat{\pi}_t \equiv \log(\pi_t) - \log(\pi_{SS})$, of:

$$\hat{\pi}_t = -\kappa_p \log \left(\frac{\mathcal{M}_t}{\overline{\mathcal{M}}} \right) + \beta \hat{\pi}_{t+1} \tag{9}$$

which we consider in the log-linearized form around a steady state with $\overline{\pi}$, and $\overline{\mathfrak{M}} = \eta$, as common in the literature. $\kappa_p \equiv \frac{1}{(\eta-1)\varphi_p \overline{\pi}^2}$ is the slope of the Phillips curve and $\mathcal{M}_t = 1/mc_t$.

Capital production There is a representative capital goods producer who produces new capital goods with the production technology $\Phi(\frac{I_t}{K_t})K_t$, 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 $\Phi(\iota) = \frac{\delta^{\varrho}}{1-\varrho}\iota^{1-\varrho} - \delta\frac{\varrho}{1-\varrho}$, with $\varrho \in [0, 1)$ a parameter. The capital goods producer chooses final goods spent on capital goods production, I_t, to maximize profits

$$Q_t \Phi(\frac{I_t}{K_t})K_t - I_t \tag{10}$$

therefore, in equilibrium the relative capital price Q_t equals:

$$Q_t = \left[\Phi'(\frac{I_t}{K_t}) \right]^{-1} = \left(\frac{I_t/K_t}{\delta} \right)^{\varrho} \tag{11}$$

I_t implicitly determined by

$$K_{t+1} = \Phi(\frac{I_t}{K_t})K_t + (1-\delta)K_t. \tag{12}$$

Government and Monetary Authority I combine the conduct of fiscal and monetary policy under the hood of the government.

The government faces the budget constraint:

$$T_t = \frac{B_t}{1+r_t^n(1+\tau)} - \frac{B_t}{1+r_t^n}$$

T_t denotes lump sum taxes raised on the household to ensure that the budget constraint is satisfied.
The monetary authority sets the nominal one-period risk-free rate r_t^n between $t-1$ and t following a standard Taylor rule, in nonlinear form, with

$$\frac{1+\frac{r_t^n}{1+\overline{r^n}}}{1+\frac{\overline{r^n}}{1+\overline{r^n}}} = \left(\frac{1+\frac{r_{t-1}^n}{1+\overline{r^n}}}{1+\frac{\overline{r^n}}{1+\overline{r^n}}}\right)^{\rho_R}\left[\left(\frac{\pi_t}{\overline{\pi}}\right)^{\nu_1}\left(\frac{\frac{y_t}{y_t^*}}{\frac{y_{t-1}}{y_{t-1}^*}}\right)^{\nu_2}\right]^{1-\rho_R}\xi_t, \tag{13}$$

where ρ_R, ν_1, and ν_2 are parameters and $\xi_t \sim N(0, \sigma_\xi)$

4.3 Representative Household and Market clearing

There is a continuum of homogeneous households maximizing the expected lifetime utility $E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t)$, where $U(C_t, L_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\frac{1}{\epsilon}}}{1+\frac{1}{\epsilon}}$, with C_t is consumption, L_t is labor, and β a discount factor. Households are the owners (shareholders) of firms. In addition to equity shares of both firms, they hold one-period bonds issued by firms. The household's recursive budget constraint is

$$\begin{aligned} & w_t L_t + \frac{b_t}{\pi_t} + \int s_t(i)(d_t(i) + p_t^s(i))di + = \\ & \frac{b_{t+1}}{1+r_t^n} + \int s_{t+1} p_t^s(i)di + T_t + C_t + \Xi_t^r, \end{aligned} \tag{14}$$

where w_t is the real wage, b_t the amount of one period bonds in real terms ($b_t = \frac{B_t}{P_{t-1}}$ and $b_{t+1} = \frac{B_{t+1}}{P_t}$), r_t^n is the nominal interest rate and $\pi_t = \frac{P_t}{P_{t-1}}$ inflation. $s_t(i)$ is the equity share of firm i, $d_t(i)$ is equity payout received from owning shares of firm i and $p_t^s(i)$ is the real market price of firm i shares. $T_t(i)$ are lump sum taxes financing the tax benefit of debt to firms and Ξ_t^r are the profits of the retail and capital goods producer.

We impose a standard set of market clearing conditions.

$$\text{Final good market clearing } : y_t = c_t + I_t \tag{15}$$

$$\text{Capital market clearing } K_t = \int k_t(i)di = 0.5(k_t^1 + k_t^2) \tag{16}$$

$$\text{Labor market clearing } L_t = \int n_t(i)di = 0.5(n_t^1 + n_t^2) \tag{17}$$

$$\text{Debt market clearing } B_t = \int b_t(i)di = 0.5(b_t^1 + b_t^2) \tag{18}$$

4.4 Collateral and dividend constraints

Inequality constraints generally prevent one to use standard local solution methods. A possible way of incorporating a borrowing constraint (5) and a dividend constraint (4) is to assume that they are eternally binding (EBC)(Jermann and Quadrini 2012). This is legitimate if impatient households' discount factor is low and shocks hitting the economy are sufficiently small. However, that set-up does not produce variation in the leverage ratio. Even more importantly, the EBC assumption makes the discussion about switching between constraint and unconstrainted states and its impact on firm behavior irrelevant.

To subvert this problem we will follow the approach of Brzoza-Brzezina et al. 2015 and approximate the occasionally binding constraints with penalty functions that subtract from the firms dividends each period. Specifically, we replace each constraint with an exponential cost function:

$$\Psi_t^{dj}(i) = \frac{1}{\chi_d} \exp\left(\chi_d \left(\omega \overline{d^j(i)} - d_t^j(i)\right)\right), \tag{19}$$

$$\Psi_t^{bj}(i) = \frac{1}{\chi_b} \exp\left(\chi_b \left(b_{t+1}^j(i) - \theta \mathbb{E}_t \left[Q_{t+1}(1-\delta)k_{t+1}^j(i)\right]\right)\right). \tag{20}$$

If $\chi_d, \chi_b \to \infty$, the penalty function collapses to the inequality constraint.

4.5 How do financial constraints affect the demand for capital and labor?

We have presented our empirical results, highlighting the key observation that leverage amplifies the impact of monetary policy on firm employment, while leveraged firms tend to become relatively less capital-intensive when monetary policy loosens. In this section, we discuss under what conditions our model reproduces our empirical findings. We will start with a discussion of the role of financial constraints in the investment channel of monetary policy transmission and then proceed to implications for the firm's labor demand.

Investment channel of Monetary policy: The investment channel of monetary policy operates through two potential mechanisms. On the one hand, financial frictions generate an upward-sloping marginal cost curve for investment, with the slope steeper for firms closer to hitting the constraint. As monetary policy motivates increases investment demand, the firms operating on a steep portion of the marginal cost (supply) curve invest less. On the other hand, monetary policy can alleviate these constraints by boosting cash flows or improving collateral values, effectively flattening the marginal cost curve and amplifying the investment response of firms. This latter view aligns with the financial accelerator theory, which posits that firms with tighter financial conditions are more responsive to changes in monetary policy. Although Ottonello and Winberry 2020 provides a detailed discussion of the conditions under which each mechanism prevails, we do not delve into this debate as it is not the primary focus of our paper. Nevertheless, Ottonello and Winberry 2020 finds a more muted investment response (which we replicate), suggesting that the first mechanism—financial frictions-steeper marginal cost curve—plays a dominant role. In our model, we impose two key constraints—dividend distribution and collateral—which influence firms' investment decisions. We calibrate the model such that the firm's investment responses align with the data, and firms with higher leverage expand their investment less after expansionary monetary shock.

Labor demand response to monetary policy: Our empirical results suggest that, contrary to capital, leveraged firms' labor demand reacts more strongly to monetary policy. Here, we show that whether employment follows capital depends crucially on the parametrization of the supply side of the model, specifically the choice of f and g.

A common approach to defining the revenue function (4.1) in the wholesale firms' problem, in a setting with multiple firms, treats all firms as price takers facing the same output price, with production functions following a Cobb-Douglas form:

$$p_t^j f(k_t^j(i), n_t^j(i)) = p_t \left(k_t^j(i)^\alpha n_t^j(i)^{1-\alpha}\right)^\nu,$$

where α represents the capital share and ν denotes returns to scale (this is exactly the function forms chosen by Ottonello and Winberry 2020). This framework implicitly makes two key assumptions. First, the elasticity of substitution between capital and labor is equal to one. Second, the output of different firms is perfectly substitutable ($g(x_t^A, x_t^B) = 0.5x_t^A + 0.5x_t^B$ and $p^A = p^B$ always holds in equilibrium). Then, each firm's labor demand function is as follows:

$$n_t^j(i) = \left(p_t \frac{\nu(1-\alpha)}{w_t} k_t^j(i)^{\alpha\nu}\right)^{\frac{1}{1-\nu(1-\alpha)}} .$$

For any value of α and ν, $\frac{\partial n}{\partial k}$ is positive, and nothing else in the labor demand function is firm-specific. In other words, across firms, labor always follows capital. In this context, if a firm's investment response to an expansionary monetary shock is muted, its labor response must also be muted, a behavior inconsistent with our empirical results.

We propose to relax both assumptions. First, we allow capital and labor to be more substitutable in production. This frees the paths of capital and labor from being tied together by technology. Second, we allow the intermediate outputs of wholesale firms A and B to be imperfectly substitutable in the production of the retailer's intermediate goods. Relaxing this second assumption ensures that the aggregate demand channel of monetary policy affects all firms. Expansionary monetary policy shocks increase demand for the consumption good, increasing demand for all retailer varieties. In turn, retailer firms demand more inputs from wholesale firms. If the output of firms A and B is not perfectly substitutable, retailers exert demand pressure on both firms to increase their output, with prices adjusting in equilibrium. Since more leveraged firms face limitations on how much capital they can raise to meet this increased demand, they are strongly motivated to expand output through increased labor demand instead. If the output of firms A and B was perfectly substitutable, the constrained firms could simply slack off, with the unconstrained firms taking over the market share.

The following analytical framework captures the intution above. First, we set

$$f(k_t^j(i), n_t^j(i)) = \left(\alpha k_t^j(i)^{-\rho} + (1-\alpha) n_t^j(i)^{-\rho}\right)^{-\frac{\nu}{\rho}} ,$$

where ρ governs the elasticity of substitution, with elasticity $= \frac{1}{1+\rho}$. If $\rho = 0$, the production function collapses to Cobb-Douglas.

Second, the production function for the retail firm is given by:

$$g(x_t^A, x_t^B) = \left(x_t^{A\,\frac{\kappa-1}{\kappa}} + x_t^{B\,\frac{\kappa-1}{\kappa}}\right)^{\frac{\kappa}{\kappa-1}} ,$$

where $\kappa > 1$ is the substitution parameter. Notice, if $\kappa = \infty$, the price of both firms is the same.

Under this upstream-downstream production structure, the equilibrium labor demand for a firm i of type j is given by:

$$n_t^j(i) = \left(\frac{\nu(1-\alpha)}{w_t}\right)^{\frac{1}{\rho+1}} \left(\widetilde{p}_t y_t^j(i)\right)^{\left(\frac{\nu+\rho}{\rho}-\frac{1}{\kappa}\right)\frac{1}{1+\rho}} y_t(k)^{\frac{1}{\kappa(1+\rho)}}, \quad j = A, B,$$

where $\widetilde{p}_t = \left({p_t^A}^{1-\kappa} + {p_t^B}^{1-\kappa}\right)^{\frac{1}{1-\kappa}}$ represents the aggregate price index for wholesale intermediary goods. It's also worth noting that $\widetilde{p}_t$ is the marginal cost $mc(p_t^A, p_t^B)$ in the retail firms' profit maximization problem.

A necessary condition for $\frac{\partial n}{\partial k}$ and $\frac{\partial n}{\partial y}$ to be negative is for $\frac{\nu+\rho}{\nu} - \frac{1}{\kappa} < 0$. This condition is more likely to hold if capital and labor are substitutable while x^A and x^B are not.

