# Beggar Thy Neighbour, Beggar Thy Policymaker

## Delayed Payments in Supply Chains and Transmission of Monetary Policy

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## ABSTRACT

This paper examines the role of firms' operating cash flows for the transmission of monetary policy. Using supplier-customer data for public US firms, I find that delayed payments for intermediate inputs in supply chains weaken suppliers' investment response to monetary policy shocks, with the effect significant up to ten quarters. I rationalise these findings using a heterogeneous firm New Keynesian model where delayed payments adversely affect suppliers' cash flows. In the presence of financial frictions, lower cash flows constrain the ability of affected suppliers to borrow and finance investment. As evidence for this mechanism, I use firm balance sheet and loan-level data to show that suppliers exposed to delayed payments face tighter borrowing constraints. Moreover, exposure to delayed payments dampens the response of suppliers' cash flows and borrowing to monetary policy shocks, consistent with the proposed mechanism. Calibrating the model to match relevant data, I show that the framework can replicate the magnitude and persistence of heterogeneity in investment response to monetary policy. Finally, I use the model to simulate the steep deterioration in payment behaviour during COVID-19 and find that the response of aggregate investment to a monetary policy shock is 17% weaker than it would be in the absence of delayed payments, highlighting the quantitative relevance of the proposed channel.

Keywords: Monetary policy, delayed payments, supply chains, investment, financial frictions

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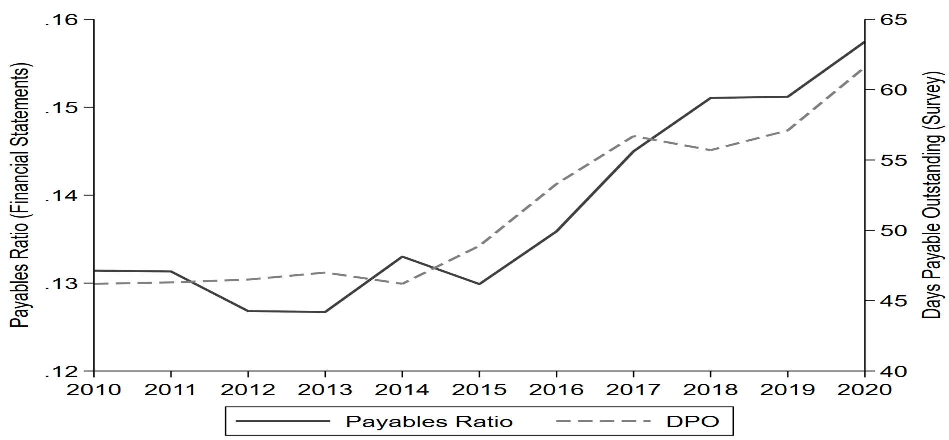
# I. Introduction

It is common for firms in supply chains to be paid after delivery of their intermediate product to customers, with the provision referred to as trade credit. However, significant delays in payment can adversely affect their operating cash flows. A considerable fraction of firms in US supply chains face delayed payments from their customers. In the cross-section, close to 55% of total business-to-business invoiced sales in 2023 are delayed (Atradius, 2023). Payment behaviour has worsened over time. Annual survey evidence shows that the 1,000 largest US public companies extended the time taken to pay for their inputs from 40.1 days in 2008 to 61.6 days in 2020 (Hackett, 2021).

**Figure 1. Payment behaviour in the US**




Notes: Median payment behaviour of US firms with bargaining power. Solid line shows the accounts payable to COGS ratio for major customers in the Compustat sample. Customers are classified as major if they make up more than 10% of the total sales of a supplier. All public firms are required to report customers with sales concentration above this threshold. Dashed line shows the average days payable outstanding for the 1000 largest US firms, obtained from Hackett Group Working Capital survey.

In this paper, I study the role of firms' operating cash flows for the transmission of monetary policy to corporate investment. I focus on investment because it is the most responsive component of aggregate demand to monetary policy. In theory, monetary policy affects firms' cash flows in two distinct ways. First, it varies the cash flows associated with the financing activities of a firm, through both the volume of borrowing and interest payments associated with the outstanding debt. Second, it affects the demand for a firm's product, which in turn impacts its operating cash flows. According to the cash flow channel of monetary policy transmission, the response of firms' cash flows to monetary policy can strongly influence their investment decisions in the presence of financial frictions. While one can empirically validate the transmission via interest payments by comparing the responsiveness of firms with varying exposures to flexible rate and fixed rate debt (Gürkaynak et al., 2019), it is much harder to establish the role of firms' operating cash flows for monetary policy transmission. This is because these cash flows are inherently correlated with the demand for a firm's product, making it difficult to isolate the role of cash flows from that of demand. Delayed payments are very useful in this context because they drive a wedge between the demand for a product and the timing of cash flows associated with that product. By studying the impact of delayed payments on firms' responsiveness to monetary policy, I seek to examine the importance of operating cash flows for the transmission mechanism.

I utilise supplier-customer data for public US firms to show that delayed payments significantly weaken the investment response of suppliers to monetary policy. The empirical analysis combines monetary policy shocks, identified using high frequency data on interest rates and stock prices (Jarociński and Karadi, 2020)[1], with quarterly data on firms' income statement and balance sheet variables, along with annual data on their major customers. Public firms in the US are required to disclose the identity of their major customers, which indicate all customers that make up more than 10% of their total sales. Suppliers frequently also disclose the bilateral sales to every major customer, which I use to estimate the strength of each supplier-customer link. For every supplier, I compute the bilateral sales weighted average payment duration of its customers, indicating its exposure to delayed payments. In order to control for permanent heterogeneity in responsiveness across suppliers, I base the identification on within-supplier variation in exposure to delayed payments. The key finding of this paper is that delayed payments weaken the investment response of suppliers to monetary policy shocks. I find that the investment response on impact is one percentage point weaker for firms with one standard deviation higher delayed payments, which implies a one-third decrease in the overall investment response. Moreover, using Jordà (2005) style local projections, I show that the heterogeneity in responsiveness remains statistically significant up to ten quarters after the realisation of the monetary policy shock. As additional evidence, I examine high frequency stock price response of firms to monetary policy shocks in a narrow window around FOMC announcements. Similar to the findings for investment response, I find that the stock price response is 63 basis points lower for suppliers exposed to one standard deviation higher delayed payments. The granular nature of the data enables me to compare the relevance of delayed payments for suppliers' responsiveness to monetary policy while controlling for other relevant characteristics of the supplier as well as the customer base.

[1] I also check for robustness of results using alternate shocks derived by Bu et al. (2021)

I propose that delayed payments dampen the investment response by adversely affecting firms' operating cash flows, which constrains their access to external finance. I show that this hypothesis is validated in the data. Firms exposed to delayed payments from their customers exhibit weaker response of operating cash flows and borrowing to monetary policy shocks, with the heterogeneity significant up to 12 quarters for both variables. Prevailing research (Lian and Ma, 2021; Drechsel, 2023) has shown that in the presence of asymmetric information in credit markets, lenders focus on borrowers' operating cash flows to evaluate their ability to repay a loan[2]. By constructing a dataset which combines firms' customer and balance sheet information with granular loan level data, I find that suppliers subject to delayed payments from their customers face tighter borrowing constraints. One standard deviation increase in customer payables is associated with 2% decline in loan volume and 140 basis points increase in loan spreads. Moreover, an increase in delayed payments is associated with lower issuance of new debt and lower leverage ratio for the affected firms.

As additional empirical validation, I employ a natural experiment to show that faster payments in supply chains strengthen transmission of monetary policy. Under the *Quickpay* reform of 2011, the US federal government committed to reducing the time between approval of an invoice and payment from 30 days to 15 days for small business contractors. In order to study the implication of this reform for the response of suppliers to monetary policy, I employ a triple difference methodology. Defining treated firms as small suppliers[3] which list the federal government as a major customer, I show that this reform resulted in a sharp decline in the receivables and a corresponding increase in cash. I find that after this reform, the investment and stock price response of treated firms to monetary policy shocks is significantly stronger. By utilising this natural experiment approach, I am able to address potential endogeneity concerns with the evidence based on panel local projections. Moreover, since the Federal government is the relevant customer in this analysis, one can be certain that the results are not driven by other characteristics of customers which may be correlated to their payment behaviour, such as profitability or default risk[4].

In order to rationalise these empirical findings and derive their aggregate implications, I develop a heterogeneous firm New Keynesian model, extending the setups in Khan and Thomas (2013) and Ottonello and Winberry (2020). In the model, heterogeneous firms invest in capital using internal finance or external borrowing. I add two key elements to

[2]Lian and Ma (2021) find that 80% of debt of US non-financial firms is based on cash flows from operations.

[3]While the exact definition of small businesses varies by industry, I use the upper bound of $40 million in annual sales as the cutoff:- https://www.census.gov/library/stories/2021/01/what-is-a-small-business.html

[4]In the panel regressions, I employ within-firm variation in payment behaviour to address endogeneity concerns and control for customer profitability and default risk.

the heterogeneous firm models in related literature to study the role of delayed payments. First, firms are subject to cash-flow based loan covenants, whereby their total borrowings cannot exceed a multiple of their operating cash flows. Second, in order to incorporate a role for timing of cash flows, firms are also subject to a cash-in-advance constraint, which arises because they need to pay their labour inputs at the outset of each period. As a result, firms need to engage in within period borrowing by selling a fraction of their receivables at a discount. An increase in payment delays implies greater required discounts on the receivables. Therefore, delayed payments negatively affect firms' operating cash flows, and consequently their ability to borrow.

The model is successful in replicating the magnitude and dynamics of the empirical findings. I calibrate it to match relevant empirical moments, selected to discipline the exposure of firms to idiosyncratic risk, their borrowing behaviour, and their lifecycle dynamics. Using this setup, I examine the heterogeneity in investment response of firms to an expansionary monetary policy shock based on model generated data. The model matches the empirical evidence on the heterogeneous response of investment, both in terms of the magnitude of heterogeneity as well as its persistence. Finally I use the model to consider the aggregate implications of the recent rise in delayed payment behaviour for the transmission of monetary policy. I find that the response of aggregate investment to a monetary policy shock is 17% weaker than it would be in the absence of the rise in delayed payments, showing the quantitative relevance of the proposed channel. For the monetary authority, this implies that in the presence of significant payment delays, stronger interventions may be necessary to achieve their inflation and employment objectives.

The analysis in this paper is focused on the investment response of suppliers to monetary policy shocks. A potential concern is whether the weaker response of suppliers due to delayed payments may be negated by a stronger response from their customers which experience an increase in cash flows by delaying payments. To address this concern, I explicitly examine whether customers delaying payments to their suppliers respond more to monetary policy. I show that there is no statistically significant heterogeneity in the investment response of customers with different payment behaviours. This finding can be attributed to the nature of customers which can unilaterally choose to delay payments. These firms are large and unconstrained, with significant bargaining power over their suppliers. Therefore, variation in cash flows due to their payment behaviour has little impact on their access to external finance. To the extent that this is the main channel for the results in this paper, we should expect delayed payments to have little impact on the investment response of these customers. Moreover, Antràs et al. (2012) find that capital expenditures are strongly skewed toward upstream sectors. If investment is concentrated in upstream firms, suppliers' investment response to monetary policy should have important aggregate implications.

**Related Literature:** This paper contributes to an extensive literature on the relevance of financial frictions for the transmission of monetary policy. First, it relates to the literature studying the cash flow channel of monetary policy. Empirical work in this area has focused primarily on the impact of monetary policy on the interest payments of firms and households. Gürkaynak et al. (2019) examine the cash flow channel by comparing the stock price response of firms with flexible rate debt to those with fixed rate debt, while Flodén et al. (2021) and Cooper et al. (2021) carry out similar analyses for households. In this paper, I focus on monetary transmission via firms' operating cash flows by leveraging delayed payments in supply chains. Similar to fixed rate date, I find that delayed payments dampen the response of firms' cash flows to monetary policy.

Second, this paper contributes to the literature studying the role of financial frictions for the heterogeneous investment response of firms to monetary policy. Ottonello and Winberry (2020) analyse the relevance of default risk for the responsiveness of capital investment to monetary policy. They find that riskier firms respond less to monetary policy because they face steeper marginal cost of financing investment and rationalise these findings using a heterogeneous firm New Keynesian model incorporating default risk. Using granular bond level data, Anderson and Cesa-Bianchi (2020) instead find that firms with high leverage respond more strongly to monetary policy, and attribute this to frictions in financial intermediation. Jeenas (2019) focuses on the role of cash holdings in the investment response of firms to monetary policy, and finds that a higher stock of cash holdings reduces the responsiveness of firms. My paper contributes to this literature by examining the relevance of *cash flows* for the transmission. It shows that even beyond the stock of cash holdings, cash flow response plays an important role in the transmission of monetary policy.