4.6 Calibration

We calibrate the model to annual frequency and take parameters from the literature. The exact values of the calibrated parameters are presented in Table 4. We set the discount factor to $\beta = 0.938$, implying an annual risk-free rate of 6.6%. We set household's elasticity of intertemporal substitution σ to 1, and labor supply elasticity to $\epsilon = 0.44$. On the production side, we set the capital share to $\alpha = 0.22$, and the returns to scale parameter to $\nu = 0.8$. Capital depreciates at a rate $\delta = 0.12$ annually. We choose the steady state markup of retailers $\eta = 1.125$. We set $\varrho = 0.25$ in the capital production function, matching the curvature of 4 from Bernanke et al. 1996. We consider a tax rate of $\tau = 0.35$ (Hennessy and Whited 2005) which is an approximation of the statutory corporate tax rate relative to personal tax rates in the U.S. We choose the limit on the loan-to-value ratio $\theta = 0.17$ and the lower bound of dividend constraint $\omega = 0.7$. We set the price adjustment cost parameter at $\phi_p = 700$, which implies that the Phillips Curve slope is equal to 0.01, similar to Hazell et al. 2022 estimates. The coefficient on inflation in the Taylor rule is $\nu_1 = 2.5$, while keeping $\nu_2 = \nu_3 = 0$ for simplicity. Finally, we choose the elasticity of substitution between capital and labor at $\rho = -0.44$ (as in Brasch et al. 2023) and set $\kappa = 1.04$, implying a strong demand for inputs variety from retailer firms.

As discussed in the Brzoza-Brzezina et al. 2015, there is a trade-off between the amount of penalty function curvature and the feasibility of solving the model using perturbation techniques. Since one of our goals is to investigate the ability of the financial constraints and generalized supply side to explain the patterns observed in the data, we opt for a moderate value of $\chi = 90$. In the same spirit, we set the standard deviation of a monetary shock to be $\sigma_{\epsilon^m} = 10^{-6}$, and the standard deviation of debt shock $\sigma_v = 10^{-2}$, so that debt shocks are the primary generator of variation in how binding financial constraints are.

Table 4: Calibrated parameters.

Parameter	**Value**	**Comment on parameterization**
(a) Structural parameters		
σ	1	Household intertemporal elasticity
α	0.22	Capital share of output
ϵ	0.44	Elasticity of labor supply
ν	0.8	Decreasing returns to scale
ρ	-0.44	Substitution parameter, intermediary production function
κ	1.04	Substitution parameter, retail production function
δ	0.12	Depreciation rate of 12% per year
β	0.938	Target steady state annual interest rate of 6.6%
ϱ	0.25	Elasticity of capital prices to aggregate investment
η	1.125	Steady state markup
τ	0.35	Corporate tax rate
ω	0.7	Dividend constraint parameter
θ	0.17	Collateral constraint parameter
χ	90	Penalty function parameter
(b) New Keynesian Parameters		
φ_p	700	Price adjustment coefficient, $\kappa_p = 0.01$
ρ_R	0.795	Interest rate auto-correlation
ν_1	2.5	Taylor rule coefficient
(c) Shocks		
σ_{ε^m}	10^{-6}	S.D. of Monetary shocks
ρ_ε	0.4	Persistence of monetary policy shock
σ_v	10^{-2}	S.D. of debt stock shock
ρ_v	0	Persistence of debt stock shock

5 Monetary policy analysis

5.1 Aggregate Response to Monetary Policy

Figure 4 plots the responses of key aggregate variables to an expansionary monetary policy shock. The shock lowers the nominal interest rate and, because prices are sticky, also the real interest rate. A lower real interest rate stimulates investment demand by shifting out the marginal benefit of investment. It also stimulates consumption demand from the household due to the standard intertemporal substitution channel. The higher aggregate demand for goods changes other prices in the economy, third subfigure "Prices" of Figure 4. If re-scaled to a monetary shock of $\varepsilon^m = -0.0025$ commonly used in the literature, the investment increases by approximately 10%, consumption increases by 1.5%, labor demand increases by 3.5%, and output increases by 2.1%. These magnitudes are broadly in line with the annualised peak effects of monetary policy shocks in Ottonello and Winberry 2020; they find that investment increases by approximately 6%, consumption increases by 1.6%, and output increases by 2%.[11]

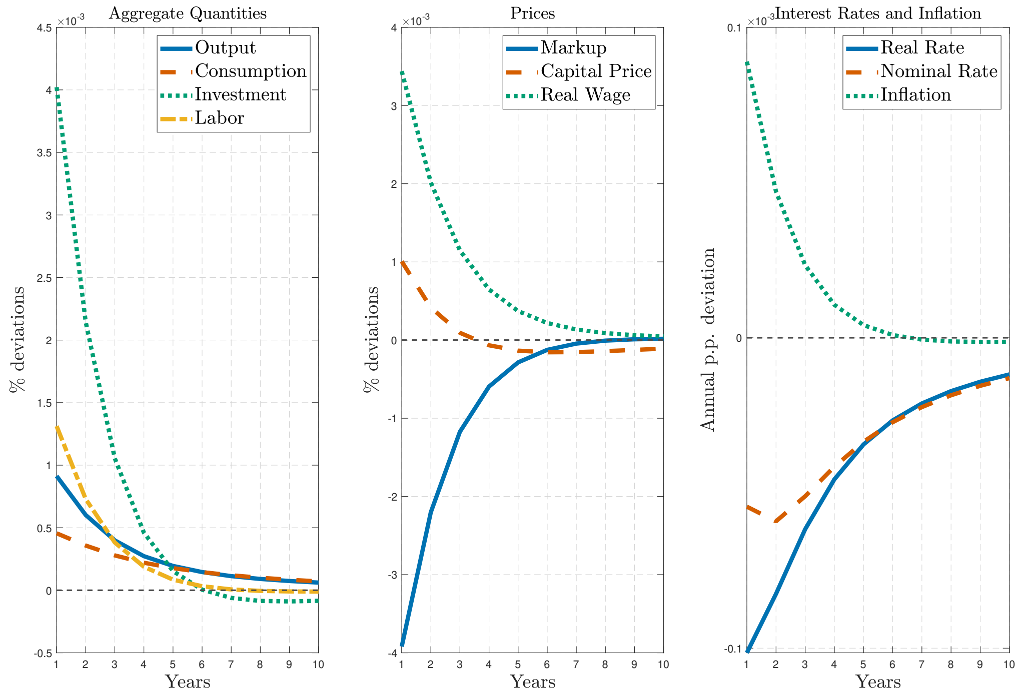
5.2 Heterogeneous Responses to Monetary Policy

To compare our model with the empirical results, we simulate a panel of economies with two firms responding to a monetary shock and estimate our empirical specification (1) using the simulated data[12]: $\Delta \log y_{j,t+h} = \alpha_j + \alpha_t + \beta^h(\ell_{j,t-1} - \overline{\ell}_j)\varepsilon_t^m + \epsilon_{j,t+h}$. We assume that the high-frequency shocks ε that we measure in the data are the innovations to the Taylor rule in the model. Figure 5 illustrate that the differential responses of labor, and the capital-labor ratio, exhibit persistence in the model and align broadly with the empiprical results. More leveraged firms become less capital-intensive while increasing employment more than more leveraged firms. Notes: Estimating equation $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \epsilon_{j,h,t+h}$ for $h = \overline{0,5}$ on simulated data without controls. The dependent variable $y_{j,t+h}$ is firm output. The standard errors are clustered at the firm and economy levels.

As in Ottonello and Winberry 2020), more leveraged firms invest less in capital after an expansionary monetary policy shock. Leveraged firms produce slightly less, but the effect is significantly muted compared to the response of capital (see Figure A1 in Appendix **??**),

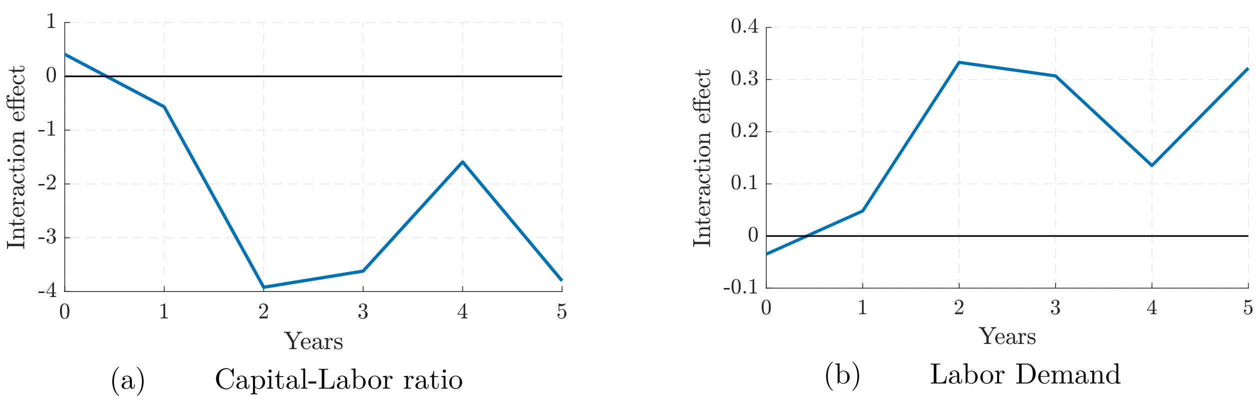
11. Ottonello and Winberry 2020 do not provide results for change in labor demand.
12. Unlike in empirical specification we do not use vector of control variables $Z_{j,t-1}$. We also use time time fixed effects rather than sector-time fixed because our model does not contain multiple sectors

Figure 4: Aggregate responses to expansionary monetary shock.



Notes: Aggregate impulse responses to a $\varepsilon^m = -10^{-6}$ innovation to the Taylor rule which decays at a rate $\rho_\varepsilon = 0.4$.

Figure 5: Dynamics of labor demand's and capital-labor ratio's differential responses to monetary shocks in the model



Notes: Estimating equation $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \epsilon_{j,h,t+h}$ for $h = \overline{0,5}$ on simulated data without controls. The dependent variables $y_{j,t+h}$ are (a) Capital-Labor ratio, (b) labor Demand. The standard errors are clustered at the firm and economy levels. A panel of 100 economies with 900 periods. y-axis values are in units of standard deviation of σ_{ε^m}

consistent with our empirical results showing no significant heterogenous responses in sales. This is because firms compensate for the lack of capital by increasing labor demand in response to the aggregate demand pressure. Overall, the primary role of heterogeneity in financial constraints across firms is in determining the mode of production.

5.3 Aggregate implications of Financial Constraints

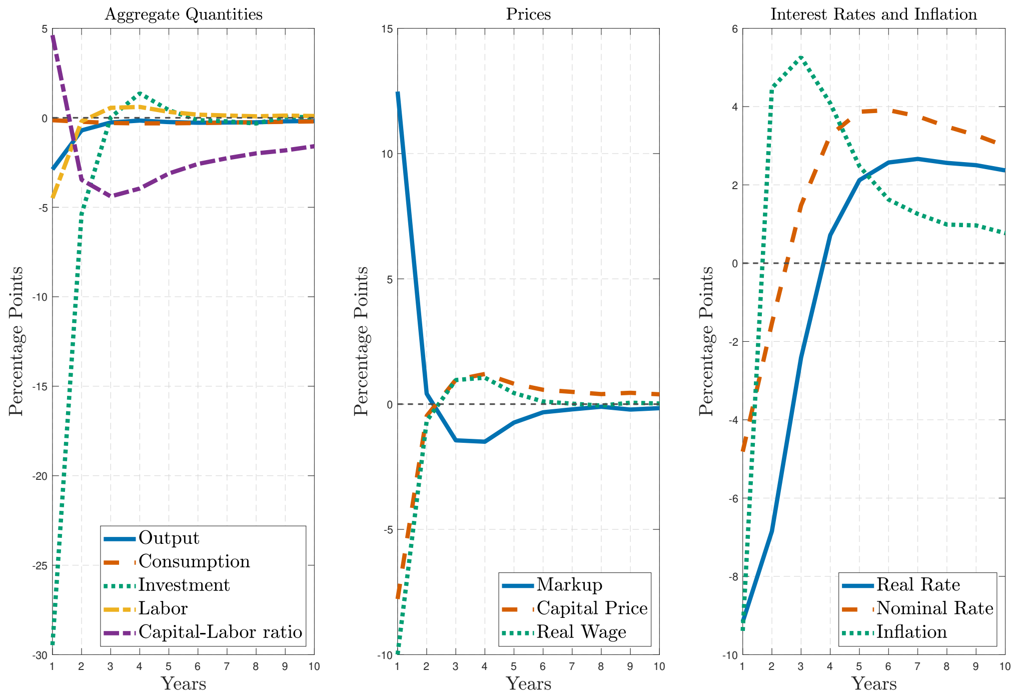
This subsection illustrates two ways financial heterogeneity matters for understanding the aggregate transmission mechanism. We first show that the aggregate effect of a given monetary shock may be weaker when one of the firms has higher leverage in our model. Nevertheless, we show that the aggregate effect of monetary policy is larger in our model than in a comparable version without weaker financial frictions or Cobb-Douglas production function (which collapses to a representative firm).

State-dependence of aggregate transmission To illustrate the scope of state dependence, we compare the baseline response to a monetary shock with a response to monetary policy that hits when firms are more leveraged. Specifically, we do this by computing an impulse response to a joint economy-wide monetary shock and a debt shock to one of the firms hitting at the same time, and subsequently subtracting the response to the debt shock itself.

Figure 6 plots the difference between the baseline impulse response to a monetary shock and the state-dependent response. The initial difference is dominated by the demand for investment. If monetary policy expands when firms are very leveraged, they cannot expand investment demand as much as they would have otherwise. Since investment demand is part of aggregate demand, this translates in a smaller response of output and employment, as firms simply do not have to produce as much. In later periods the response is driven more by the capital-labor mix. Since in the leveraged-state one of the firms does not have enough capital, it instead substitutes towards employment. The effect of leverage on the response of output and consumption to monetary policy, at least beyond the first period, is negligible. Figure 6 also shows that leverage interferes with monetary policy transmission to prices and inflation, initially muting the response of inflation, wage, and real price of capital while amplifying the effect on the markup.

The results shown in figure 6 differ from the heterogeneous effects of monetary policy across firms, highlighting the need to account for general equilibrium effects when evaluating the role of leverage. While the cross-sectional analysis indicated that leverage amplifies the labor demand response in our model, this does not necessarily extend to the aggregate

Figure 6: Differential of aggregate impulse responses



Notes: Aggregate generalized impulse responses to a $\varepsilon^m = -10^{-6}$innovation to the Taylor rule which decays at rate $\rho_\varepsilon = 0.4$, and $\varepsilon^v = 10^{-2}$ and $\rho_v = 0.0$. y-axis values are scaled by the standard deviation of σ_{ε^m}

response. Instead, at least in the initial period of the shock, the opposite happens.

Alternative calibration choices To gain additional insight into the mechanisms behind aggregate responses, we compare the effect of monetary policy in our model to alternative calibrations[13].

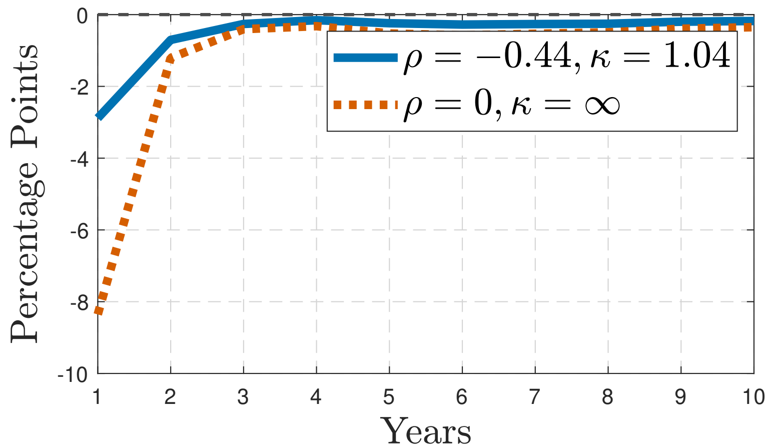
First, we compare our model with one in which wholesale intermediate goods firms have a production function close to Cobb-Douglas their products are perfectly substitutable.

In Figure 7 we plot the same exercise as in paragraph 5.3, comparing the difference in output responses. We see that while the responses are similar in shape, the effect of leverage is stronger in magnitude in the standard model.

Figure 8 (a) shows that the effect of monetary policy on output is more persistent but smaller on impact in our baseline calibration than in the alternative. Second, we compare our model to one in which we somewhat relax the dividend constraint. We do so by lowering the

13. It is worth pointing out that our model collapses to a representative firm model with dividend and collateral constraints whenever only aggregate shocks are allowed.

Figure 7: Differential of aggregate output's impulse responses

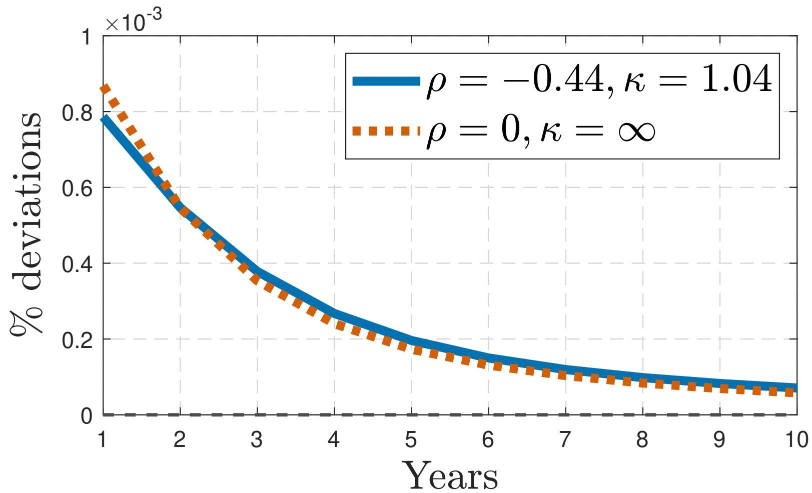


Notes: Aggregate generalized impulse responses to a $\varepsilon^m = -10^{-6}$innovation to the Taylor rule which decays at rate $\rho_\varepsilon = 0.4$, and $\varepsilon^v = 10^{-2}$ and $\rho_v = 0.0$. y-axis values are scaled by the standard deviation of σ_{ε^m}

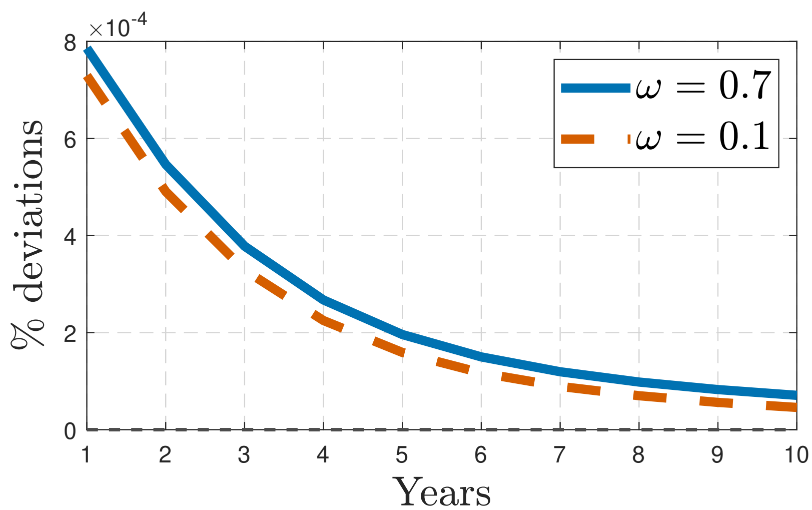
threshold bellow which the firm cannot lower its dividend payments[14]. In line with previous studies, the effect of monetary policy is amplified in the model with the stronger constraints (see Figure 8 (b) in Appendix G). Here the financial accelerator channel is operating: when constraints are tight, monetary policy has the additional expansionary effect of loosening them (through higher capital and output prices).

14. When lower dividends are not penalized, the firm does not have to raise excessive debt to finance an investment boom.

Figure 8: Aggregate output's impulse response



(a) Capital-labor complementarity



(b) Relaxation of dividend constraint

Notes: Aggregate impulse responses to a $\varepsilon^m = -10^{-6}$ innovation to the Taylor rule which decays at rate $\rho_\varepsilon = 0.4$.

6 Conclusion

In conclusion, this paper highlights how financial frictions, particularly leverage, shape the transmission of monetary policy to firms' labor and capital decisions. Rather than uniformly dampening firms' capacity to expand, leverage drives more leveraged firms to increase labor demand while reducing capital intensity following expansionary monetary shocks, without affecting overall growth.

Our New Keynesian model with financial frictions and flexible CES production reveals that leverage moderates the capital stock response but amplifies it more in standard models than in ours. This suggests that in a standard model with Cobb-Douglas production, financial frictions play a greater role in interfering with monetary transmission. By contrast, the flexibility in our model reduces leverage's aggregate impact.

For policymakers, these findings raise concerns about the concentration of labor in highly leveraged firms, potentially heightening economic vulnerability to financial shocks. Macroprudential measures may be needed to complement monetary policy to address this risk and promote balanced employment growth.

Further research is necessary to estimate how these cross-firm dynamics translate into macroeconomic outcomes and ensure that policy designs consider the growing role of financial frictions in a highly leveraged environment.

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A Monetary shock construction

Our baseline shock used in the firm-level analysis is based on the standard high-frequency-identified series of monetary policy surprises. We utilize the event-study methodology pioneered by Cook and Hahn (1989) to measure surprise in monetary policy. Following Gurkaynak et al. (2005) we define a shock ε_t as:

$$\varepsilon_t = \tau(t) \times (\text{ffr}_{t+\Delta_+} - \text{ffr}_{t-\Delta_-}), \tag{21}$$

Here, t denotes the specific timing of the monetary announcement, while ffr_t denotes the implied Fed Funds Rate derived from a current-month Federal Funds futures contract at time t. The parameters Δ_+ and Δ_- determine the exact time window surrounding the announcement. The term $\tau(t)$ adjusts for the timing of the announcement within the month, defined as $\tau(t) \equiv \frac{\tau^n(t)}{\tau^n(t)-\tau^d(t)}$. In this formulation, $\tau^d(t)$ represents the day of the meeting in the month, and $\tau^n(t)$ denotes the total number of days in the month. Our focus is on a window where Δ_- is 15 minutes before the announcement and Δ_+ is 45 minutes after (labeled as 'wide'). We construct a moving average of the raw shocks, weighting them by the number of days remaining in the year (or quarter) after the shock occurs.

The sectoral-level exercise uses variation across NAICS industries. Since these have only been used since 2000, all data before 2000 are based on an imputation from the larger SIC categories. For this reason, we prefer to run this analysis inclusive of the post-2007 (zero-lower bound) period, to maximize the time that variation is not based on any imputation. However, we do not have access to the baseline series for this extended time period. Thus, for now, we use the 'target' shock from Swanson 2021 which extends the original methodology of Gurkaynak et al. 2005 to a longer sample. Gurkaynak et al. 2005 show that the effects on a variety of asset prices can be well summarized by 2 factors: one that captures variation related to current short-term interest rates (especially current and next month federal funds futures) and a second one that is constrained to only load on future or longer-term interest rates (labeled the 'target' factor and the 'path' factor, respectively). Swanson 2021 extends this analysis to the post great-recession period (capturing 241 FOMC announcements from July 1991 to June 2019), adding a third factor to account for quantitative easing. We use the 'target' factor as identified by Swanson 2021 and (made publicly available) as the monetary policy shock in this paper, and sum over the quarter to aggregate the high-frequency shocks to a quarterly frequency.[15] This shock is designed to reflect variation in a variety[16] of asset prices, yet is primarily identified from movements of short-term interest rates (stripping away the forward guidance aspect of monetary policy). Consequently, it correlates very strongly with our baseline shock series: table A1 shows that on the overlapping part of the sample the correlation between the baseline shock and the traget shock is 0.945.