Other papers have highlighted alternative sources of heterogeneous responsiveness to monetary policy, such as age (Cloyne et al., 2018) and size (Gertler and Gilchrist, 1994). The novelty in this paper is that it highlights the relevance of the attributes of its counterparties. This opens up new avenues to study how investment response to monetary policy may vary depending on the customers or suppliers of a firm. It emphasises the importance of incorporating the supply chains when analysing transmission of monetary policy.

Third, this paper contributes to the literature which studies the role of trade credit in driving aggregate fluctuations. Altinoglu (2021), Reischer et al. (2019), Luo (2020), and Demir and Javorcik (2018), among others, find that variations in the duration of trade credit in supply chains have a significant impact on aggregate output. Jacobson and Von Schedvin

(2015) find that trade credit linkages may lead to upstream propagation of corporate bankruptcy in supply chains. Barrot and Nanda (2020) and Murfin and Njoroge (2015) study the impact of variation in timing of payments for the employment and investment outcomes of firms, respectively. I extend this literature by examining the relevance of payment behaviour of customers for investment response to monetary policy. The model I develop is inspired by the analysis in Barrot (2016), who shows that in competitive industries, trade credit can have an important role in driving industry dynamics by affecting the profitability of constrained firms. This paper is also related to the body of work which finds a strong link between firm cash flows and investment (Lamont, 1997; Gilchrist and Himmelberg, 1995). Relative to this literature, this paper provides granular empirical evidence on an important channel through which operating cash flows impact investment, while also examining the relevance of this link for monetary policy transmission. Finally, I use a natural experiment to show that a reform accelerating payments to suppliers has a positive impact on their investment response to monetary policy.

The paper is organized as follows: Section II explains the data. Section III discusses the panel regression empirical results, Section IV dicusses the Quickpay reform and its impact on monetary policy transmission, Section V discusses the model, Section VI conducts the monetary policy analysis using the model, and Section VII concludes.

# II. Data Description

**Firm-Level Variables**: Quarterly firm level variables for publicly listed US firms are obtained from Compustat. Compustat is well suited for this study since it is quarterly, and hence, is at a high enough frequency to allow for the study of monetary policy. The key variable for the analysis of investment is the stock of tangible capital, where $k_{it}$ is the capital stock at the end of quarter t. I measure investment response as the accumulation of tangible capital stock overtime. While Compustat provides a firm-level measure of investment rates, the measure is very lumpy and erratic. This makes it difficult to conduct analyses of dynamic investment responses based on this measure. The approach of using accumulation of capital stock to measure investment is also followed in other closely related work in this literature, such as Ottonello and Winberry (2020) and Jeenas (2019).

I obtain data for the customers of a firm from Compustat Customer Segment Database. Statement of Financial Accounting Standard (SFAS) No. 14 requires all public firm in the US to disclose the identity of customers which account for more than 10% of their total sales. An important advantage of the Compustat Customer Segment Database over the alternative databases is that, in addition to the identity of the customers, it provides data on the pairwise sales for each customer, allowing us to delineate the relative importance of each customer. Moreover, this database is available for the longest duration compared to alternatives[5]. I estimate the payment behaviour of customers using ratio of accounts payable to cost of goods sold, where the latter is a commonly used proxy for the value of inputs:

$$p_j = \frac{AP_j}{COGS_j}$$

where $AP$ denotes accounts payable, $COGS$ denotes cost of goods sold, and j denotes each customer. Using this estimate, I measure for each supplier i the exposure to delayed payment behaviour as the bilateral sales weighted average of the payables ratio across all major customers:

$$cp_i = \frac{1}{n}\sum_{j=1}^{n}(\%Sales_{ij} \times p_j) \tag{1}$$

where $\%Sales_{ij}$ denotes the ratio of bilateral sales from supplier $i$ to customer $j$ relative to the total sales of supplier $i$ and n is the total number of major customers. I compute the average in order to ensure results are not driven by concentration of customers[6]. Table I lists the relevant characteristics of suppliers and customers in the sample. Note that customers are, on average, significantly bigger than suppliers and the default risk of customers is significantly lower than that of suppliers. Additionally, the capital to assets ratio of customers is higher than that of the suppliers. Delayed payments by customers therefore imply a transfer of liquidity from constrained firms to their unconstrained counterparts.

Table II presents the correlation of the measure of customer payment behaviour with the firm leverage, firm default risk, customer payables, and customer profitability. Customer profitability is constructed similar to the measure of customer payables as the weighted average profitability across all major customers for each firm. This table shows that the correlation between the measure of customer payables and measures of customer profitability or the firm's leverage and default risk is quite low. This indicates that the customer payables measure captures a distinct characteristic of a supplier's customer base.

**Loan level data:** I obtain information on bank loan terms from LPC-Dealscan and link

[5]FactSet Revere provides information on a greater number of customers; however, the sample begins from 2003, thus minimising the possible window of analysis of conventional monetary policy. Additionally, Factset Revere does not offer information regarding the magnitude of bilateral sales for the majority of supplier-customer links, thus making it impossible to measure the strength of the relationships.

[6]The results in the subsequent analysis are also robust to using a measure of customer payables which is not weighted by the bilateral sales.

**Table I. Summary Statistics of Firm Level Risk Variables**

| | Suppliers | | | | Customers | | | |
|---|---|---|---|---|---|---|---|---|
| | Size | Profit | EDF | K/A | Size | Profit | EDF | K/A |
| Mean | 4.76 | -1.38 | 0.09 | 0.25 | 8.19 | -0.16 | 0.04 | 0.31 |
| Median | 4.78 | 0.09 | 0.00 | 0.15 | 8.40 | 0.15 | 0.00 | 0.24 |
| S.D. | 2.34 | 8.87 | 0.21 | 0.25 | 2.37 | 4.46 | 0.15 | 0.25 |
| 95th Percentile | 8.42 | 0.53 | 0.66 | 0.80 | 11.62 | 0.47 | 0.31 | 0.79 |
| Unique Firms | 7859 | | | | 1484 | | | |

Notes: Summary statistics of firm-level variables for the period 1994q1 to 2018q4. EDF is the expected default frequency which measures the probability of default. K/A denotes the ratio of capital to total assets. Size is measured as the log of total assets.

**Table II. Correlation Matrix**

| | $\ell_{jt}$ | $\text{edf}_{jt}$ | $\text{cpayable}_{jt}$ | $\text{cprofit}_{jt}$ |
|---|---|---|---|---|
| $\ell_{jt}$ | 1.00 | | | |
| | | | | |
| $\text{edf}_{jt}$ | 0.28 | 1.00 | | |
| | (0.00) | | | |
| $\text{cpayable}_{jt}$ | 0.04 | -0.02 | 1.00 | |
| | (0.00) | (0.00) | | |
| $\text{cprofit}_{jt}$ | -0.01 | -0.02 | -0.01 | 1.00 |
| | (0.00) | (0.00) | (0.12) | |

Notes: Pairwise correlations of firm-level variables for the period 1990q1 to 2007q4. $\ell_{jt}$ is the firm's leverage, measured as the ratio of total debt to total assets, $\text{edf}_{jt}$ is the expected default frequency of a firm, $\text{cpayable}_{jt}$ is the weighted average payables ratio of the firm's customers, and $\text{cprofit}_{jt}$ is the weighted average profitability of the firm's customers. $p$-values in parentheses.

this to Compustat firm level data using the methodology in Chava and Roberts (2008). In subsequent analyses, I focus on three key variables in the loan contracts: loan spread, loan volume and the maturity. I follow Campello and Gao (2017) in calculating the loan spread as the difference between the sum of coupon and annual loan fees, and the six month LIBOR.

**Monetary Policy Shocks:** I employ monetary policy shocks constructed by Jarociński and Karadi (2020) for the empirical analysis. The results are robust to using an alternative measure of monetary policy shocks developed by Bu et al. (2021), who cleanly identify shocks arising from not only conventional monetary policy but also uncoventional monetary policy. The times series variation of the identified shocks used in the analysis is shown in Appendix B.

The Jarociński and Karadi (2020) measure of monetary policy shocks is based on high frequency negative co-movement between interest rates and stock prices in a narrow 30 minute window around an FOMC announcement. FOMC announcements can convey information about the immediate and near term monetary policy along with information about the state of the economy. The identification is based on the simple idea that a monetary policy surprise should move the stock prices in the opposite direction to the short term rates. Positive co-movement may imply that the FOMC announcement also conveyed relevant information about the central bank's assessment of the economic outlook. It is important to disentangle movements in the short term rates arising due to pure monetary policy surprises from those arising due to Fed information. A Bayesian structural VAR based on high-frequency identification along with sign restrictions is employed to disentangle these two components.

I focus on the period from 1994 to 2018. During this interval, there were a total of 211 shocks with a mean of approximately -0.6 basis points (bp henceforth) and a standard deviation of 6 bp. For the empirical analysis based on quarterly firm variables, I aggregate the high-frequency shocks over the quarterly frequency. In order to do this, I construct a moving average of the raw shocks weighted by the number of days in the quarter after the shock occurs. This time aggregation strategy ensures that the shocks are weighted by the amount of time firms have had to react to them. Table III indicates that these "smoothed" shocks have similar features to the original high-frequency shocks. For robustness, I also run all the tests for the alternative aggregation where I simply sum all the shocks within a quarter. Table III shows that these alternative shocks do not significantly from the smoothed shocks.

Note that the start and end dates are determined by data availability. Formal FOMC announcements were initiated in 1994, which determines the start year for the analysis. I do not use data beyond 2018 because of a new accounting rule in 2019 relating to operating leases which significantly affect the assets and liabilities of firms in the Compustat sample, as discussed in Lian and Ma (2021). Before 2019, firms did not report operating leases on their balance sheets. However, after the passage of this new law, firms were required to report the present value of operating leases in the assets and liabilities side of their balance sheets. This led to a rise in the total assets and liabilities of Compustat firms in 2019. Additionally, these changes in accounting were also incorporated in the Compustat definitions of plant, property, and equipment (PPENT), debt in current liabilities (DLC), and long-term debt (DLTT). Since these variables are used in the analysis, I restrict the sample to years before this law was passed. In the appendix, I show that the results are robust to using an extended sample from 1990 to 2020.

**Table III. Summary Statistics of Monetary Shocks**

| | High Frequency | Smoothed | Sum |
|---|---|---|---|
| Mean | -0.583 | -1.294 | -1.230 |
| Median | -0.176 | -0.452 | -0.510 |
| S.D. | 6.252 | 6.656 | 8.304 |
| Min | -34.25 | -31.13 | -37.19 |
| Max | 14.23 | 10.95 | 17.44 |
| Observations | 211 | 100 | 100 |

Notes: Summary statistics of monetary policy shocks for the period 1/1/1994 to 12/31/2018. Shocks are obtained from Jarociński and Karadi (2020). High frequency shocks refer to the estimates from a 30 minute window around FOMC announcement. Smoothed shocks refer to high frequency shocks aggregated to a quarterly frequency using based on a weighted average, where the weights are determined by the number of remaining days in the quarter. Summed shocks refer to high frequency shocks aggregated by summing all shocks within a quarter.

# III. Empirical evidence

This section is structured as follows: Subsections A and B examine the heterogeneity in investment response and high frequency stock price response to monetary policy shocks, respectively. In Subsection C, I study the potential mechanism for these results. I show that firms exposed to delayed firms exhibit weaker response of operating cash flows and borrowing to monetary policy shocks. Using granular balance sheet and loan level data, I examine the impact of delayed payments and operating cash flows on firms' access to external finance. Finally, in Subsection D, I study how delayed payments impact the investment response of customers to monetary policy.

## A. Investment Response to Monetary Policy

In this subsection, I examine the relevance of payment behaviour of customers for the investment response of suppliers to monetary policy shocks. I employ the following empirical specification:

$$\Delta \log\, k_{it} = \alpha_i + \alpha_j + \alpha_{st} + \beta_1 (cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_2 cp_{it-1} + (\Gamma_1' + \epsilon_t^m \Gamma_2') Z_{it-1} + e_{it} \quad (2)$$

where $\alpha_i$ refers to the firm fixed effect, $\alpha_j$ denotes customer fixed effect[7], and $\alpha_{st}$ denotes sector-quarter fixed effect. $\epsilon^m$ refers to the monetary policy shock, cp denotes the customer payable measure derived in the previous section, and $E_i[cp_{it}]$ is the average value of customer payables for supplier i. Finally, $Z_{it-1}$ denotes the controls while $e_{it}$ is the residual. The main coefficient of interest is $\beta_1$ which measures the extent to which within-firm variation in customer payables affects the investment response of a firm to a monetary policy shock. I employ within firm variation in customer payables $(cp_{it-1} - E_i[cp_{it}])$ to ensure that the results are not driven permanent heterogeneity in responsiveness of firms[8].