15. As is standard in the literature, we exclude the FOMC announcement on September 17, 2001, which took place before markets opened but after financial markets had been closed for several days following the 9/11 terrorist attacks.

16. Including federal funds futures contracts of different maturities, Eurodollar futures contracts of different maturities, and the 2-, 5-, and 10-year Treasury yields.

Table A1: Summary statistics of quarterly monetary policy shocks

	Raw High Frequency	Smoothed	Smoothed, +, sd 1	GSS target, +, sd 1
Mean	-0.0185	-0.0429	0.395	-0.112
Median	0	-0.0127	0.117	-0.303
S.D.	0.0855	0.108	1	0.820
Min	-0.463	-0.480	-2.149	-1.869
Max	0.152	0.233	4.430	4.679
Observations	164	71	71	111
Corr with (Smoothed, +, sd 1)	.	.	.	0.945

Note: Summary statistics of monetary policy shocks for the period 1/1/1990 to 12/31/2007. "High frequency" shocks are estimated using the event study strategy as in Ottonello and Winberry 2020. "Smoothed" shocks are time aggregated to a quarterly frequency using the weighted average. In the third column, shocks have a flipped sign to ease interpretation and are standardized. The last column summarize a series of 'target' shocks from Swanson 2021 based on the methodology of Gurkaynak et al. 2005 (flipped sign and standardized), which capture essentially the same variation for the main sample (as seen in the last cell of the table) and are available to us extended up till 2019. These are used in the sectoral quarterly analysis where most of the sources start only in 2000.

B Firm Level data

This appendix outlines the procedures used to build the key variables and to define the sample of Compustat firm-year observations used in estimating equation 1.

B.1 Capital Stock Construction via the Perpetual Inventory Method

To measure firms' physical capital, we construct a real capital stock series using the perpetual inventory method (PIM) (see Mongey and Williams (2017)), rather than relying directly on the book value recorded in `PPEGT`. The procedure is implemented at the firm level as follows:

1. **Initial Capital Estimate:** The series begins with the first non-missing value of `PPEGT`, which we treat as the initial capital stock k_{it} for firm i at time t.

2. **Capital Update Rule:** We update the capital stock recursively using the standard law of motion:

$$k_{it} = (1-\delta)k_{i,t-1} + i_{it}, \tag{22}$$

where δ is the depreciation rate and i_{it} denotes the firm's investment. Instead of directly observing investment, we recover it from changes in property, plant, and equipment (`PPENT`) as:

$$i_{it} = \texttt{PPENT}_{it} - \texttt{PPENT}_{i,t-1} + \delta k_{i,t-1}. \tag{23}$$

3. **Addressing Missing Observations:** If there are any gaps in the `PPENT` series during a firm's operating period, we fill them by linearly interpolating between adjacent non-missing values to maintain continuity in investment estimation.

4. **Real Capital Adjustment:** To obtain a measure of capital in real terms, we deflate net investment using the `IPD` (Nonfarm business sector: implicit price deflator, BEA-NIPA Table 1.3.4 Line 3) before applying it in the accumulation formula.

B.2 Other Variables construction

We construct the key variables employed in Section 2.2 as follows.

1. Leverage is measured as the ratio of total debt to total assets ($\texttt{ATQ}_{i,t}$). Total debt is calculated by summing the firm's short-term debt obligations and its long-term liabilities, specifically $\texttt{DLCQ}_{i,t}$ (debt due within one year) and $\texttt{DLTTQ}_{i,t}$ (long-term debt).

2. We measure liquidity using the ratio of cash and cash equivalents to total assets, defined as $\texttt{CHEQ}_{i,t}/\texttt{ATQ}_{i,t}$, following Jeenas (2023).

3. We define firm age as the minimum of four available measures: the number of years since CRSP listing, since the IPO date, since the incorporation year reported in Ritter (2021), and since the firm's first appearance in the Annual Compustat database.

B.3 Sample Selection

Following the sample selection procedure in Ottonello and Winberry (2020), We apply several filters to the Compustat quarterly dataset. Specifically, We exclude all firm-year observations that meet any of the following criteria:

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

2. The firm operates in the financial sector (SIC codes 6000–6999) or in utilities (SIC codes 4900–4999).

3. Key financial variables—total assets ($\texttt{ATQ}_{i,t}$, item 44), net property, plant, and equipment ($\texttt{PPENTQ}_{i,t}$, item 42), sales ($\texttt{SALEQ}_{i,t}$, item 2), or inventories ($\texttt{INVTQ}_{i,t}$, item 38)—are either missing or non-positive.

4. Measures of short-term debt ($\texttt{DLCQ}_{i,t}$, item 45), long-term debt ($\texttt{DLTTQ}_{i,t}$, item 51), or cash and short-term investments ($\texttt{CHEQ}_{i,t}$, item 38) are missing or recorded as negative values.

5. The observation precedes the firm's first available value for gross property, plant, and equipment ($\texttt{PPENTQ}_{i,t}$, item 118) across the full Compustat-annual panel.

6. The investment rate falls in the top or bottom 0.05 percent of its empirical distribution.

7. The firm's sales growth lies outside the interval $[-1, 1]$.

8. Leverage is not in the range $(0, 10]$.

9. The liquidity ratio is outside the interval $[-10, 10]$.

10. All subsequent firm-year observations are dropped once any of the above conditions are met, to ensure a consistent and comparable time series.

C Additional Firm-Level Results

This section reports supplementary results that extend the main empirical analysis. The tables presented here provide further evidence on the immediate heterogeneous effects of monetary policy across firms, focusing on three key outcomes: investment, sales, and employment.

Table A2: Heterogeneous investment responses to monetary policy

	(1)	(2)	(3)	(4)	(5)
leverage × ffr shock	-0.00218	-0.00463*	-0.00201		-0.00276
	(0.00174)	(0.00255)	(0.00218)		(0.00211)
leverage (with mean) × ffr shock				-0.00075	
				(0.00169)	
Observations	53079	53079	51593	51593	42849
R^2	0.268	0.268	0.309	0.309	0.273
Firm controls	no	no	yes	yes	yes
Interaction of leverage with L.GDP	no	yes	yes	yes	yes
Time sector FE	yes	yes	yes	yes	yes
Time clustering	yes	yes	yes	yes	yes
Spell of at least X years					yes
p-value on main coefficient	0.23	0.09	0.37	0.66	0.21

Note: Results from estimating variants of the baseline specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma'_h Z_{j,t-1} + \Omega'_h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, for $h = 0$. The dependent variable $y_{j,t+h}$ is physical capital. Point estimates and standard errors are reported in log units. All control variables are defined in the main text, Section 2.3. Columns 1 and 2 omit the firm-level control variables. Column 1 omits the interaction of past GDP with past leverage. Column 4 reports the result for non-demeaned leverage. The last column restricts the sample to spells of at least 10 years of data on investment (a sample restriction adopted by Ottonello and Winberry 2020). Standard errors in parentheses are clustered two ways, on firm and year. The last row of the table reports the p-value on the main effect of interest.

Table A3: Heterogeneous sales responses to monetary policy

	(1)	(2)	(3)	(4)	(5)
leverage × ffr shock	-0.00036	-0.00090	0.00042		0.00213
	(0.00232)	(0.00208)	(0.00207)		(0.00210)
leverage (with mean) × ffr shock				0.00069	
				(0.00240)	
Observations	52904	52904	51426	51426	42790
R^2	0.266	0.266	0.274	0.274	0.245
Firm controls	no	no	yes	yes	yes
Interaction of leverage with L.GDP	no	yes	yes	yes	yes
Time sector FE	yes	yes	yes	yes	yes
Time clustering	yes	yes	yes	yes	yes
Spell of at least X years					yes
p-value on main coefficient	0.88	0.67	0.84	0.78	0.32

Note: Results from estimating variants of the baseline specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, for $h = 0$. The dependent variable $y_{j,t+h}$ is sales. Point estimates and standard errors are reported in log units. All control variables are defined in the main text, Section 2.3. Columns 1 and 2 omit the firm-level control variables. Column 1 omits the interaction of past GDP with past leverage. Column 4 reports the result for non-demeaned leverage. The last column restricts the sample to spells of at least 10 years of data on investment (a sample restriction adopted by Ottonello and Winberry 2020). Standard errors in parentheses are clustered two ways, on firm and year. The last row of the table reports the p-value on the main effect of interest.

Table A4: Heterogeneous capital-labor ratio responses to monetary policy

	(1)	(2)	(3)	(4)	(5)
leverage × ffr shock	-0.00591*	-0.00621	-0.00745*		-0.00663*
	(0.00331)	(0.00362)	(0.00395)		(0.00357)
leverage (with mean) × ffr shock				-0.01099***	
				(0.00339)	
Observations	51303	51303	49940	49940	42221
R^2	0.166	0.166	0.217	0.217	0.177
Firm controls	no	no	yes	yes	yes
Interaction of leverage with L.GDP	no	yes	yes	yes	yes
Time sector FE	yes	yes	yes	yes	yes
Time clustering	yes	yes	yes	yes	yes
Spell of at least X years					yes
p-value on main coefficient	0.09	0.11	0.08	0.01	0.08

Note: Results from estimating variants of the baseline specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma'_h Z_{j,t-1} + \Omega'_h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, for $h = 0$. The dependent variable $y_{j,t+h}$ is capital intensity. Point estimates and standard errors are reported in log units. All control variables are defined in the main text, Section 2.3. Columns 1 and 2 omit the firm-level control variables. Column 1 omits the interaction of past GDP with past leverage. Column 4 reports the result for non-demeaned leverage. The last column restricts the sample to spells of at least 10 years of data on investment (a sample restriction adopted by Ottonello and Winberry 2020). Standard errors in parentheses are clustered two ways, on firm and year. The last row of the table reports the p-value on the main effect of interest.

D Sector-Level Analysis

This appendix presents supplementary empirical results based on a sector-quarter panel dataset. The analysis parallels the firm-level regressions reported in the main text but is conducted at a higher level of aggregation, using industry-level data identified by 3-digit SIC codes. Our goal is to examine whether the heterogeneous effects of monetary policy on employment, sales, and physical capital observed at the firm level also appear in sectoral dynamics. We begin by describing the data sources and construction of the sector-quarter panel, and then report estimation results for each outcome variable.

D.1 Sector-Level Data

To conduct this analysis, we merge labor market data from the Quarterly Census of Employment and Wages (QCEW) with financial data from the Quarterly Financial Report (QFR).

QCEW (Quarterly Census of Employment and Wages): The QCEW, maintained by the U.S. Census Bureau, provides comprehensive coverage of private and public employers covered by unemployment insurance, with observations aggregated at the state and industry level using 3-digit NAICS codes. To ensure compatibility with the QFR, we restrict our sample to three major sectors: manufacturing, wholesale trade, and retail trade. From the QCEW, we extract total employment, total wages, and average weekly wages as our primary labor market measures. Summary statistics for these variables are reported in Table A5.

The sectoral QCEW employment data aligns with the firm-level data (Table 2) in terms of the mean and median employment growth but exhibits five times less variation, as expected given the aggregation.

Table A5: Summary statistics of QCEW state-sector data

	e_{jt}	$\Delta \log e_{jt}$	$w \cdot e_{jt}$	$\Delta \log w \cdot e_{jt}$	w_{jt}	$\Delta \log w_{jt}$
Mean	1012542.7	-0.004	8.64e+09	0.006	654.118	0.010
Median	805680.6	-0.001	6.66e+09	0.009	615.006	0.011
S.D.	601733.1	0.023	5.95e+09	0.035	290.687	0.036
5th Percentile	191009.7	-0.028	1.98e+09	-0.041	251.870	-0.029
95th Percentile	2063046.8	0.012	2.03e+10	0.049	1235.191	0.046
Observations	1913.0	1913.000	1913.00	1913.000	1913.000	1913.000

Summary statistics of sector-level variables in QCEW sample in 1990-2007.

QFR (Quarterly Financial Report): The QFR data offers aggregate statistics on the financial status of U.S. corporations prepared by the Census Bureau. Derived from a sample survey, the QFR provides estimated income statements, retained earnings statements, balance sheets, and associated financial and operating ratios. An advantage of the dataset is its coverage of publicly traded and privately held firms. It covers manufacturing corporations with assets of $250,000 and above, as well as wholesale trade and retail trade corporations with assets of $50 million and above. The aggregate statistics are available by industry and asset size. Prior to 2000, the data is only available for industries at the 2-digit SIC code level; since 2000, the data is available at the 3-digit NAICS code levels. We construct the same variables used in the firm-level analysis with Compustat: leverage, sales growth, size, current assets. The sales data in QFR come seasonally adjusted (using X-12-ARIMA method by the U.S. Census Bureau). The rest of the variables are balance sheet variables.

Table A6 presents summary statistics of the relevant financial variables for sectors matched with QCEW data for the period 1990-2007, with the final sample of 25 sectors over 106 quarters. Sectoral-level data on leverage mimics well the firm-level Compustat data in terms of the mean and median.[17]

Table A6: Summary statistics of QFR sector-level data

	ℓ_{jt}	$\Delta \log k_{jt+1}$
Mean	0.291	-0.002
Median	0.293	-0.001
S.D.	0.072	0.060
5th Percentile	0.169	-0.031
95th Percentile	0.403	0.033
Observations	1913.000	1913.000

Summary statistics of sector level variables in QFR sample. ℓ_{jt} is the debt-to-asset ratio and $\Delta \log k_{jt+t}$ is the log change in the book value of tangible capital stock. The sample is a set of sectors matched with QCEW data for the period 1990-2007.

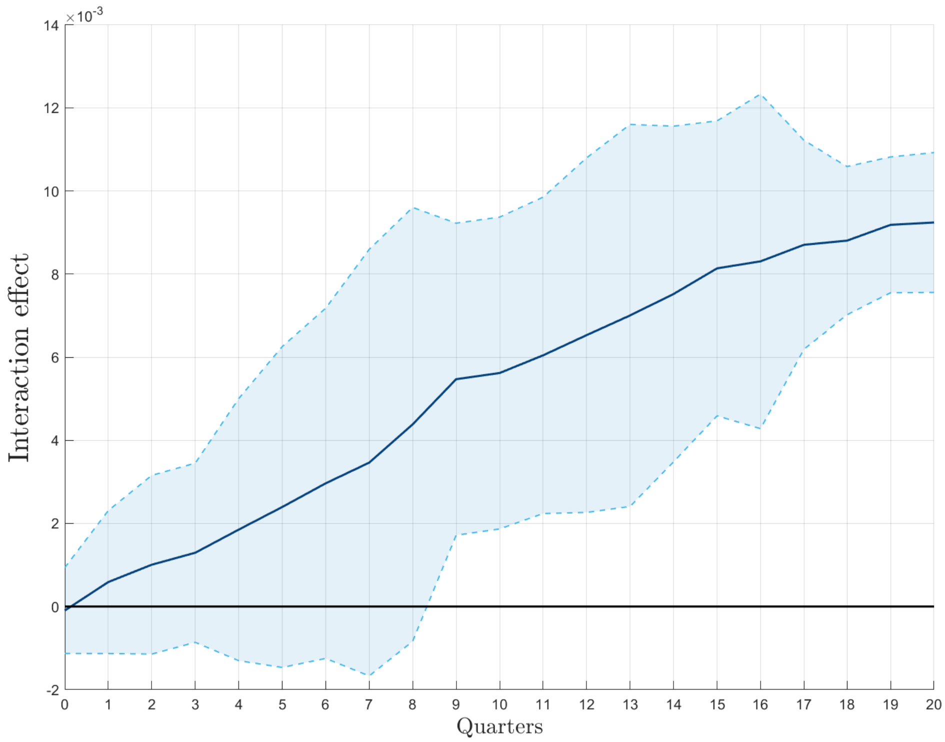
D.2 Sector-Level Results

Here we present results using simple sectoral variation. Specifically, we run the regression specified in equation 1 with j a 3-digit NAICS sector and t quarterly time, α_τ are simply

17. As is expected for a more aggregated series, both leverage and $\Delta \log k$ exhibit far less variation in the sectoral panel.

time fixed effects. The vector $Z_{j,t-1}$ includes leverage $\ell_{j,t-1}$, total assets, sales growth, current assets as a proportion of total assets at the sector level, as well as the interaction of $\ell_{j,t-1}$ with the previous year's GDP growth and unemployment rate to control for differences in firms' cyclical sensitivities.

Figure A1: Response of employment to a monetary shock, sector level

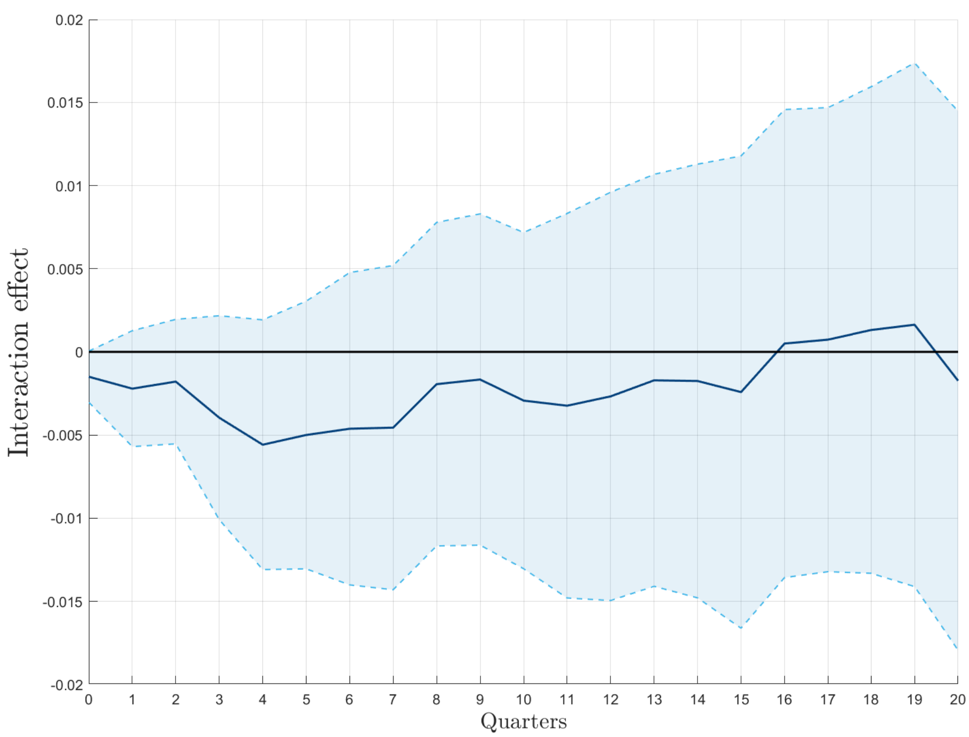


Notes: This figure shows the estimated dynamic interaction coefficient β^h between leverage and monetary policy shocks over a twenty-quarter horizon ($h = \overline{0, 20}$). The dependent variable $y_{j,t+h}$ is employment, measured at the 3-digit NAICS sector level. Estimates are based on the regression specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{\tau,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, where all variables are defined in Section 2.3 of the main text. Dashed lines represent 95% confidence intervals, constructed using two-way clustered standard errors at the sector and quarter.

Figure A1 shows the differential in the impulse response of employment for each horizon $h \in \overline{0, 20}$. A surprise in monetary policy towards easing leads to a stronger employment expansion in sectors with higher prior leverage. Specifically, a one standard deviation change in the monetary shock results in a 0.5 percentage point increase in employment in sectors with one standard deviation more leverage observed nine quarters after the shock (p-value = 0.01). This effect is persistent, lasting up to 20 quarters post-shock. These findings are consistent with recent evidence by Bahaj et al. 2022 and our firm-level evidence, demonstrating that employment in financially constrained firms responds more strongly to monetary policy shocks.

We also test for the differential response of capital investment and sales as the dependent variable. Figure A2 confirms that the shape of the impulse response functions matches Ottonello and Winberry 2020 with more leveraged sectors expanding their investment less in response to an easing of monetary policy, even though the results are insignificant. Figure A3 shows sales of leveraged sectors might be more sensitive to monetary policy, although the effect is very imprecisely estimated.

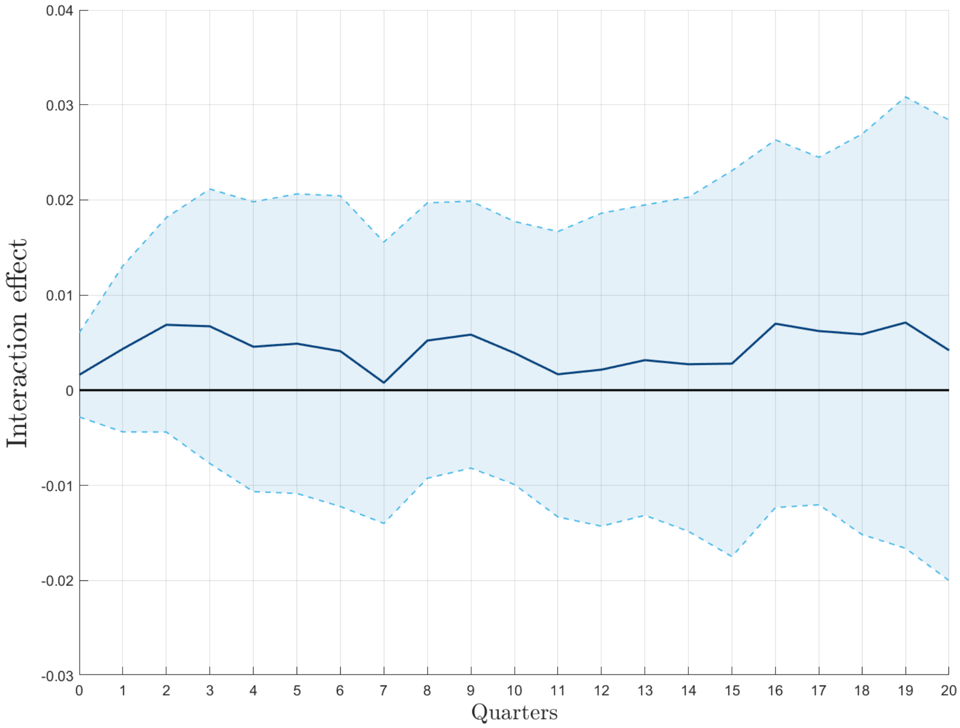
Figure A2: Response of capital to a monetary shock, sector level



Notes: This figure shows the estimated dynamic interaction coefficient β^h between leverage and monetary policy shocks over a twenty-quarter horizon ($h = \overline{0,20}$). The dependent variable $y_{j,t+h}$ is physical capital, measured at the 3-digit NAICS sector level. Estimates are based on the regression specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{\tau,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, where all variables are defined in Section 2.3 of the main text. Dashed lines represent 95% confidence intervals, constructed using two-way clustered standard errors at the sector and quarter.