In the benchmark specification, I control for the firm's demeaned probability of default, demeaned leverage, and size. Given the focus on the responsiveness to monetary policy, these controls are also interacted with the monetary shocks. The results are also robust to the inclusion of customer related controls such as customer profitability, customer leverage, and customer size. Additionally, I control for lagged sales growth of the firm along with four lags of investment to take into account any pre-trends in investment or sales behaviour across the cross section of firms. The sector-quarter fixed effects control for variation across different sectors in responsiveness to monetary policy shocks. In the benchmark specification, I define sectors at the one digit NAICS level. In Appendix F, I show that these results are robust to using more granular definitions of the industry. The standard errors are clustered by firm and quarter to account for correlations within firms and quarters.

Finally, I make two normalisations to ease interpretation: First, I standardise each firm's demeaned measures of risk $(cp_{it-1} - E_i[cp_{it}])$ over the entire sample, so their units are standard deviations. Second, I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive value corresponds to an expansionary monetary shock.

*Results:* Following the intuition in the previous section, we should expect the investment response of firms to monetary policy shocks to be negatively related to the payment behaviour

[7]While each supplier may have multiple customers, the customer fixed effect is applied for the largest customer of a supplier

[8]This follows the specification employed in Ottonello and Winberry (2020)

**Table IV. Heterogeneous response of investment to monetary policy**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Customer Payables $\times$ FFR Shock | -1.04** | -0.45 | -0.74* | -0.71** | -1.00** |
| | (0.43) | (0.34) | (0.41) | (0.35) | (0.42) |
| FFR Shock | | | | 2.08 | |
| | | | | (2.34) | |
| Observations | 31231 | 31231 | 31231 | 31231 | 31231 |
| $R^2$ | 0.228 | 0.175 | 0.222 | 0.221 | 0.251 |
| Firm controls | no | yes | yes | yes | yes |
| Firm FE | yes | no | yes | yes | yes |
| Customer FE | yes | yes | no | yes | yes |
| Time Sector FE | yes | yes | yes | no | yes |

Notes: Reports the coefficient $\beta_1$ estimated from the specification $\Delta\log\, k_{it} = \alpha_i + \alpha_j + \alpha_{st} + \beta(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_2 cp_{it-1} + (\Gamma_1' + \epsilon_t^m \Gamma_2')Z_{it-1} + e_{it}$, where $k$ is the capital stock, $\alpha_i$ is a firm fixed effect, $\alpha_j$ is a customer fixed effect, $\alpha_{st}$ is a sector-by-quarter fixed effect, $cp_{it-1} - E_i[cp_{it}]$ is the demeaned measure of customer payables, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls containing demeaned leverage, default probability, sales growth, size, and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardise $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

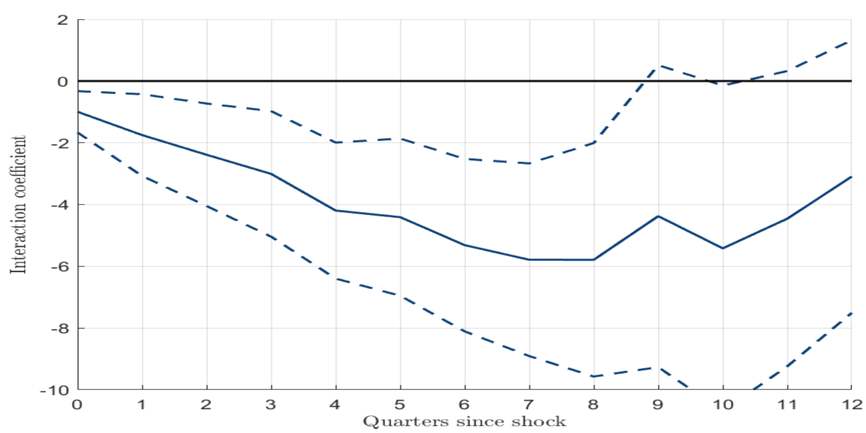
of their customer base. In Table IV, I show the results for the regression 2 using different combinations of controls or fixed effects in each column. The benchmark specification in Column (5) shows that one standard deviation increase in customer payables is associated with one percentage point weaker response of investment to monetary policy shocks. In order to understand the quantitative importance of this heterogeneity, I exclude sector-quarter fixed effects in Column (4) so as to obtain the coefficient for the monetary policy shock. I find that one standard deviation increase in customer payables leads to one-third decrease in the investment response to monetary policy. Column (1) shows that the responsiveness is not significantly affected by the exclusion of the controls. Columns (2) and (3) show that controlling for permanent heterogeneity across firms and their customers is important in this analysis.

**Dynamic Response to Monetary Policy:** I employ local projections to examine the dynamic investment response of firms to monetary policy (Jordà, 2005):

$$\log\, k_{it+h} - \log\, k_{it} = \alpha_{ih} + \alpha_{jh} + \alpha_{sth} + \beta_{1h}(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_{2h} cp_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h}) Z_{it-1} + e_{ith} \quad (3)$$

where h = 0,1,2,....,H denotes the horizon of the capital accumulation response to a monetary policy shock at time t; $k_{it}$ denotes the stock of capital of firm i at the end of quarter t. Following the benchmark specification in Equation 2, I consider how the investment response to monetary policy depends on the within-firm variation in payment behaviour of the customer base $cp_{it-1} - E_i[cp_{it}]$. The coefficient of interest $\beta_{1h}$ shows the cumulative capital accumulation at time t+h in response to a monetary policy shock at time t. Inclusion of controls, fixed effects, and clustering of standard errors follows the baseline specification in Equation 2.

**Figure 2. Heterogeneous Dynamic Response of Investment**




Notes: Reports the coefficient $\beta_{1h}$ over quarters 0 to 12 for the specification $\log\, k_{it+h} - \log\, k_{it} = \alpha_{ih} + \alpha_{jh} + \alpha_{sth} + \beta_{1h}(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_{2h} cp_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h}) Z_{it-1} + e_{ith}$, where y is the capital stock, $\alpha_{ih}$ is a firm fixed effect, $\alpha_{jh}$ is a customer fixed effect, $\alpha_{sth}$ is a sector-by-quarter fixed effect, $cp_{it-1} - E_i[cp_{it}]$ is the demeaned measure of customer payables, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls containing demeaned leverage, default probability, sales growth, size, and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardise $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Dashed lines report 90% error bands.

*Results:* In Figure 2, I plot the estimated values of the coefficient $\beta_{1h}$. I find that the heterogeneity in investment responses is quantitatively significant and persistent up to 10 quarters after the monetary policy shock. At its peak, the investment response of firms with one standard deviation higher customer payables is six percentage points lower. In Appendix G, I show that the results are robust to using a different measure of monetary policy shocks. Additionally, Appendix H shows that the results are also robust to using the extended sample from 1990 to 2020.

## B. Stock Market Response to Monetary Policy

In response to an expansionary monetary shock, stock prices tend to increase, indicating the positive effect of lower interest rates on the firm's intrinsic value. If the heterogeneous response to monetary policy due to delayed payments is quantitatively significant, and the information on customer payment behaviour publicly available, then the high frequency stock price response to monetary shocks should reflect the same. In this section, I show that the response of stock prices around an FOMC announcement indicates that investors take into account the payment behaviour of a firm's customers. I measure the stock price response as the stock return within a two day window around the monetary policy shock, i.e. the change from the day before the FOMC announcement to the day after. The data on stock prices is obtained from the Center for Research in Security Prices (CRSP) database. The specification remains similar to the one used in the previous section:

$$\Delta p_{it} = \alpha_i + \alpha_j + \alpha_{st} + \beta_1(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_2 cp_{it-1} + (\Gamma_1' + \epsilon_t^m \Gamma_2')Z_{it-1} + e_{it} \tag{4}$$

where $\Delta p_{it} = \frac{p_{it} - p_{it-1}}{p_{it-1}} \times 100$, $p_{it}$ is the stock price, and the other notations follow the description in 2. The only difference in this specification relative to 2 is that instead of sector-quarter fixed effects, I include sector-date fixed effects, on account of the higher frequency of data in this analysis. As before, the underlying objective of this specification is to examine how within-firm variation in delayed payments influences the response of stock prices to monetary policy shocks.

*Results:* In Table V, I show the results for regression specification 4 using different combinations of controls and fixed effects. Column (4) shows the results for the benchmark specification with all the fixed effects and controls. I find that one standard deviation increase in customer payables is associated with 63 basis point lower stock returns. Column (1) reflects the importance of including sector-time fixed effects in examining heterogeneous stock price responses. This is natural since the stock price behaviour varies significantly across sectors. In Columns (2) and (3), I find that the results are robust to the exclusion of firm-level controls and fixed effects. In Appendix I, I show that these results are also robust to using

**Table V. Heterogeneous Response of Stock Prices to Monetary Policy**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Customer Payables × FFR shock | -0.30 | -0.72** | -0.66** | -0.63** |
| | (0.31) | (0.30) | (0.26) | (0.29) |
| MP shock | 10.51*** | | | |
| | (1.69) | | | |
| Observations | 56609 | 56609 | 56609 | 56609 |
| $R^2$ | 0.041 | 0.098 | 0.070 | 0.100 |
| Sector-Date FE | no | yes | yes | yes |
| Firm Controls | yes | no | yes | yes |
| Firm FE | yes | yes | no | yes |
| Buyer FE | yes | yes | no | yes |

Notes: Results from estimating $\Delta p_{it} = \alpha_i + \alpha_j + \alpha_{st} + \beta(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_2 cp_{it-1} + (\Gamma_1' + \epsilon_t^m \Gamma_2')Z_{it-1} + e_{it}$, where $\Delta p_{it}$ refers to stock returns in percentages, $\alpha_i$ is a firm fixed effect, $\alpha_j$ is a customer fixed effect, $\alpha_{st}$ is a sector-by-quarter fixed effect, $cp_{it-1} - E_i[cp_{it}]$ is the demeaned measure of customer payable, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls consisting of demeaned leverage, default risk, and size of the supplier along with their interaction with the monetary shock, sales growth and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and date. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I have standardised $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

a one day window around the FOMC policy announcement.

## C. Inspecting the Mechanism

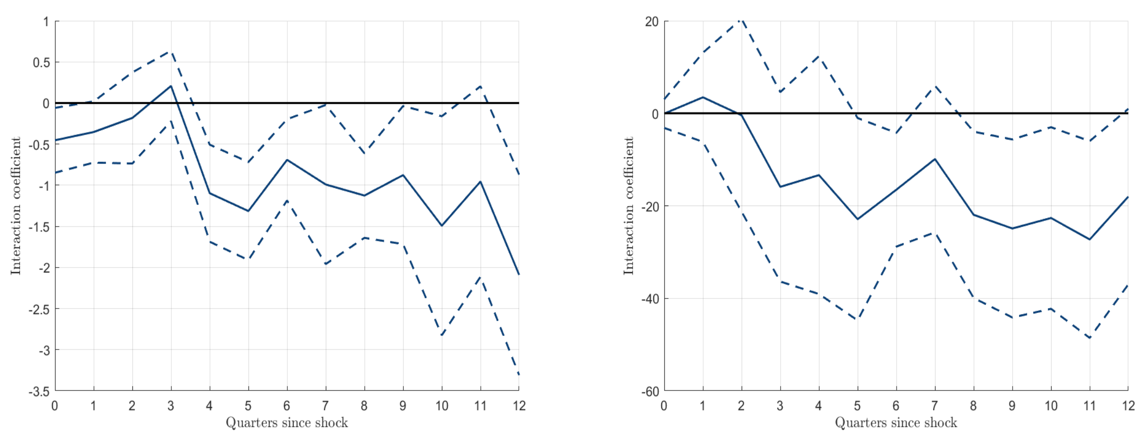
In this section, I inspect the underlying mechanism for the weaker investment and stock price response of firms subject to delayed payments. I propose that delayed payments weaken firms' response by adversely affecting their operating cash flows, which constrains their access to external finance. Consistent with this proposed mechanism, firms subject to delayed payments exhibit weaker response of operating cash flows and borrowing to monetary policy shocks. The key reason for this finding is the importance of operating cash flows for firms' access to external finance. Prevailing research (Lian and Ma, 2021; Drechsel, 2023) has shown that in the presence of asymmetric information in credit markets, lenders focus on borrowers' cash flows to evaluate their ability to repay a loan. Using firm balance sheet and loan level data, I then show that delayed payments are associated with tighter borrowing constraints.

**Dynamic Response of Operating Cash Flows and Borrowing to Monetary Policy:** I employ local projections to study the dynamic response of firms' cash flows from operating activities and borrowing to monetary policy shocks. The empirical specification follows 3:

$$y_{it+h} - y_{it} = \alpha_{ih} + \alpha_{jh} + \alpha_{sth} + \beta_{1h}(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_{2h}cp_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h})Z_{it-1} + e_{ith} \quad (5)$$

where y either denotes the firm's operating cash flows or Log(debt). The rest of the notations follow the discussion for 3. In Figure 3, I plot the estimated coefficient $\beta_1$ over the time horizon h. Consistent with the proposed hypothesis, I find that firms subject to delayed payments from their customers exhibit weaker response of cash flows from operating activities and borrowing to monetary policy shocks. Note that I use the measure for operating cash flows, instead of the total cash flows of a firm. This ensures that the results are not driven by the impact of monetary policy on firms' cash flows from financing activities. I use these findings as evidence for the modelling decisions in the next section.