Figure A4 presents the dynamic response of average wages to a monetary policy shock

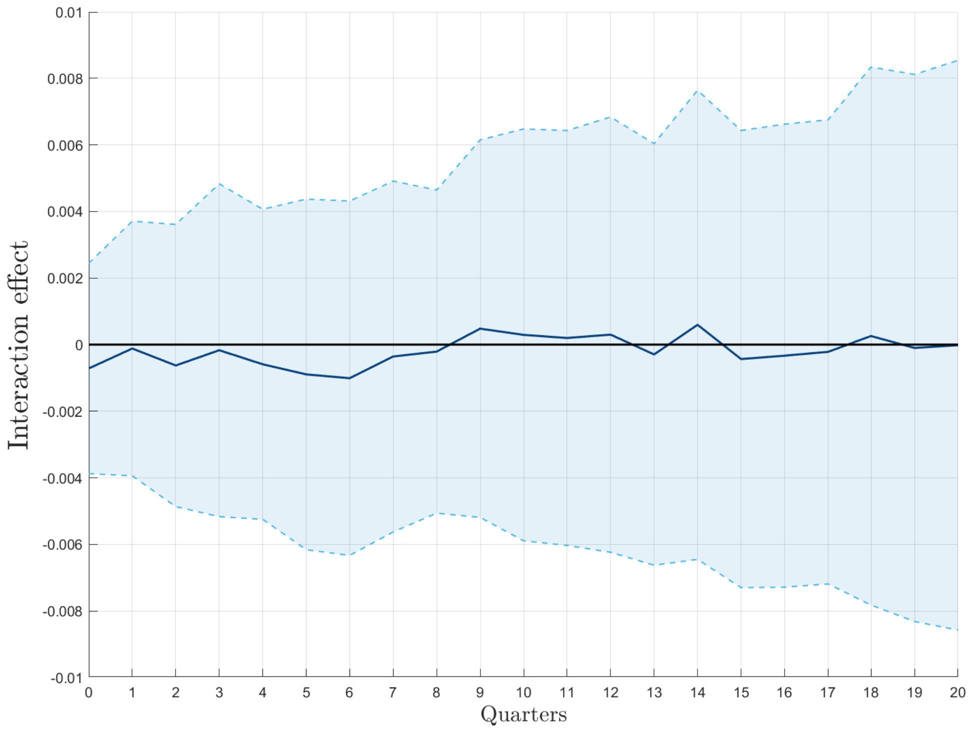
Figure A3: Response of sales to a monetary shock, sector level



Notes: This figure shows the estimated dynamic interaction coefficient β^h between leverage and monetary policy shocks over a twenty-quarter horizon ($h = \overline{0, 20}$). The dependent variable $y_{j,t+h}$ is sales, measured at the 3-digit NAICS sector level. Estimates are based on the regression specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{\tau,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, where all variables are defined in Section 2.3 of the main text. Dashed lines represent 95% confidence intervals, constructed using two-way clustered standard errors at the sector and quarter.

at the sector level. We observe a slight decline in wages following an expansionary monetary shock, consistent with a labor market reallocation toward lower-paid jobs or sectors. While the estimated effect is economically meaningful in magnitude, it is imprecisely estimated, and the confidence intervals include zero throughout most of the horizon.

Figure A4: Response of average wages to a monetary shock, sector level



Notes: This figure shows the estimated dynamic interaction coefficient β^h between leverage and monetary policy shocks over a twenty-quarter horizon ($h = \overline{0, 20}$). The dependent variable $y_{j,t+h}$ is average wage, measured at the 3-digit NAICS sector level. Estimates are based on the regression specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{\tau,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, where all variables are defined in Section 2.3 of the main text. Dashed lines represent 95% confidence intervals, constructed using two-way clustered standard errors at the sector and quarter.

E Robustness Checks

E.1 Alternative monetary policy shocks

We begin by examining whether our findings hold when using different measures of monetary policy. Table A7 in Appendix E.3 presents the results for the log changes in employment, capital stock, and capital intensity across various shock measures drawn from the literature. The results are broadly consistent across alternative measures.

First, we replicate the baseline firm-level analysis using the target shock from Swanson 2021. The results are broadly consistent, with column 2 indicating that any differences stem from sample coverage rather than the shock itself.

The strategy of using high-frequency surprises as monetary policy shocks has been the subject of much scrutiny. Several studies argue that these shocks may capture more than just changes in monetary policy orthogonal to current economic conditions. To mitigate these concerns, various authors have proposed methods to orthogonalize high-frequency surprises with respect to the information effect.

Our results remain robust across alternative shocks, with few notable exceptions. The Romer and Romer 2004 series, extended by Wieland and Yang 2020 through 2012Q4, and Aruoba and Drechsel 2024, which utilizes natural language processing on Federal Reserve documents, show similar effects on employment, though these estimates are less precise. In contrast, the effects on capital investment are negligible.

E.2 Robustness to controlling for the shock interacted with firm-level controls

We verify that our baseline results on the impact of firm leverage in response to monetary policy shocks are not confounded by other firm characteristics. Specifically, we examine whether the estimated effects are driven by differences across firm size, growth rates, or liquidity, proxied by the share of current assets in total assets. Across all outcomes – employment, capital, and the capital-labor ratio – the central role of leverage remains robust (see Tables A8, A9, and A10).

Table A10 also provides suggestive evidence that large and growing firms tend to increase their capital intensity more than others during monetary policy easing episodes. This pattern may reflect differences in financial flexibility: firms with better access to external financing may respond to policy loosening by expanding investment rather than employment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					$\Delta \log k_{jt+1}$				
lev × mp shock	-0.0046**	-0.0036	-0.0050***	-0.0050**	-0.0029**	-0.0030*	-0.0016	0.0017	0.0002
	(0.0020)	(0.0022)	(0.0016)	(0.0020)	(0.0012)	(0.0016)	(0.0018)	(0.0021)	(0.0015)
p-value	0.03	0.11	0.01	0.03	0.02	0.07	0.38	0.41	0.91
Observations	49516	40146	47112	37729	59610	42849	45438	89773	64978
R^2	0.256	0.281	0.263	0.287	0.243	0.273	0.270	0.229	0.253
					$\Delta \log e_j$				
lev × mp shock	0.0040	0.0057*	0.0032	0.0058*	0.0023	0.0056*	0.0062***	0.0042	0.0042
	(0.0026)	(0.0028)	(0.0025)	(0.0028)	(0.0021)	(0.0029)	(0.0021)	(0.0026)	(0.0031)
p-value	0.14	0.06	0.22	0.05	0.29	0.07	0.01	0.11	0.19
Observations	48768	39571	46361	37151	58644	42221	44753	88450	63941
R^2	0.215	0.232	0.218	0.233	0.200	0.222	0.219	0.174	0.196
					$\Delta \log \frac{k_{jt}}{e_{jt}}$				
lev × mp shock	-0.0058**	-0.0066*	-0.0075**	-0.0092**	-0.0039*	-0.0072**	-0.0064***	-0.0039	-0.0040
	(0.0027)	(0.0032)	(0.0033)	(0.0038)	(0.0021)	(0.0026)	(0.0022)	(0.0032)	(0.0032)
p-value	0.05	0.06	0.04	0.03	0.07	0.02	0.01	0.22	0.23
Observations	48768	39571	46361	37151	58644	42221	44753	88450	63941
R^2	0.169	0.184	0.173	0.189	0.156	0.177	0.174	0.134	0.153
Baseline sample		yes		yes		yes			
Firm controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Spells >= 10 y	yes	yes	yes	yes	yes	yes	yes	yes	yes
MP shock	Swanson 2021 (target)	Swanson 2021 (target)	Jarocinsky & Karadi	Jarocinsky & Karadi	Bauer & Swanson	Bauer & Swanson	Miranda-Agrippino & Ricco	Romer & Romer extended	Arouba & Drechsel

Table A8: Robustness: shock interacted with firm-level controls– employment

	(1)	(2)	(3)	(4)
leverage × ffr shock	0.00550**	0.00547**	0.00518*	0.00540*
	(0.00258)	(0.00256)	(0.00246)	(0.00261)
size × ffr shock		0.00083		
		(0.00184)		
sales growth × ffr shock			-0.00369	
			(0.00304)	
Share of current assets × ffr shock				-0.00090
				(0.00159)
Observations	49940	49940	49940	49940
R^2	0.261	0.261	0.261	0.261
Firm controls	yes	yes	yes	yes
Interaction of leverage with L.GDP	yes	yes	yes	yes
Time sector FE	yes	yes	yes	yes
Time clustering	yes	yes	yes	yes
p-value on main coefficient	0.05	0.05	0.05	0.06

Note: Results from estimating variants of the baseline specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, for $h = 0$. The dependent variable $y_{j,t+h}$ is employment. Point estimates and standard errors are reported in log units. All control variables are defined in the main text, Section 2.3. Columns 1 is baseline specification. Column 2,3 and 4 include additional control interacting sales, sales growth and hare of current assets in total assets with baseline monetary shock respectively. Standard errors in parentheses are clustered two ways, on firm and year. The last row of the table reports the p-value on the main effect of interest.

Table A9: Robustness: shock interacted with firm-level controls – capital

	(1)	(2)	(3)	(4)
leverage × ffr shock	-0.00201	-0.00205	-0.00220	-0.00219
	(0.00218)	(0.00216)	(0.00219)	(0.00217)
size × ffr shock		0.00193		
		(0.00213)		
sales growth × ffr shock			-0.00240	
			(0.00253)	
Share of current assets × ffr shock				-0.00194
				(0.00190)
Observations	51593	51593	51593	51593
R^2	0.309	0.309	0.309	0.309
Firm controls	yes	yes	yes	yes
Interaction of leverage with L.GDP	yes	yes	yes	yes
Time sector FE	yes	yes	yes	yes
Time clustering	yes	yes	yes	yes
p-value on main coefficient	0.37	0.36	0.33	0.33

Note: Results from estimating variants of the baseline specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma'_h Z_{j,t-1} + \Omega'_h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, for $h = 0$. The dependent variable $y_{j,t+h}$ is physical capital. Point estimates and standard errors are reported in log units. All control variables are defined in the main text, Section 2.3. Columns 1 is baseline specification. Column 2,3 and 4 include additional control interacting sales, sales growth and hare of current assets in total assets with baseline monetary shock respectively. Standard errors in parentheses are clustered two ways, on firm and year. The last row of the table reports the p-value on the main effect of interest.

Table A10: Robustness: shock interacted with firm-level controls – capital intensity

	(1)	(2)	(3)	(4)
leverage × ffr shock	-0.00745*	-0.00763*	-0.00660*	-0.00728*
	(0.00395)	(0.00392)	(0.00375)	(0.00399)
size × ffr shock		0.00613*		
		(0.00298)		
sales growth × ffr shock			0.00997**	
			(0.00431)	
Share of current assets × ffr shock				0.00168
				(0.00271)
Observations	49940	49940	49940	49940
R^2	0.217	0.217	0.218	0.217
Firm controls	yes	yes	yes	yes
Interaction of leverage with L.GDP	yes	yes	yes	yes
Time sector FE	yes	yes	yes	yes
Time clustering	yes	yes	yes	yes
p-value on main coefficient	0.08	0.07	0.10	0.09

Note: Results from estimating variants of the baseline specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, for $h = 0$. The dependent variable $y_{j,t+h}$ is capital-labor ratio. Point estimates and standard errors are reported in log units. All control variables are defined in the main text, Section 2.3. Columns 1 is baseline specification. Column 2,3 and 4 include additional control interacting sales, sales growth and hare of current assets in total assets with baseline monetary shock respectively. Standard errors in parentheses are clustered two ways, on firm and year. The last row of the table reports the p-value on the main effect of interest.

E.3 Robustness to Controls Motivated by Prior Literature

Relation to Ottonello and Winberry 2020 and Distance to Default: As a robustness exercise, we follow Ottonello and Winberry 2020 and construct a measure of distance to default to capture firm-level financial conditions. The construction follows the approach in Gilchrist et al. 2012, using firm equity, liabilities, and volatility to approximate a structural default threshold. We interact this measure with monetary policy shocks to assess whether our baseline findings are sensitive to alternative measures of financial health. The results, reported below for employment, capital, sales, and capital-labor ratio in Figure A1, confirm that the key patterns documented in the main text are broadly preserved under this alternative specification. The strongest differential response is observed for capital intensity: firms further from default increase their capital-labor ratio by approximately 2 percentage points more than their more financially constrained counterparts within two years following an expansionary monetary policy shock.