**Figure 3. Heterogeneous Response of Operating Cash Flows and Borrowing**




(a) Operating Cash Flows

(b) Debt

Notes: Left panel shows the dynamics for the response of operating cash flows and the right panel shows the dynamics for borrowing response to monetary shocks. Figure report the coefficient $\beta_{1h}$ over quarters 0 to 12 for the specification $y_{it+h} - y_{it} = \alpha_{ih} + \alpha_{jh} + \alpha_{sth} + \beta_{1h}(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_{2h}cp_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h})Z_{it-1} + e_{ith}$, where y denotes the cash flows from operating activities in the left panel and Log(Debt) in the right panel, $\alpha_{ih}$ is a firm fixed effect, $\alpha_{ih}$ is a customer fixed effect, $\alpha_{sth}$ is a sector-by-quarter fixed effect, $cp_{it-1} - E_i[cp_{it}]$ is the demeaned measure of customer payables, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls containing demeaned leverage, default probability, sales growth, size, and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardize $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Dashed lines report 90% error bands.

**Loan terms and delayed payments:** In the following discussion, I provide empirical evidence for the relation between delayed payments and borrowing constraints using firm-quarter level balance sheet and income statement data from Compustat and loan level data from LPC Dealscan. While it is widely understood that delayed payments can have a negative impact on borrowing constraints when receivables are used as collateral[9], note that most of the firms in the sample of Compustat and LPC Dealscan use cash flow based debt (Lian and Ma, 2021). Therefore, the following results help in showing that the link between delayed payments and borrowing constraints extends to cash flow based loans where there is no pledged collateral.

I estimate the following regression specification to examine the effect of delayed payments on loan terms:

$$y_{it} = \alpha_i + \alpha_{sq} + \beta cp_{it-1} + \mathbf{\Gamma}' Z_{it-1} + \epsilon_{it} \tag{6}$$

where $\alpha_{sq}$ denotes the sector-quarter fixed effects to control for any sectoral variation in loan terms. The identification is, therefore, based on within sector heterogeneity in loan terms. I also include firm fixed effects $\alpha_i$ to control for permanent differences across firms. For this analysis, $\beta$ is the main coefficient of interest. It measures the extent to which variations in a supplier's exposure to delayed payments from its customers, measured by customer payables or cp as discussed previously, affect loan terms. Here $\text{y} \in \{\text{Log(Debt)}; \text{Debt issuance}; \text{Leverage ratio}; \text{Interest expense rate}\}$ is a vector containing either the stock of total debt, net debt issuance, the leverage ratio, or the interest expense rate of a firm in quarter t. By looking at the multiple variables, I aim to verify that delayed payments have a negative impact on not only the stock of debt or leverage ratio but also the volume of newly issued debt. Additionally, I include a measure of the ratio of interest expenses to total liabilities in order to show that these results extend to both quantity of borrowing and the pricing. Inclusion of interest expense rate is also crucial in showing that these results are not driven by demand for loans, but by supply side effects. Z denotes the controls used in the regression, which include the probability of default, profitability, tangible assets, and the total size of the firm.

In Table VI, I show the results for the estimated coefficient $\beta$. I find that exposure to delayed payments has a strong impact on the borrowing of the supplier, with 1 standard deviation increase in customer payables resulting in 7% lower debt, with similar findings for

[9] Financial Accounting Standards Board (FASB) No. 105 requires firms to disclose credit concentration, including trade credit offered to major customers. Kermani and Ma (2020) study the liquidation recovery rates of different types of asset held by borrowers. They find that receivables accruing to concentrated large customers or government have significantly lower recovery rates since they are difficult to collect.

the other variables. Moreover, as confirmation of the tightened borrowing constraints on the suppliers, I find that interest expenses, controlling for the stock of debt, are significantly higher for suppliers more exposed to delayed payments.

**Table VI. Loan Terms and Customer Payables**

| | Ln(Debt) | Debt Issuance | Leverage Ratio | Interest Expense Rate |
|---|---|---|---|---|
| Customer Payables | -0.066*** | -1.303** | -0.005*** | 2.283** |
| | (0.0166) | (0.5251) | (0.0017) | (0.9140) |
| Observations | 28374 | 28374 | 28374 | 25003 |
| $R^2$ | 0.921 | 0.070 | 0.808 | 0.713 |
| Firm controls | yes | yes | yes | yes |
| Firm FE | yes | yes | yes | yes |
| Customer FE | yes | yes | yes | yes |
| Sector-Date FE | yes | yes | yes | yes |

Notes: Results for coefficient $\beta$ from estimating regression specification $y_{it} = \alpha_i + \alpha_{sq} + \beta cp_{it-1} + \mathbf{\Gamma}' Z_{it-1} + \epsilon_{it}$, where $\alpha_{sq}$ denotes the sector-quarter fixed effects, and $\alpha_i$ is a firm fixed effect. Z denotes the controls used in the regression, which include the probability of default, profits, tangible assets, and the total size of the firm. The dependent variable, y $\in \{$Log(Debt); Debt issuance; Leverage ratio; Interest Expense Rate$\}$. The variable cp is standardized over the entire sample. The standard errors are two way clustered by firm and quarter.

In Table VII, I provide further evidence for this using loan level data from LPC Dealscan. This data allows me to additionally control for permanent differences in loan terms offered by different lenders through the inclusion of lender fixed effects. I run the following regression specification: $y_{it} = \alpha_l + \alpha_s + \beta cp_{it-1} + \mathbf{\Gamma}' Z_{it-1} + \epsilon_{it}$, where $\alpha_l$ denotes the lender fixed effects, $\alpha_s$ denotes the sector fixed effects, and y $\in \{$Loan Spread; Log(Loan Amount)$\}$. The results with loan level data are consistent with those presented in Table VI. I find that suppliers with higher customer payables are characterised by lower loan amounts and higher loan spreads.

## D. Investment Response of Customers

The preceding results show that suppliers exposed to delayed payments exhibit weaker investment response to monetary policy due to the adverse impact of delayed payments on the their cash flows. Whether delayed payments have an impact on the aggregate investment response of an economy to monetary policy depends on how they affect the investment

**Table VII. Loan Terms and Customer Payables: Loan Level Data**

| | Spread | Log(Amount) |
|---|---|---|
| Customer payables | 0.0137** | -0.0202** |
| | (0.0068) | (0.0091) |
| Observations | 1830 | 1978 |
| $R^2$ | 0.591 | 0.701 |
| Lender FE | yes | yes |
| Industry FE | yes | yes |

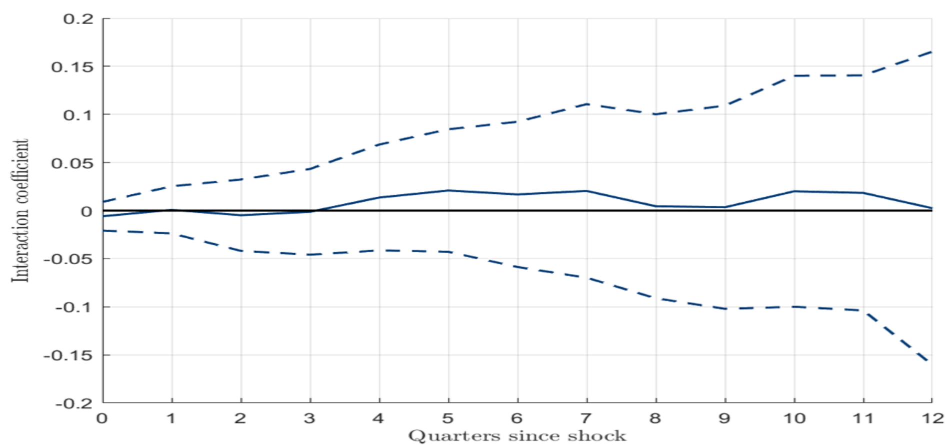
Notes: Results for coefficient $\beta$ from estimating regression specification $y_{it} = \alpha_l + \alpha_s + \beta cp_{it-1} + \mathbf{\Gamma}' Z_{it-1} + \epsilon_{it}$ for loan level data, where $\alpha_s$ denotes the sector fixed effects, and $\alpha_l$ is a firm fixed effect. Z denotes the controls used in the regression, which include the probability of default, profits, tangible assets, total size of the firm, and the loan maturity. The dependent variable, y $\in$ {Loan Spread; Log(Loan Amount)}. The variable cp is standardized over the entire sample. The standard errors are two way clustered by firm and quarter.

behaviour of the customers. An increase in cash flows accruing from delaying payments may strengthen investment response of customers to monetary policy shocks, which would imply that delayed payments should not have a significant impact on aggregate investment response. In the following discussion, I show that delayed payments are not associated with stronger investment response of customers. The key reason for this finding is that customers are, on average, less financially constrained than their suppliers. This is apparent in the comparison of suppliers and customers in Table I, which shows that the customers are larger, more profitable, less risky, and possess more tangible assets than their suppliers. This is natural since customers capable of delaying payments to their suppliers are usually firms which enjoy bargaining power over their suppliers. Since these customers are financially unconstrained, the primary mechanism discussed in the previous subsection, whereby changes in cash flows influence the borrowing ability of constrained firms, is not operative. Therefore, we should not expect the heterogeneity in responsiveness of customers to be as significant as it is for the financially constrained suppliers. In order to test this, I run the following regression specification for the sample of customers:

$$\log\, k_{it+h} - \log\, k_{it} = \alpha_{ih} + \alpha_{sth} + \beta_{1h}(pay_{it-1} - E_i[pay_{it}])\epsilon_t^m + \beta_{2h} pay_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h}) Z_{it-1} + e_{ith} \tag{7}$$

where *pay* refers to the accounts payable to cogs ratio for the customers. In this specification, I examine whether within-firm variation in the payables to COGS ratio has a significant impact on the firm's investment responsiveness to monetary policy. In Figure 4, I plot the regression coefficient $\beta_{1h}$ over the time horizon. It is evident that firms which delay payments to their supplpiers do not respond more to monetary policy shocks. This finding has important implications for the relevance of delayed payments for aggregate investment response to monetary policy. While delayed payments do not have any significant impact on the investment responsiveness of the customers, they significantly depress the responsiveness of the suppliers, thus weakening the aggregate investment response.

**Figure 4. Heterogeneous Investment Response of Customers**




Notes: Reports the coefficient $\beta_{1h}$ over quarters 0 to 12 for the specification $\log k_{it+h} - \log k_{it} = \alpha_{ih} + \alpha_{sth} + \beta_{1h}(pay_{it-1} - E_i[pay_{it}])\epsilon_t^m + \beta_{2h} pay_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h})Z_{it-1} + e_{ith}$, where $k$ is the capital stock, $\alpha_{ih}$ is a firm fixed effect, $\alpha_{jh}$ is a customer fixed effect, $\alpha_{sth}$ is a sector-by-quarter fixed effect, $pay_{it-1} - E_i[pay_{it}]$ is the demeaned measure of payables to COGS ratio, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls containing demeaned leverage, default probability, sales growth, size, and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardise $pay_{it-1} - E_i[pay_{it}]$ over the entire sample. Dashed lines report 90% error bands.

If the customers delaying payments to their suppliers do not use the additional cash flow generated to finance higher investment, it is interesting to examine the how they use the cash. In Appendix D, I show that customers delaying payments show higher responsiveness of share repurchases to monetary policy shocks. This finding is consistent with recent commentary on the significant rise in share repurchases by large firms in the US economy.

# IV. Quickpay Reform and Monetary Transmission

In 2011, the U.S. federal government passed a reform indefinitely accelerating payments to its small business contractors, reducing the time between approval of invoice and payment from 30 days to 15 days. The reform covered more than \$200 billion in purchases of goods and services, and claimed to have generated more than \$1 billion in liquidity for small businesses[10]. Barrot and Nanda (2020) examine the impact of this reform on small firms' employment decisions, finding a strong positive effect. In this section, I study whether accelerating payments to firms strengthened their investment response to monetary policy shocks.

All contractors of the federal government classified as small businesses were eligible for this reform. The formal definition of a small business varies by industry, with the annual sales cutoff ranging from \$1 million to \$40 million[11] Following the upper bound of this definition, I classify firms with less than \$40 million in sales as small businesses. I define treated firms as all small firms in the Compustat sample for which the US federal government was a major customer at the time of the reform[12]. In Figure 5, I show that following the announcement of the reform in the third quarter of 2011, treated firms experienced a sharp decline in their receivables from close to 20% of their annual sales to less than 14%. Correspondingly, cash doubled from 6% of their annual sales to almost 12%, showing the strong impact of the reform. During the same duration, the receivables and cash for the control group of firms remained stable.