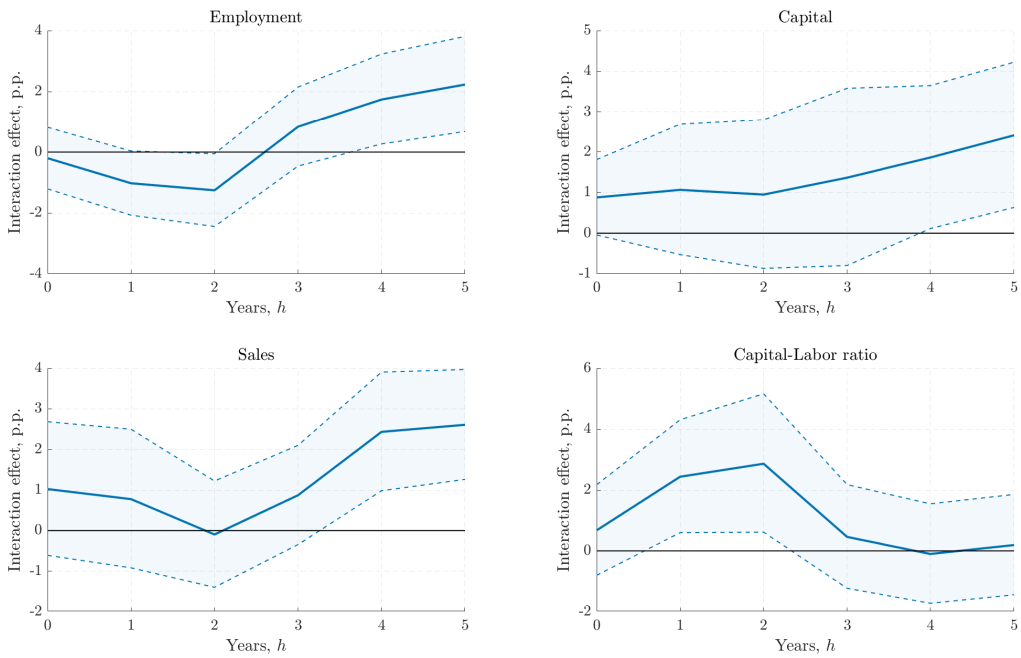
Relation to Jeenas 2023 and liquidity: Jeenas 2023 shows that differences in liquidity (which are correlated with leverage) matter for heterogenous responses of firms to monetary policy. Here we show that our conclusions are robust to accounting for differences in liquidity in our main specifications. Figure A2 shows the results of running the baseline firm-level regressions, adding a within-firm measure of liquidity as a control.

$$\begin{aligned}\Delta_h \log y_{j,t+h} = {} & \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \gamma^h(\mathcal{L}_{j,t-1} - \mathbb{E}_j[\mathcal{L}_{j,t}])\varepsilon_t^m \\ & + \Gamma'_h Z_{j,t-1} + \Omega'_h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \Delta^h(\mathcal{L}_{j,t-1} - \mathbb{E}_j[\mathcal{L}_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}, \quad (24)\end{aligned}$$

The effect of leverage on capital-labor substitution after a monetary policy shock is effectively unchanged when differences in liquidity are accounted for.

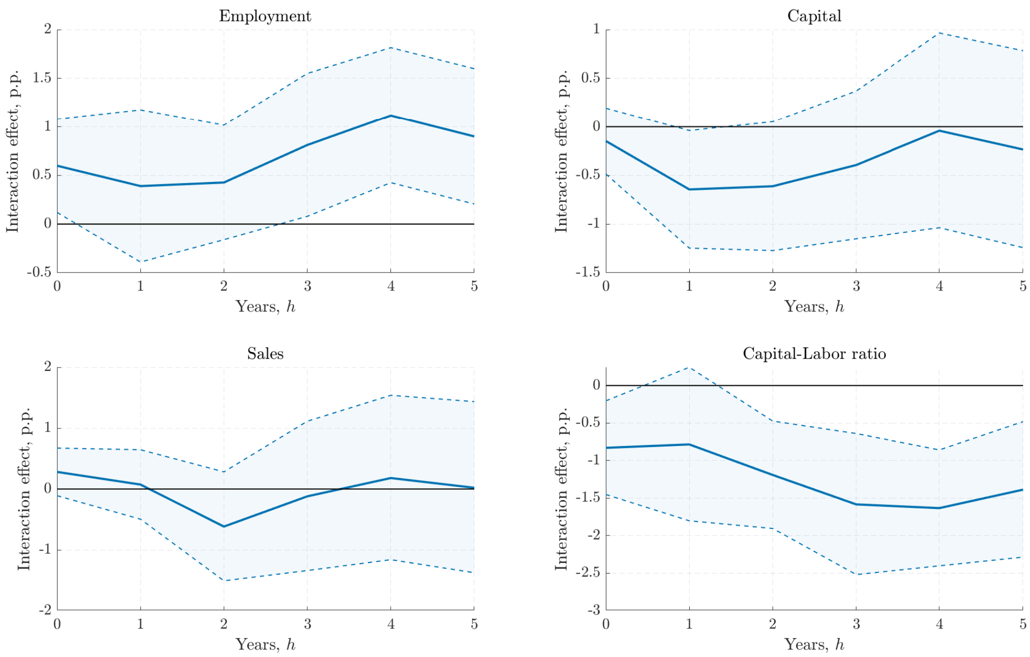
Jeenas 2023 also argue that low-leverage firms are in fact less responsive to monetary policy over longer horizons in their capital investment, the opposite of the conclusion in Ottonello and Winberry 2020. Part of the difference comes from focusing on a different time horizon (Jeenas 2023 shows results for several years after the policy shock). Moreover, Ottonello and Winberry 2020 show low-leverage firms' investment is more sensitive only when leverage is not demeaned within firm–i.e. when the conclusion relies on permanent differences across firms. However, these are very possibly correlated with many other permanent differences across firms (in their business models, production modes, permanent productivity

Figure A1: Heterogeneous responses to monetary policy by distance to default



Notes: This figure displays the dynamic interaction coefficient β^h between distance to default and monetary policy shocks over a five-year horizon $h = \overline{0,5}$. The dependent variables $y_{j,t+h}$ are employment, physical capital, sales and capital intensity. Estimates are obtained from the specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(d2d_{j,t-1} - \mathbb{E}_j[d2d_{j,t}])\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(d2d_{j,t-1} - \mathbb{E}_j[d2d_{j,t}])Y_{t-1} + \epsilon_{j,h,t+h}$, where all variables are defined in the main text, Section 2.3. The figure plots point estimates and 90% confidence intervals, constructed using standard errors clustered at both the firm and time levels. All estimates are scaled to percentage point units.

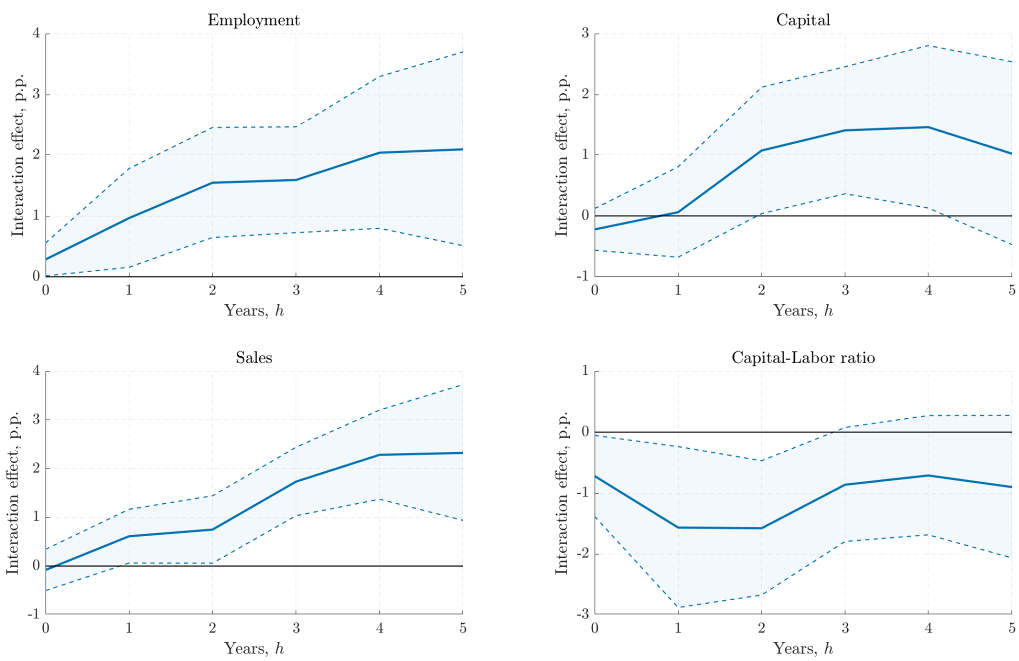
Figure A2: Heterogeneous responses to monetary policy – controlling for firm liquidity



Notes: This figure displays the dynamic interaction coefficient β^h between leverage and monetary policy shocks over a five-year horizon $h = \overline{0,5}$. The dependent variables $y_{j,t+h}$ are employment, physical capital, sales and capital intensity. Estimates are obtained from the specification 24 where all other variables are defined in the main text, Section 2.3. The figure plots point estimates and 90% confidence intervals, constructed using standard errors clustered at both the firm and time levels. All estimates are scaled to percentage point units.

etc.). In contrast, when leverage is measured within firm, those who find themselves in a less-leveraged point in their lifecycle are robustly more sensitive to monetary policy in investment. Bellow we reproduce our baseline results, using raw $\ell_{j,t-1}$ instead of $(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])$. Indeed, figure A3 shows that when the variation in leverage does include permanent differences across firms, leveraged firms react more to monetary policy. This is true for capital, but is even more so for labor. Thus, the conclusion that leveraged firms substitute towards labor from capital after easing of monetary policy is robust to the measure used by Jeenas 2023.[18]

Figure A3: Heterogeneous responses to monetary policy – leverage in levels



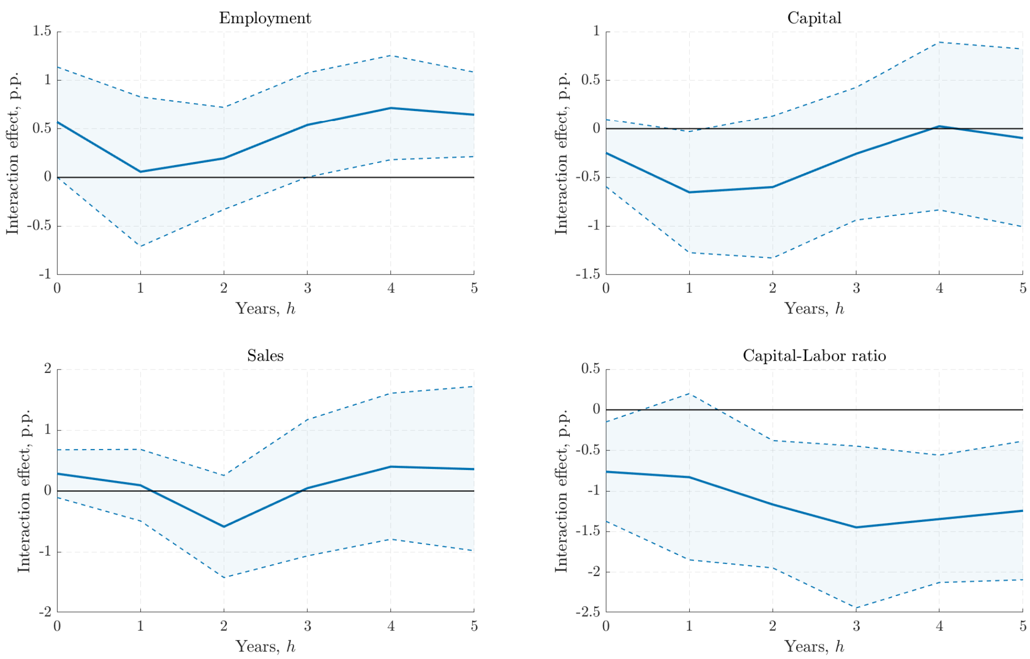
Notes: This figure displays the dynamic interaction coefficient β^h between leverage and monetary policy shocks over a five-year horizon $h = \overline{0,5}$. The dependent variables $y_{j,t+h}$ are employment, physical capital, sales and capital intensity. Estimates are obtained from the specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h \ell_{j,t-1}\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h' \ell_{j,t-1} Y_{t-1} + \epsilon_{j,h,t+h}$, where all other variables are defined in the main text, Section 2.3. The figure plots point estimates and 90% confidence intervals, constructed using standard errors clustered at both the firm and time levels. All estimates are scaled to percentage point units.