Having shown that the reform was effective in reducing delayed payments, I now examine its implications for the investment response to monetary policy using the following specification:

$$\Delta \text{log k}_{it+1} = \alpha_i + \alpha_{st} + \beta_1 \; \mathbb{1}\{QP\} * \epsilon_t^m * \mathbb{1}\{Post\} + \Gamma' Z_{it-1} + e_{it}$$

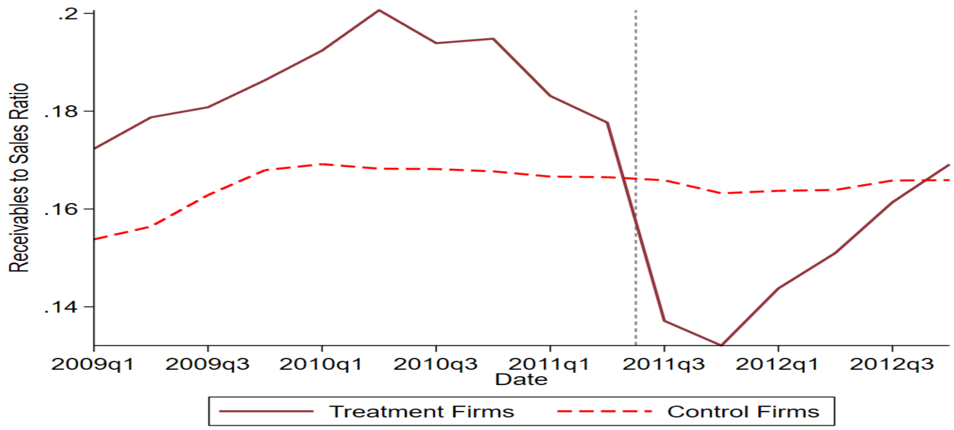
where $\Delta$log $\text{k}_{it+1}$ refers to change in capital stock from t-1 to t+1. I examine accumulation over a window of two quarters since capital is a slow moving variable which takes some time to respond to the monetary policy shock, as can be seen in Figure 2. $\mathbb{1}\{QP\}$ is a dummy variable which takes the value of 1 for treated firms and 0 for control firms, 1{Post} is a dummy variable which takes the value 1 for quarters after the reform and 0 for the quarters before, $\epsilon_t^m$ is the monetary shock, and the fixed effects follow the notation from before.

[10]https://obamawhitehouse.archives.gov/the-press-office/2014/07/11/president-obama-announces-new-partnership-private-sector-strengthen-amer

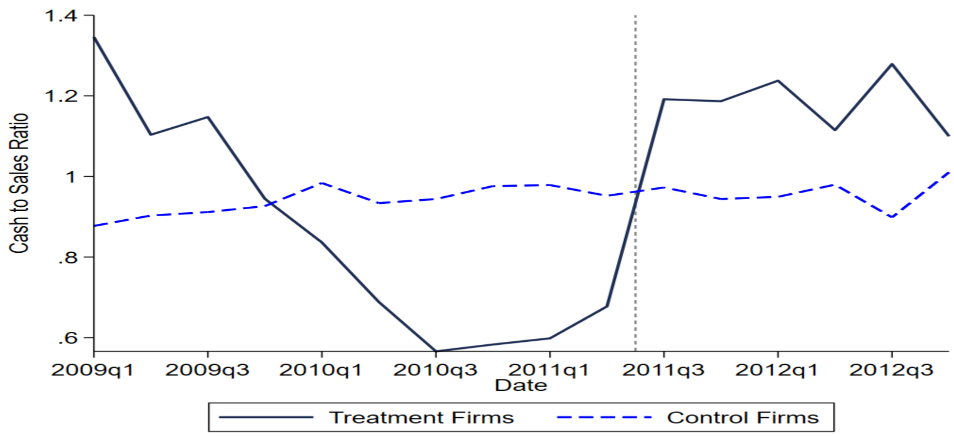
[11]https://www.census.gov/library/stories/2021/01/what-is-a-small-business.html

[12]Major customer refers to a customer that accounts for more than 10% of a suppliers total sales.

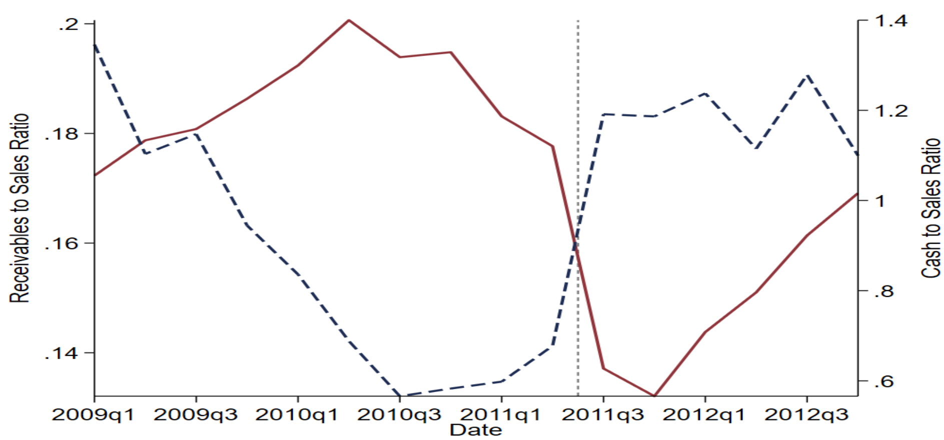
## Figure 5. Impact of Quickpay Reform on Payments and Cash




(a) Receivables




(b) Cash




(c) Receivables and Cash

Notes: Treated firms refer to all firms with less than $40 million in annual sales and the U.S. federal government as a major customer, while control firms refer to the firms that do not satisfy either of these conditions. Quickpay reform was formally announced on 14 Septemember, 2011. Panel (a) shows the receivables to sales ratio for the treated and control group of firms. Panel (b) shows the cash to sales ratio for the treated and control group of firms. Finally, Panel (c) shows the receivables to sales ratio of treated firms on the left y-axis and cash to sales ratio on the right y-axis.

Note that in addition to the triple interaction, I also include all combinations of double interactions in the specification. The coefficients for standalone measures of $\mathbb{1}\{QP\}$ and $\mathbb{1}\{Post\}$ are omitted due to the inclusion of firm fixed effects and sector-time fixed effects.

**Table VIII. Impact of Quickpay Reform on Investment Response**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| $\mathbb{1}\{QP\} \times$ MP shock $\times$ $\mathbb{1}\{Post\}$ | 43.44*** | 34.03** | 28.23** | 37.62*** |
| | (7.28) | (11.70) | (12.84) | (12.10) |
| Observations | 5672 | 5672 | 5672 | 5672 |
| $R^2$ | 0.036 | 0.375 | 0.366 | 0.379 |
| Firm FE | no | yes | yes | yes |
| Firm controls | yes | no | yes | yes |
| Sector-Date FE | yes | yes | no | yes |

Notes: Results from estimating $\Delta\log \text{k}_{it+1} = \alpha_i + \alpha_{st} + \beta_1 \mathbb{1}\{QP\} * \epsilon_t^m * \mathbb{1}\{Post\} + \Gamma' Z_{it-1} + e_{it}$ where $\Delta\log \text{k}_{it+1}$ refers to change in capital stock from t-1 to t+1, $\alpha_i$ is a firm fixed effect, $\alpha_{st}$ is a sector-by-quarter fixed effect, $\mathbb{1}\{QP\}$ is a dummy variable which takes the value of 1 for treated firms and 0 for control firms, 1{Post} is a dummy variable which takes the value 1 for quarters after the reform and 0 for the quarters before the reform, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls consisting of uninteracted terms, (log) size, and leverage, with each control also interacted with the post dummy and the monetary policy shock. Standard errors are two-way clustered by firms and date. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

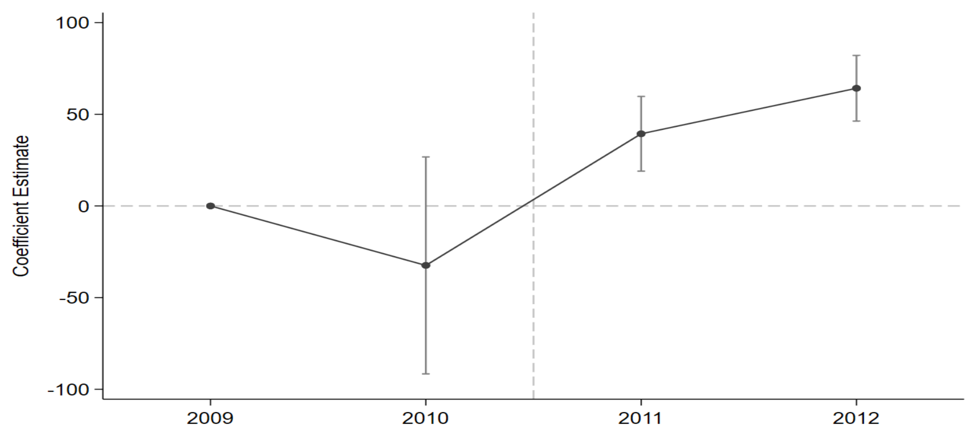
*Results:* The coefficient of interest in this exercise is $\beta_1$, which signifies the extent to which treated firms exhibit higher responsiveness of investment to monetary policy shocks after the reform accelerating payments. I find that the investment response to a 1 pp decrease in federal funds rate for the treated group is stronger by 37 bp after the reform. This analysis highlights the important role of payment behaviour in supply chains for the transmission of moentary policy. Additionally, since this is based on a difference-in-difference framework, it addresses potential identification concerns with the empirical evidence based on local projections provided in the preceding sections.

In order to ensure that these results do not simply reflect pre-trends, I use the following regression specification:

$$\Delta\log \text{k}_{it+1} = \alpha_i + \alpha_{st} + \beta_1 \mathbb{1}\{QP\} * \epsilon_t^m * \mathbb{1}_y + \Gamma' Z_{it-1} + e_{it}$$

where $\mathbb{1}_q$ refers to a dummy variable which takes the value 1 for year y and 0 otherwise. This specification enables us to study how the coefficient $\beta_1$ varies overtime. In Figure 6, I present the results for this specification by plotting the estimated $\beta_1$ for each year of the analysis. There is a sharp rise in investment responsiveness of treated firms after the reform, providing further evidence that the reform improved the transmission of monetary policy to firm level investment. In Appendix J, I show that we obtain similar results for the impact of Quickpay reform on the high frequency stock price response of firms to monetary policy.

**Figure 6. Parallel Trends**




Notes: Figure plots the coefficient $\beta_1$ form the regression specificaiton: $\Delta\log \text{k}_{it+1} = \alpha_i + \alpha_{st} + \beta_1 \ \mathbb{1}\{QP\} * \epsilon_t^m * \mathbb{1}_y + \Gamma' Z_{it-1} + e_{it}$ where $\mathbb{1}_q$ refers to a dummy variable which takes the value 1 for year y and 0 otherwise, $\Delta\log \text{k}_{it+1}$ refers to change in capital stock from t-1 to t+1, $\alpha_i$ is a firm fixed effect, $\alpha_{st}$ is a sector-by-quarter fixed effect, $\mathbb{1}\{QP\}$ is a dummy variable which takes the value of 1 for treated firms and 0 for control firms, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls consisting of the uninteracted terms, (log) size, and leverage, with each control also interacted with the post dummy and the monetary policy shock. Standard errors are two-way clustered by firms and date. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates.

# V. Model

In this section, I present a heterogeneous firm New Keynesian model to rationalise the empirical findings and derive their quantitative aggregate implications. I study the transition of an economy to simultaneous and unexpected delayed payment and monetary policy shocks. The delayed payment shock affects a subset of firms in the economy, which is calibrated based on the data. Apart from these shocks, there is no aggregate uncertainty in the model. In the steady state, all firms have the same timing of cash flows. The objective is to examine how the investment response to a monetary policy shock is impacted by within-firm variation in payment terms, consistent with the empirical analysis. By introducing delayed payments as a shock, I ensure that we compare responsiveness across otherwise similar firms.

## A. Environment

The timing in the model is discrete and infinite. The model features an upstream heterogeneous block of firms that invest in capital and produce homogeneous goods, a downstream retail block of monopolistically competitive firms, a representative household, a representative capital goods producer, and a monetary authority which sets the nominal interest rate according to the Taylor rule. I use the terms upstream and downstream to signify the suppliers and customers in a supply chain. Consistent with the empirical analysis, the focus is on the heterogeneity in the investment response of suppliers. The model builds on the framework developed in Khan and Thomas (2013) and Ottonello and Winberry (2020), to which I introduce intra-period differences in timing of revenues, along with cash flow based borrowing constraints. Cash flow based borrowing constraints are very common in the US economy, with almost 80% of total US borrowing estimated to be of this nature (Lian and Ma, 2021). These borrowing constraints serve to explicitly link cash flows of firms to their borrowing capacity. Delayed payments adversely affect a firm's cash flows, thus constraining their ability to borrow and finance investment.