18. Jeenas 2023 also trim the data on leverage more aggressively, getting rid of the top 1%. We drop observations with over 1000% leverage and then winsorize the top 0.5%. Shaving another 1% of most leveraged observations from the sample does not change any qualitative conclusions, but makes estimates less precise. This is not surprising given that theory predicts that the firms closest to being constrained are the ones relevant for the mechanism.

Relation to Cloyne et al. 2023 and firm age: Following Cloyne et al. 2023, we examine whether our baseline results are sensitive to firm age by allowing monetary policy shocks to interact with firm-level age measure. We define firm age as the minimum of four available indicators: the number of years since CRSP listing, since the IPO date, since the incorporation year reported in Ritter 2021, and since the firm's first appearance in the Annual Compustat database.

The results, shown in Figure A4, indicate that controlling for firm age does not alter our main findings. The heterogeneity in responses by leverage remains stable across all outcome variables, suggesting that firm age is not a confounding factor in the transmission of monetary policy in our setting.

Figure A4: Heterogeneous responses to monetary policy – controlling for firm age



Notes: This figure displays the dynamic interaction coefficient β^h between leverage and monetary policy shocks over a five-year horizon $h = \overline{0,5}$. The dependent variables $y_{j,t+h}$ are employment, physical capital, sales and capital intensity. Estimates are obtained from the specification $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \alpha_{s,t,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \gamma^h \text{Age}_{j,t-1}\varepsilon_t^m + \Gamma_h' Z_{j,t-1} + \Omega_h'(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])Y_{t-1} + \Delta^h \text{Age}_{j,t-1} Y_{t-1} + \epsilon_{j,h,t+h}$, where all other variables are defined in the main text, Section 2.3. The figure plots point estimates and 90% confidence intervals, constructed using standard errors clustered at both the firm and time levels. All estimates are scaled to percentage point units.

F Details on the model

F.1 Firm problem and optimality conditions

We first set up the firm problem, using the representation of the penalty function for the constraints of the dividend and the collateral. The objective of both firm types $j \in \{A, B\}$ is to maximize the expected stream of dividends, discounted at its owner's discount factor $m_{t,t+1}$.

$$\max_{n_t^j(i), k_{t+1}^j(i), b_{t+1}^j(i)} E_0 \sum_{t=0}^{\infty} m_{0,t} d_t^j(i) \tag{25}$$

subject to

$$d_t^j(i) = d_t^{0j}(i) - \Psi_t^{dj}(i) - \Psi_t^{bj}(i) \tag{26}$$

$$\begin{aligned} d_t^{0j}(i) = {} & p_t^j x(k_t^j(i), n_t^j(i)) - w_t n_t^j(i) - Q_t[k_{t+1}^j(i) - (1-\delta)k_t^j(i)] - Q_t \cdot AC(k_{t+1}^j(i), k_t^j(i)) \\ & - \frac{b_t^j(i)}{\pi_t} + \frac{b_{t+1}^j(i)}{R_t} \end{aligned} \tag{27}$$

$$\Psi_t^{dj}(i) = \frac{1}{\chi}\exp(-\chi d_t^{0j}(i)) \tag{28}$$

$$\Psi_t^{bj}(i) = \frac{1}{\chi}\exp(\chi[b_{t+1}^j(i) - \theta E_t \pi_{t+1} Q_{t+1} k_{t+1}^j(i)]) \tag{29}$$

For both firm types $j \in \{A, B\}$, the optimality conditions with respect to $b_{t+1}^j(i), k_{t+1}^j(i), n_t^j(i)$

are

$$b_{t+1}^j(i): \frac{1}{R_t} - \frac{\partial \Psi_t^{dj}(i)}{\partial b_{t+1}^j} - \frac{\partial \Psi_t^{bj}(i)}{\partial b_{t+1}^j} - E_t m_{t,t+1}\frac{1}{\pi_{t+1}} - E_t m_{t,t+1}\frac{\partial {\Psi_{t+1}^d}^j(i)}{\partial b_{t+1}^j} = 0 \tag{30}$$

$$n_t^j(i): p_t^j x_n'(k_t^j(i), n_t^j(i))^j - \frac{\partial \Psi_t^{dj}(i)}{\partial n_t^j} - w_t = 0 \tag{31}$$

$$\begin{aligned} k_{t+1}^j(i): Q_t = & -Q_t \cdot AC_1'(k_{t+1}^j(i), k_t^j(i)) - \frac{\partial \Psi_t^{dj}(i)}{\partial k_{t+1}^j} - \frac{\partial \Psi_t^{bj}(i)}{\partial k_{t+1}^j} + \\ & E_t m_{t,t+1}\Big[p_t^j x_k'(k_{t+1}^j(i), n_{t+1}^j(i)) + Q_{t+1}(1-\delta) - Q_{t+1}AC_2'(k_{t+2}^j(i), k_{t+1}^j(i)) \\ & - \frac{\partial {\Psi_{t+1}^d}^j(i)}{\partial k_{t+1}^j}\Big] \end{aligned} \tag{32}$$

$$\frac{\partial \Psi_t^{bj}(i)}{\partial b_{t+1}^j} = \chi \Psi_t^{bj}(i) \tag{33}$$

$$\frac{\partial \Psi_t^{bj}(i)}{\partial k_{t+1}^j} = -\chi \theta^j E_t \pi_{t+1} Q_{t+1} \Psi_t^{bj}(i) \tag{34}$$

$$\frac{\partial \Psi_t^{dj}(i)}{\partial n_t^j} = \chi w_t^j \Psi_t^{dj}(i) \tag{35}$$

$$\frac{\partial \Psi_t^{dj}(i)}{\partial b_{t+1}^j} = -\chi \frac{1}{R_t} \Psi_t^{dj}(i) \tag{36}$$

$$\frac{\partial {\Psi_{t+1}^d}^j(i)}{\partial b_{t+1}^j} = \chi \frac{1}{\Pi_{t+1}} {\Psi_{t+1}^d}^j(i) \tag{37}$$

$$\frac{\partial \Psi_t^{dj}(i)}{\partial k_{t+1}^j} = \chi Q_t[1 + AC_1'(k_{t+1}^j(i), k_t^j(i))]\Psi_t^{dj}(i) \tag{38}$$

$$\frac{\partial {\Psi_{t+1}^d}^j(i)}{\partial k_{t+1}^j} = \chi Q_{t+1}[-(1-\delta) + AC_2'(k_{t+2}^j(i), k_{t+1}^j(i))]{\Psi_{t+1}^d}^j(i) \tag{39}$$

F.2 Steady state

F.2.1 Household problem

$$\text{Labor supply} \quad \frac{U_n(c,n)}{U_c(c,n)} = -w \tag{40}$$

$$\text{Budget constraint} \quad c = wL + (b - \frac{b}{1+r^n}) + d - T \tag{41}$$

F.2.2 Prices

$$\text{Stochastic discount factor} \quad m = \beta \tag{42}$$

$$\text{Bond supply} \quad \frac{1}{1+r^n} = \beta \tag{43}$$

$$\text{Capital price} \quad Q = 1 \tag{44}$$

$$\text{Gross interest rate} \quad R = 1 + (1-\tau)r^n \tag{45}$$

$$\text{Markup} \quad \mathcal{M} = \eta \tag{46}$$

$$\text{Wholesale prices} \quad p^j = \left(\frac{y}{x^j}\right)^{\frac{1}{\kappa}} \frac{1}{\mathcal{M}} \tag{47}$$

F.2.3 Firm problem

$$\Psi^{dj} = \frac{1}{\chi^d} \exp\left(\chi^d(\omega-1)d^j\right), \tag{48}$$

$$\Psi^{bj} = \left(\frac{1}{R} - \beta\right)\left(1 + \chi^d \Psi^{dj}\right)\frac{1}{\chi^b}, \tag{49}$$

$$b^j = \frac{\log(\chi^b \Psi^{bj})}{\chi^b} + (1-\delta)\theta k^j, \tag{50}$$

$$n^j = \left[\frac{w}{\nu(1-\alpha)p^j(x^j)^{(\nu+\rho)/\nu}}\right]^{\frac{1}{-\rho-1}}, \tag{51}$$

$$d^j = p^j x^j - wL^j - Q \cdot \left(k^j - (1-\delta)k^j\right) - b^j + \frac{b^j}{R}, \tag{52}$$

$$0 = \beta\nu\alpha p^j (k^j)^{-\rho-1}(x^j)^{\frac{\nu+\rho}{\nu}} - \left(1 - \beta(1-\delta) - (1-\delta)\theta\left(\frac{1}{R} - \beta\right)\right), \tag{53}$$

$$x^j = \left(\alpha(k^j)^{-\rho} + (1-\alpha)(L^j)^{-\rho}\right)^{\frac{-\nu}{\rho}}. \tag{54}$$

F.2.4 Aggregation

$$y = x^j \tag{55}$$

$$L = n^j \tag{56}$$

$$K = k^j \tag{57}$$

$$B = b^j \tag{58}$$

$$C = y - \delta K \tag{59}$$

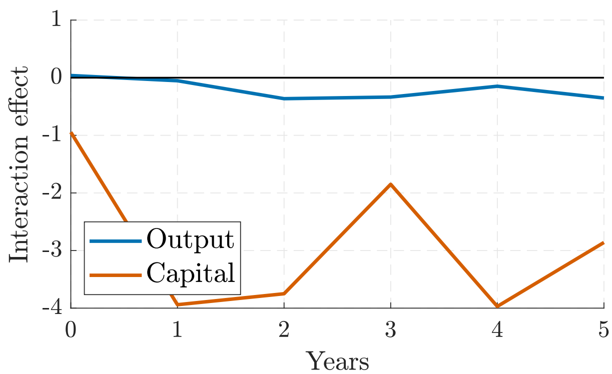
$$T = (\frac{1}{R} - \frac{1}{1 + r_n})B \tag{60}$$

G Firms' output and capital path dependence

While our model matches qualitatively the patterns observed in the data, the quantitative response is not comparable. First, if the variation in leverage in the model was to be taken literally as having the same effect on financial constraints in the data, the differential response of capital in A1 was many orders of magnitude too large. This is not surprising. The firm heterogeneity in our model is by design set up to illustrate the role of binding versus lax financial constraints, while using only very small shocks (a requirement of the perturbation method). Thus, a tiny variation in leverage has to translate to a large variation in how binding financial constraints are, so it would affect behavior. In contrast, the link in the data between leverage and the severity of financial constraints is bound to be much weaker. For this reason, the model is not well suited for quantitative comparisons across firms.

Second, while in the empirical analysis the differential response of capital and labor are similar in magnitude (in absolute terms), our mechanism can only generate a labor demand response that is weaker than the capital demand response. This is a limitation of our approach and suggests that other mechanisms influencing a differential response of employment might be in play.

Figure A1: The Dynamics of capital and output's differential response to monetary shocks by the firm's leverage



Notes: Estimating equation $\Delta_h \log y_{j,t+h} = \alpha_{j,h} + \beta^h(\ell_{j,t-1} - \mathbb{E}_j[\ell_{j,t}])\varepsilon_t^m + \epsilon_{j,h,t+h}$ for $h = \overline{0,5}$ on simulated data without controls. The dependent variable $y_{j,t+h}$ is firm output. The standard errors are clustered at the firm and economy levels. A panel of 100 economies with 900 periods. y-axis values are in units of standard deviation of σ_{ε^m}