### A.1. Production

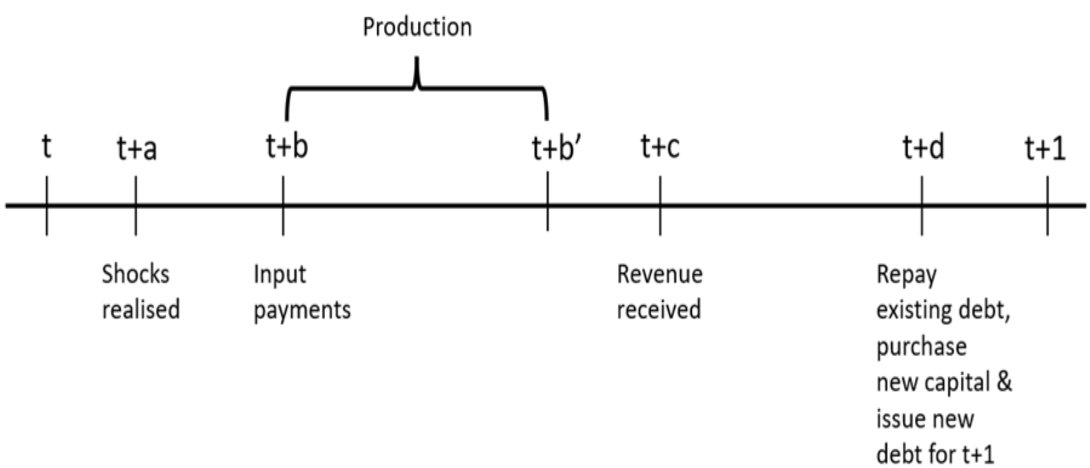
There is a unit mass of production firms in the economy every period. Each firm produces a homogeneous good $y$, employing a decreasing returns to scale production function:

$$y_{it} = z_{it} k_{it}^{\theta} l_{it}^{\nu} \tag{8}$$

where z denotes an idiosyncratic productivity shock, k is the predetermined capital stock, l denotes labor, and $\theta + \nu < 1$. The idiosyncratic productivity shock z follows a log-AR(1) process $\log z_{it} = \rho \log z_{it-1} + \epsilon_{it}$, where $\epsilon_{it} \sim N(0, \sigma^2)$. If all firms are allowed to grow indefinitely, then they will outgrow the borrowing constraints, thus making financial frictions meaningless. In order to prevent this scenario, in each period a fraction $\pi_d$ of firms receive an i.i.d. exit shock and leave the economy after production. They are then replaced by new entrants to ensure that there is a unit mass of firms in each period. These entrants start with lower average productivity (Foster et al., 2008), lower level of capital $k_0$ and zero debt.

### A.2. Timeline

**Figure 7. Payment behaviour of large US firms**




In each period t, the timing of events for an individual firm i, depicted in Figure 7, is as follows:

(a) Mass $\pi_d$ of new firms enter the economy and idiosyncratic productivity shocks are realised.

(b) The firm begins production using predetermined capital stock $k$ and labour $l$, hiring workers from a competitive market at the wage rate $w_t$. It is subject to a cash-in-advance constraint since the wage bill $w_t l$ is required to be paid before production begins. However, it receives revenue $p_t y$ at a later time t+c. In order to satisfy this constraint, the firm sells a fraction of its receivables $\omega$ to banks at a discount $\Upsilon^{rec}$, with the superscript $rec$ denoting the price of receivables. The value of $\Upsilon_t^{rec}$ is determined by the number of days until revenue is due.

(c) The firm receives the revenue from the customer for the fraction of receivables that it still holds $(1 - \omega_{it}) p_t y_{it}$, with the rest of the revenue accruing to the bank.

(d) Finally, the firm purchases new capital $k_{t+1}$ and issues new debt $b_{t+1}$ for period t+1.

### A.3. Firm cash flows

As discussed above, a firm is subject to a cash-in-advance constraint, whereby it is required to cover the wage bill before production begins. In order to do so, it will sell a fraction $\omega$ of its receivables at a price $\Upsilon_t^{rec}$ such that the following condition is satisfied:

$$\omega \Upsilon_t^{rec} p_t y = w_t l \tag{9}$$

The price of receivables is derived by adjusting the quarterly interest rate $r_t$ by the number of days until the payment is due. Denoting the ratio of number of days until the payment is received to the number of days in a quarter by $\chi$, the price of receivables is as follows:

$$\Upsilon_t^{rec} = \frac{1}{\{1 + (r_t + s)\chi)\}} \tag{10}$$

where s is spread on the risk-free rate. It usually ranges from 0.25% to 75%, with the rates quoted on a quarterly basis. In the following analysis I assume a spread of 0.5%. Note that the key parameter in this equation is $\chi$, which measures the extent of delayed payments. An increase in delayed payments is associated with higher $\chi$ and lower price of receivables $\Upsilon_t^{rec}$. The profits, which can be interpreted as the operating cash flows of the firm, are:

$$\pi = p_t y - \frac{w_t l}{\Upsilon_t^{rec}} \tag{11}$$

This equation shows the impact of delayed payments on the cash flows of the supplier. An increase in delayed payments increases the effective cost of making upfront payments to inputs due to the lower price of receivables. This is then associated with lower cash flows for the supplier. The net worth of a firm is:

$$n = \pi + q_t(1 - \delta)k - Q_t b - \xi \tag{12}$$

where $q_t$ refers to the price of capital, $\delta$ is the depreciation rate, b is the debt outstanding from period t-1, $Q_t$ is the price of debt, and $\xi$ is the fixed operating cost. Introducing the fixed operating cost is useful in matching relevant moments in the data.

### A.4. Financial frictions

Firms in this model can finance investment using both internal finance and external finance. However, financial frictions imply that their is a limit to a firm's capacity to utilise external finance. Firms are subject to two main frictions:

1. **Non-negative dividend constraint:** This assumption implies that firms in the model are unable to issue equity. This is a common assumption in the literature, used in Khan and Thomas (2013), Ottonello and Winberry (2020), Jeenas (2019), among others. It is consistent with the findings which show that equity issuance is more expensive and infrequent than debt financing (Hansen and Torregrosa, 1992; Altınkılıç and Hansen, 2000; Bazdresch, 2013). In the absence of these constraints on issuing equity, firms can costlessly finance additional investment expenditure, thus subverting any borrowing constraints. An alternative albeit more computationally intensive method would to introduce a non-infinite cost to issuing equity.

2. **Borrowing constraint:** I assume that loan contracts in the economy feature debt-to-earnings covenants. These covenants specify a maximum limit for firm level debt as a multiple of it's earnings, with the borrower required to be compliant in any given quarter. If the borrower breaches the covenant, it is said to be in 'technical default'. This shifts the control rights from the borrower to the lender, thus imposing significant costs from the perspective of the borrower. Lian and Ma (2021) find that more than 60% of loan contracts in the US explicitly feature earnings based financial covenants, with the debt-to-earnings covenants being the most common. In this model, I assume that firms make their borrowing decisions so as to never be in violation of these debt-to-earnings covenants. This implies the borrowing for the next period is limited to the covenant determined multiple $\phi_\pi$ of a firm's earnings, conditional on the worst possible realisation of the idiosyncratic productivity shock next period. The borrowing constraint for a firm can then be represented as:

$$b' \leq \phi_\pi[\pi_{t+1}|z'_{min}]$$

   where $z'_{min}$ is the minimum productivity realisation for the next period, conditional on the productivity shock $z$ today. This self-imposed constraint ensures that, irrespective of the idiosyncratic productivity shock realised next period, there are no technical defaults in equilibrium[13].

### A.5. Firms' optimisation problem

At the beginning of a period, firms differ in their idiosyncratic productivity shock $z$, delayed payment shock $\chi$, outstanding capital $k$, and debt $b$. The distribution of firms is summarised

[13]This requires an assumption that the idiosyncratic productivity shocks have a finite support.

over (z,k,b,$\chi$), using the probability measure $\mu$ defined on the Borel algebra, which is generated by the open subsets of the product space $\mathbf{Z}\times\mathbf{K}\times\mathbf{B}\times\mathbf{X}$. Consistent with Khan et al. (2014), since there are no micro-economic frictions which prevent reallocation of capital in the model, the individual state variables $k_t$ and $b_t$ can be encapsulated through the net worth of the firm $n_t$. In every period, a fraction $\pi_d$ of the firms exit the economy and are replaced by new entrants with initial capital $k_0$ and no debt. The productivity of the new entrants is drawn from a distribution $\mu_{ent}(z) \sim \log N\Big(-m\frac{\sigma}{\sqrt{1-\rho^2}}, \frac{\sigma}{\sqrt{1-\rho^2}}\Big)$, where $m$ determines the productivity of the entrants. The level of initial capital stock $k_0$ and productivity of entrants $m$ are exogenous parameters which are calibrated from the data.

I characterise the maximisation problem of the firm recursively. The firm seeks to maximise the present discounted value of its dividends:

$$v_t(z,n,\chi) = \max_{k',b',d} \Bigg\{ n + (1-\delta)q_t k - b \Bigg\} - q_t k' + Q_t b' \\ + \beta \mathbb{E}_t \Bigg[ \Lambda_{t+1} \Bigg( \pi_d \hat{n}_{t+1}(z',k',b',\chi') + (1-\pi_d) v_{t+1}(z', \hat{n}_{t+1}(z',k',b',\chi'),\chi') \Bigg) \Bigg] \quad (13)$$

Subject to the non-negative dividend constraint and the earnings based borrowing constraint:

$$n - q_t k' + Q_t b' \geq 0 \quad (14)$$

$$b' \leq \phi_\pi [\pi_{t+1} | z'_{min}] \quad (15)$$

where $v$ denotes the value of the firm, and the dividends $div$ are represented as $n - q_t k' + Q_t b'$, and $\pi_d$ is the probability that the firm receives an exit shock. The firm chooses labor to maximise its net worth for the current period, implying $\hat{n}_t(z,k,b,\chi) = \max_{l} \ \pi + q_t(1-\delta)k - b - \xi$.

In order to determine the firms' choices of dividends, capital, and debt, I employ the strategy introduced in Khan and Thomas (2013) of partitioning firms into three separate categories based on the extent to which their decisions are affected by financial frictions. The first category identifies *Unconstrained firms*, comprising of those firms which are not subject to binding borrowing constraints today, and have zero probability of being subject to binding borrowing constraints in the future. These firms have, therefore, permanently outgrown financial frictions. The second category identifies *Type 1 constrained firms*. These firms are not subject to binding borrowing constraints today, but have a non-zero probability of the borrowing constraint binding in the future. Finally, the third set of firms are

*Type 2 constrained firms*, which are subject to binding borrowing constraints today. This demarcation enables a simpler solution of the optimal forward looking decisions of the firms.

**Unconstrained firms:** These firms have accumulated sufficient net worth to finance efficient level of capital in every future state. The efficient choice of capital is:

$$k^*(z) = \underset{k'}{argmax} \;\; -q_t k' + \mathbb{E}_t[\Lambda_{1,t+1}(\iota(z',k') + (1-\delta)k')|z] \tag{16}$$

where $\iota(z,k) = \underset{l}{max}\; zk^\theta l^\eta - \frac{wl}{\Upsilon_t^{rec}}$. This efficient choice of capital solves the following:

$$q_t = \mathbb{E}_t[\Lambda_{1,t+1}\mathrm{MRPK}_{t+1}] \tag{17}$$

Since these firms are not subject to binding borrowing constraints today or in the future, the present discounted marginal value of savings is equal to the marginal value of dividends shared with the households today. This implies that unconstrained firms are indifferent between saving or issuing dividends. Following Khan and Thomas (2013), I solve this indeterminacy by assuming that these firms follow a maximum borrowing policy, under which they borrow as much as possible while ensuring that the borrowing constraint does not bind for any state in the future. To derive this, note that the dividends of a firm for efficient capital choice $k^*(z)$ and borrowing choice $b^*(z)$ are given by:

$$div = \iota(z',k^*(z)) + (1-\delta)q_t k^*(z) - b^*(z) - \xi - q_t k^*(z') + Q_t b^*(z') \tag{18}$$

The borrowing choice of the firm in this case will be the maximum amount that the firm can borrow without having to pay negative dividends even if the worst possible shocks are realised next period:

$$b^*(z) = \underset{z',\chi'}{min}\; \tilde{b}^*(z) \tag{19}$$

$$\tilde{b}^*(z) = \iota(z',k^*(z)) + (1-\delta)q_t k^*(z) - q_t k^*(z') + Q_t min\; \{b^*(z'), \phi_\pi[\pi_{t+1}|z'_{min}]\} \tag{20}$$

By ensuring that the firm does not have negative dividends in response to the worst realisation of shocks tomorrow, the maximum borrowing policy can guarantee that it remains unconstrained for all possible states. An implication of this is that there is a threshold level of net worth above which a firm will always chose to adopt this policy:

$$n > q_t k^*(z) - Q_t b^*(z) \tag{21}$$

**Constrained firms:** A firm can be characterised as constrained if it cannot finance the efficient choice of capital $k^*(z)$ without having to borrow more than the level defined by the maximum borrowing policy discussed above. The cutoff level of net worth above which a firm is unconstrained follows from Equation 21:

$$n^c = q_t k^*(z) - Q_t b^*(z) \tag{22}$$

All firms with net worth $n \in [0, n^c]$ can be characterised as constrained. Having identified the constrained firms in the economy, the decision rules are straightforward. Type 1 constrained firms solve the optimization problem in Equation 13, subject to the non-negative dividend constraint 14; while Type 2 constrained firms are additionally subject to the binding borrowing constraint in Equation 15.

### A.6. Investment choice:

Constrained firms' optimal choices of capital $k'$ and borrowing $b'$ for the next period satisfy the following conditions:

$$q_t k' = n + Q_t b' \tag{23}$$

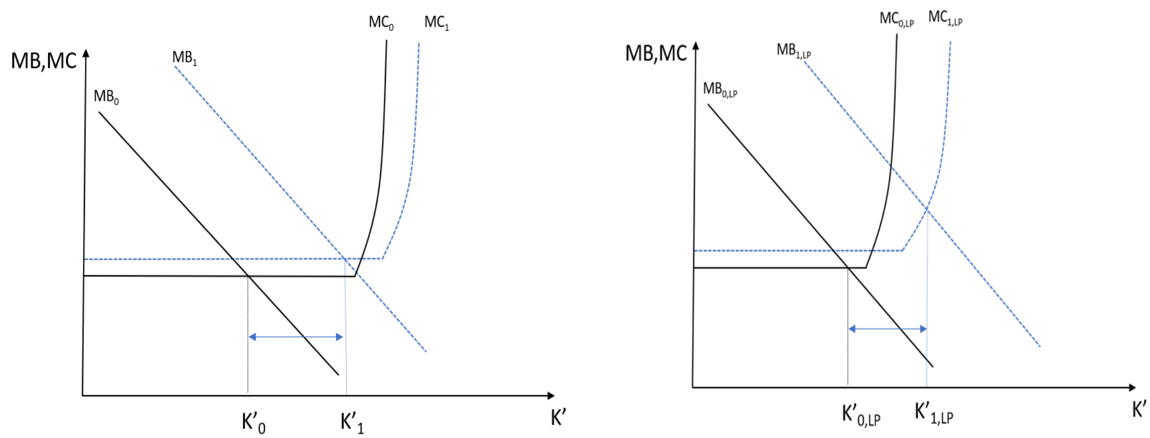
$$\underbrace{q_t\Big(1 + \lambda_{1,t+1}\Big) + \lambda_{2,t}\Big(q_t - \phi_\pi[\text{MRPK}_{t+1}|z'_{min}]\Big)}_{\text{Marginal cost}} = \underbrace{\mathbb{E}_t[\Lambda_{1,t+1}(1 + \lambda_{1,t+1})\text{MRPK}_{t+1}]}_{\text{Marginal benefit}} \tag{24}$$

where $\lambda_1$ refers to the lagrange multiplier for the non-negative dividend constraint 14 and $\lambda_2$ refers to the lagrange multiplier for the borrowing constraint 15. The left side of Equation 24 shows the marginal cost of capital investment, which consists of two parts. The first part $q_t\Big(1 + \lambda_{1,t+1} - \Lambda_{t+1})$ shows the cost of buying one additional unit of capital, inclusive of its effect on the non-negative dividend constraint. The second part shows the effect of this purchase on the borrowing constraint. While capital investment requires additional borrowing which tightens the constraint, it also leads to higher cash flows in the next period, which has the opposite effect on the constraint. Whether an additional unit of capital tightens or loosens the borrowing constraint depends on the relative magnitudes of these two terms. In my calibration, $q_t > \phi_\pi[\text{MRPK}_{t+1}|z'_{min}]$, thus implying that additional capital investment tightens the borrowing constraint.

The right side of Equation 24 shows the marginal benefit of investment, which is equal to the present discounted value of marginal revenue product of capital in the next period, inclusive of its effect on the non-negative dividend constraint.

**Response to monetary policy:** Expansionary monetary policy has two distinct effects on marginal benefit. First, a reduction in interest rates increases the present discounted

**Figure 8. Investment response to monetary policy with and without delayed payments**




(a) Without delayed payments

(b) With delayed payments

Notes: The figure plots the marginal cost and marginal benefit of capital investment as a function of capital choice for the next period. The left panel shows the investment response of firms not exposed to delayed payments and the right panel shows the investment response of firms exposed to delayed payments. The dashed blue lines show the marginal benefit and marginal cost after the realisation of the monetary policy shock.

value of the revenues tomorrow. Additionally, lower interest rates are associated with higher relative prices of goods $p_t$, wages $w_t$, and lower cost of intra-temporal credit $R^{rec}$. The net effects of these changes is an increase in the marginal revenue product of capital, which further increases the marginal benefit of investment.

The response of marginal cost to monetary policy is more nuanced. For a firm without binding borrowing constraints, expansionary monetary policy raises the price of capital $q_t$ due to the increased demand for capital. The overall increase in marginal cost depends on whether the borrowing constraint is binding. Binding borrowing constraints, $\lambda_2 > 0$, substantially raise the shadow marginal cost of investment. Expansionary monetary policy is therefore less effective if the firm is subject to delayed payments on account of the tighter borrowing constraints which limit the investment response.

### A.7. Households

The economy features a representative infinitely lived household. The household seeks to maximise its lifetime utility, which is positively related to its consumption $c$ and negatively related to its supply of labor $l$. It holds one-period shares in firms, denoted by $\Lambda$, along with one-period non-contingent bonds $b$. While the household receives its wages at the beginning of production in the period, it consume at the end of the period. I assume that it holds these wages in unremunerated checking deposits $cd$ at the financial intermediaries, which are then used to make the intra-period loans to the firms for the cash-in-advance constraint. The household owns the financial intermediary, retail firms, capital goods firm, as well as the final goods firm. Hence, all profits from these entities are distributed to the household at the end of each period. The household maximises its lifetime utility subject to the budget constraint as follows:

$$V_t^h\Big(d, \lambda)\Big) = \underset{c,n,b',\lambda'}{max}\Big\{\log\, c - \phi l + \beta V_{t+1}^h\Big(d', \lambda'\Big)\Big\} \tag{25}$$

subject to

$$c + Q_t d' + \int_{\mathbf{S}} \rho_{1,t}(k', b', z', \chi')\lambda'(dk', db', dz', d\chi') \\ \leq w_t l + d + \int_{\mathbf{S}} \rho_{0,t}(k, b, z, \chi)\lambda(dk, db, dz, d\chi) + div + \Psi_t^I \tag{26}$$

where $div$ denotes the dividends of the retail firm, financial intermediary, and capital goods producer; $\rho_{1,t}(k', b', z', \chi')$ is the ex-dividend real price of shares of the production firm with the state $(k', b', z', \chi')$ in the next period, $\rho_{0,t}(k, b, z, \chi)$ is the price of shares of the production firms with the state $(k, b, z, \chi)$ in the current period. $d$ denotes the one period deposits held by the households in the financial intermediary, $\lambda$ denotes the number of shares bought in the respective firms and $\Psi_t^I$ is the lump sum intermediation cost rebated by the financial intermediary to the household.

### A.8. Financial Intermediary

There exists a perfectly competitive financial intermediary which accepts savings and checking deposits from households and uses them to make one-period and intra-period loans, respectively. I assume that intra-period loans are subject to an intermediation cost $\phi_I$ to the financial intermediary which results in a non zero intra-period borrowing cost for the firms. Consistent with the price of receivables $\Upsilon_t^{rec}$, I assume that the intermediation cost per unit of intra-period lending takes the following form:

$$\phi_t^I = \frac{1}{\Upsilon_t^{rec}} \tag{27}$$

where $\Upsilon_t^{rec}$ as discussed in Section A.3. These intermediation costs are transferred back lump sum to the household, such that they do not have any impact on the aggregate resource constraint of the economy. Since the financial intermediary is perfectly competitive, its optimisation problem can be denoted as follows:

$$V_t^I(b,d) = \max_{b,d,cd,b^{rec}} \Big\{ div^I + \Lambda_{t+1} V_t^I(b',d') \Big) \Big\} \tag{28}$$

subject to:

$$div^I \leq b - d - Q_t b' + Q_t d' + (R_t^{rec} - \phi_t^I) b^{rec} - cd \tag{29}$$

where $d$ denotes the one-period deposits, $b$ denotes the one period loans, and $Q_t$ denotes the price of loans and deposits, cd denotes the intra-period deposits, and $R^{rec}$ is the effective interest rate on intra-period loans based on the price of receivables $\Upsilon_t^{rec}$, and $b^{rec}$ denotes the volume of intra-period loans.

### A.9. Retail and Final Good Firm

The model features a unit mass of monopolistically competitive retailers i∈[0,1] which produce differentiated goods $y_{it}^R$ using the undifferentiated intermediate input $y_{it}$ in the following production function: $y_{it}^R = y_{it}$. The retail firms set a price $p_{it}^R$ subject to a quadratic price adjustment cost: $\frac{\varphi}{2}\left(\frac{p_{it}^R}{p_{it-1}^R} - 1\right)^2 Y_t$, where $Y_{it}$ denotes the final good. The final good producers are perfectly competitive, taking the price of the retail goods and final good as given. Denoting the intermediate inputs elasticity of substitution as $\Gamma$, the production function of the final good producer is:

$$Y_t = \left( \int \tilde{y}_{it}^{\frac{\Gamma-1}{\Gamma}} di \right)^{\frac{\Gamma}{\Gamma-1}} \tag{30}$$

The retail producer and final good producer yield the New Keynesian Phillips Curve:

$$\log \Pi_t = \frac{\Gamma - 1}{\varphi} \log \frac{p_t}{\overline{p}} + \beta \mathbb{E}_t \log \Pi_{t+1} \tag{31}$$

where $\varphi$ determines the magnitude of price adjustment costs, $\overline{p}$ denotes the steady state relative price of intermediate inputs and $Pi$ denotes inflation.

**Capital Good Producer:** I introduce a representative capital good producers which is subject to a capital adjustment cost. This is incorporated in order to generate time varying price of capital. The price of capital is as follows:

$$q_t = \frac{1}{\Phi'\left(\frac{I_t}{K_t}\right)} = \left(\frac{I_t/K_t}{\hat{\delta}}\right)^{\frac{1}{\phi}} \tag{32}$$

where $K_t$ is the aggregate capital stock, $I_t$ is the aggregate investment, and $\delta$ is the depreciation rate of capital.

**Monetary Policy:** I impose that the Central Bank sets nominal interest rates in accordance with the Taylor rule:

$$\log \ R_t = \log \frac{1}{\beta} + \varphi_\pi \log \Pi_t + \epsilon_t^m \tag{33}$$

where the nominal interest rate is denoted by $R_t$ and the monetary policy shock as $\varepsilon^m$. The monetary policy shock follows a normal distribution: $\varepsilon^m \sim N(0, \sigma_m^2)$.

## B. Calibration

A subset of parameters employed in the model are fixed based on estimates from the literature. Parameters which are central to the model mechanism are calibrated internally. They are either estimated directly from available data or fitted to match the steady state of the model to relevant empirical moments.

**Externally fixed parameters:** In the discussion below, I briefly explain the rationale for the values used. One period in the model corresponds to a quarter. Consistent with an annual interest rate of 4%, I set the value of the discount factor $\beta$ to 0.99. The rate of capital depreciation is 0.025, a value commonly used in the literature. Similarly, in keeping with the total returns to scale of 0.85 estimated in the literature, I set the coefficient of capital to 0.21 and the coefficient of labor to 0.64. The elasticity of substitution of the final goods producer over intermediate inputs to 10, in order to match the labor share in the US [14]. The exponent of aggregate capital adjustment costs is set to 4, consistent with the range of 2 to 4 estimated in Bernanke et al. (1999). The value of the parameter $\varphi$ dictating the magnitude of price adjustment cost is set at 90 in order to match the slope of Phillips Curve estimated in Kaplan et al. (2018). Finally, I assume that the monetary authority only targets inflation, the coefficient for which in the Taylor rule is set at 1.25.

In order to set the earnings multiple $\varphi_\pi$ for the debt to earnings based covenant, I rely on empirical findings in the literature on debt covenants. This is consistent with the estimates in Lian and Ma (2021) and Drechsel (2023), who find that the value of debt to annual earning

[14] Karabarbounis and Neiman (2014)

commonly specified in covenants ranges from 3 to 4. Since my analysis is at a quarterly frequency, I set the value of the multiple $\varphi_\pi$ to 12, corresponding to an annual value of 3.

The idiosyncratic productivity shock follows a log AR(1) process as follows: $\log z' = \rho \log z + \epsilon_z$. I follow Ottonello and Winberry (2020) in setting the persistence of the productivity parameter to 0.90. The volatility of the productivity shock is calibrated internally. In addition to the idiosyncratic productivity shocks, firms in the model are also subject to an idiosyncratic delayed payment shock $\chi$, which follows an AR(1) process $\chi_{it} = \rho_\chi \chi_{i,t-1} + \epsilon_{\chi,it} X_t$. Here $\epsilon_{\chi,it}$ is independently and identically distributed, taking the values 1 and 0 with probabilities $\pi_\chi$ and $1 - \pi_\chi$ respectively. The variable $X_t$ determines the magnitude of the delayed payment shock. It is assumed to be 0 in the steady state, implying that the timing of revenue receipts and input payments is matched for the firms in the economy. I analyse the transition of the economy to the monetary policy shock and delayed payment shock at time T, implying a positive value $X_T$, and a value of 0 thereafter. I calibrate the value of $X_T$ to correspond to one standard deviation change in demeaned customer payables measure, consistent with the standardised measure used in the empirical analysis. The parameter $\rho_\chi$ is set to match the persistence of the investment response to monetary policy shocks, as shown in Figure 2.

**Internally Calibrated Parameters:** I set the values of the parameters $\{\sigma, \xi, m, k_0\}$ to match relevant moments in the data. The estimates for the empirical moments are derived from Ottonello and Winberry (2020). Through this exercise, I seek to discipline three main aspects of the model: extent of idiosyncratic risk faced by the firms, borrowing behaviour of firms, and their lifecycle dynamics. To discipline exposure to idiosyncratic risk, I match the standard deviation of investment rate estimated from Census plant level data by Cooper and Haltiwanger (2006). The moments defining the borrowing behaviour of firms in the model consist of the mean gross leverage ratio and the fraction of firms in the economy with positive debt, with both estimates derived from Crouzet and Mehrotra (2020). Finally, in order to discipline the lifecycle dynamics, I target share of employment across firms partitioned on the basis of age. I consider three buckets: firms less than 1 years old, firms between 1 and 10 years old, and firms greater than 10 years old.

In Table X, I compare the predictions of the model to the target estimated moments from the data. Firms in the model are slightly more exposed to idiosyncratic risk, as evident from the higher volatility of investment rates. They are more leveraged than the sample of firms considered in the data, with a lower fraction having positive debt. Finally, the model predicts a higher share of employment in the bracket of firms aged 1 to 10, which implies a somewhat faster rate of growth as compared to the data. Notwithstanding, across all the

**Table IX. Calibration**

| Parameter | Description | Value |
|---|---|---|
| Household | | |
| $\beta$ | Discount Rate | 0.99 |
| Firms | | |
| $\nu$ | Labour Coefficient | 0.64 |
| $\alpha$ | Capital Coefficient | 0.21 |
| $\delta$ | Depreciation | 0.025 |
| New Keynesian Block | | |
| $\phi$ | Aggregate capital AC | 4 |
| $\gamma$ | Demand elasticity | 10 |
| $\Phi_{\Pi}$ | Taylor rule coefficient | 1.25 |
| $\varphi$ | Price adjustment cost | 90 |
| Idiosyncratic Shock Processes | | |
| $\rho$ | Persistence of TFP (fixed) | 0.90 |
| $\sigma$ | SD of innovations to TFP | 0.03 |
| Delayed payment shock | | |
| $X_T$ | Delayed payment magnitude | 0.25 |
| $\rho_{\chi}$ | Persistence | 0.95 |
| Financial Frictions | | |
| $\varphi_{\pi}$ | Debt to quarterly EBITDA ratio | 12 |
| Firm Lifecycle | | |
| m | Mean shift of entrants' prod | 3.12 |
| $k_0$ | Initial capital | 0.18 |
| $\pi_d$ | Exogenous exit rate | 0.02 |

targets considered, the estimates from the model do a reasonably good job of matching the estimated moments. Moreover, the model predictions also match closely to those in other prominent works in the literature (Ottonello and Winberry, 2020).

**Table X. Data and Model**

| Moment | Description | Data | Model |
|---|---|---|---|
| Investment behaviour (annual) | | | |
| $\sigma(\frac{i}{k})$ | SD investment rate | 0.33 | 0.36 |
| Finance behaviour (annual) | | | |
| $\mathbb{E}[\frac{b}{k}]$ | Mean gross leverage ratio | 0.34 | 0.35 |
| Frac(b>0) | Firms w/ positive debt | 0.81 | 0.57 |
| Firm Growth (annual) | | | |
| $\mathrm{N}_1/N$ | Share of employment in age $\leq 1$ | 0.03 | 0.03 |
| $\mathrm{N}_{1-10}/N$ | Share of employment in age $\in$ (1,10) | 0.21 | 0.50 |
| $\mathrm{N}_{11+}/N$ | Share of employment in age $\geq 10$ | 0.76 | 0.47 |

# VI. Monetary Policy Analysis

In the following section, I examine the transition path of the economy, initially at steady state, in response to simultaneous monetary policy and delayed payment shocks. The objective is to study the heterogeneous response of firms to a monetary policy shock conditional on the realisation of the delayed payment shock. I begin by studying the heterogeneity in impact response of investment and market value of firms in the model to monetary policy shocks. I show that the model simulated results are both qualitatively and quantitatively similar to the values obtained in the empirical analysis. Next, I examine the heterogeneity in dynamic investment response to monetary policy shocks. I find that the model performs well in matching the magnitude and persistence of the empirical results. Finally, I examine aggregate investment response of an economy subject to significant payment delays, as experienced in recent times, to a counterfactual economy which is not subject to delayed payments. I find that delayed payments significantly dampen the aggregate investment response to monetary policy shocks.

## A. Heterogeneous Response to Monetary Policy

I employ the model to examine the relevance of delayed payments for firm level investment response to a monetary policy shock. The objective is to estimate the value of the coefficient $\beta_1$ from the Equation 2 using model simulated data, $\Delta \log k_{it} = \alpha_i + \alpha_j + \alpha_{st} + \beta_1 (cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_2 cp_{it-1} + (\Gamma_1' + \epsilon_t^m \Gamma_2') Z_{it-1} + e_{it}$. Note that there exists a sample selection bias in the empirical results on account of the inclusion of only public firms in Compustat. I address this by evaluating the model simulated responses of firms which are as old as the average firm in the Compustat sample.

In replicating the empirical results on heterogeneous investment responses discussed in the previous sections, we must note that the specification accounts for the variation in firm-level investment response conditional on delayed payments with and without the monetary policy shock. This implies that in order to identify the coefficient $\beta_1$ using model simulated data, we need to compare the investment response of the economy with both monetary and delayed payments shocks to the response of a counterfactual with *only* the delayed payment shock. If we denote $k'_{MP,\chi}$ as the capital choice with both shocks, $k'_{\chi}$ as the capital choice with only the delayed payment shock, and $k'_{SS}$ as the steady state level of capital, then the heterogeneous response to monetary policy we seek to measure is: $\left(k'_{MP,\chi} - k'_{SS}\right) - \left(k'_{\chi} - k'_{SS}\right)$. In order to derive the coefficient, I combine two panels: one subject to both monetary policy shock and delayed payment shock at time t, and another subject to only delayed payment shock at time t. Using this combined panel, I estimate the following regressions using model simulated data from t-4 to t+12[15]:

$$\Delta \log\, k_{it} = \alpha_i + \alpha_t + \beta_1\ (\chi_{it}\epsilon_t^m) + \beta_2\ \chi_{it} + e_{it} \tag{34}$$

There are two key differences between this specification and the one in Equation 2. First, this does not include customer fixed effects, since they are not modelled explicitly. Second, the model specification only includes time fixed effects and not sector-time fixed effects employed in the empirical specification. This is because the model only includes a single sector. In the future, the model could be extended to account for inter-sectoral differences. The delayed payment $\chi_{it}$ directly corresponds to the inter-firm variation in customer payables $(cp_{it-1} - E_i[cp_{it}])$.

Similar to the analysis of investment response, I also examine the heterogeneity in stock price response of firms using model simulated data. While the model does not feature a direct measure of stock prices, I employ the value of a firm, which is the present discounted value of future dividends, as the proxy for stock prices. Variations in the stock price in response to monetary policy shocks should reflect changes in the value of the firm:

$$\Delta V_{it} = \alpha_i + \alpha_t + \beta_1\ (\chi_{it}\epsilon_t^m) + \beta_2\ \chi_{it} + e_{it} \tag{35}$$

[15] Note that the choice of the number of quarters included before the shocks at time t is not important for the results. I set this interval based on Ottonello and Winberry (2020)

where $\Delta V_{it} = \frac{V_{it}-V_{it-1}}{V_{it-1}} \times 100$, $V_{it}$ is the value of firm $i$ at time $t$, and other notations follow the description in Equation 34.

The heterogeneity in impact response of investment and stock prices to monetary policy shock as compared to the data is shown in Table XI. We find that impact response of investment to monetary policy shocks is stronger than that observed in the data. This is not surprising because of the borrowing constraint assumed in the model $b' \leq \phi_\pi[\pi_{t+1}|z'_{min}]$. Greenwald (2019) highlights that most lending covenants specify the maximum debt limit with respect to the four quarter moving average of a firm's cash flows. This implies that variation in cash flows in response to monetary policy should loosen the borrowing constraint of a firm with a lag, which is what we observe in the data. In the model, I specify the borrowing constraint as a function of only the cash flows in the current period since introducing lags of cash flows would significantly complicate the computation. This can rationalise the stronger impact response of investment to monetary policy shocks in the model. Consistent with the investment response, there is significant heterogeneity in stock price response in the model. The magnitude is lower than that observed in the data, since there are other potential channels not explicitly modelled which may further weaken the stock price response to monetary policy shocks.

In order to analyse the dynamic response of investment to a monetary policy shock, I employ the following specification:

$$\text{log}k_{it+h} - \text{log}k_{it-1} = \alpha_{ih} + \alpha_{th} + \beta_{1h}\ (\chi_{ith}\epsilon_t^m) + \beta_{2h}\ \chi_{ith} + e_{ith} \tag{36}$$

The results for this specification are shown in Figure 9. The model performs well in replicating both the persistence and magnitude of heterogeneity in investment response of firms. The response of the model mostly remains within the 90% confidence intervals of the data up to 12 quarters after the realization of the shocks. Consistent with a standard monetary policy shock lasting up to 8 quarters[16], as shown in Figure 10, the heterogeneity in capital accumulation increases up to 8 quarters both in the model as well as the data.

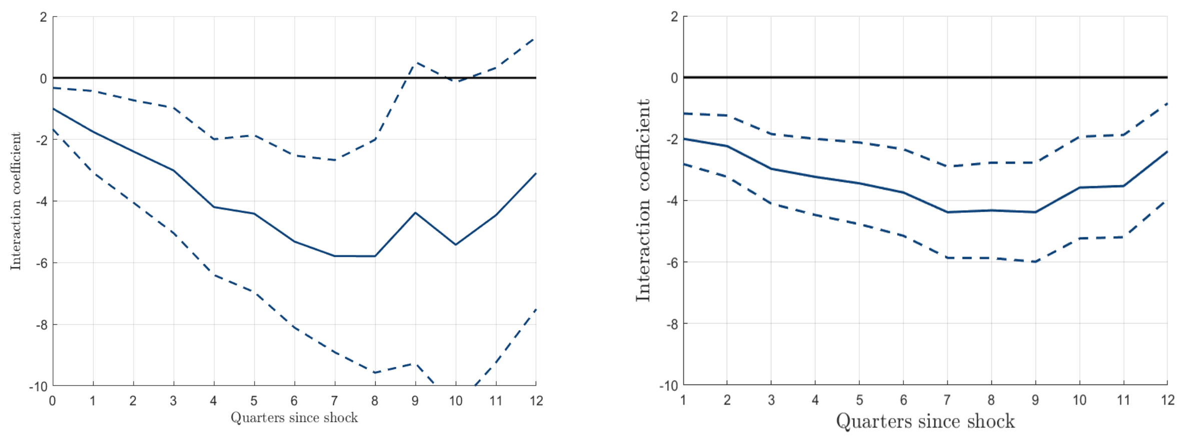
[16]This is the standard specification of monetary policy shocks considered in the literature(Ottonello and Winberry, 2020; Jeenas, 2019).

**Table XI. Empirical Results: Data & Model**

| | Investment Response | | Stock Price Response | |
|---|---|---|---|---|
| | Data | Model | Data | Model |
| Customer Payable × FFR Shock | -1.00** | -1.99*** | -0.63** | -0.32*** |
| | (0.42) | (0.50) | (0.29) | (0.08) |
| $R^2$ | 0.251 | 0.744 | 0.100 | 0.086 |
| Firm FE | yes | yes | yes | yes |
| Time FE | yes | yes | yes | yes |

Notes: Results for the estimated coefficient $\beta_1$ from the specifications 2, 34, 4, and 35, respectively. Standard errors are two-way clustered by firm and time. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. Standard errors in parentheses.

**Figure 9. Heterogeneous Dynamic Investment Response: Data and Model**




(a) Data (b) Model

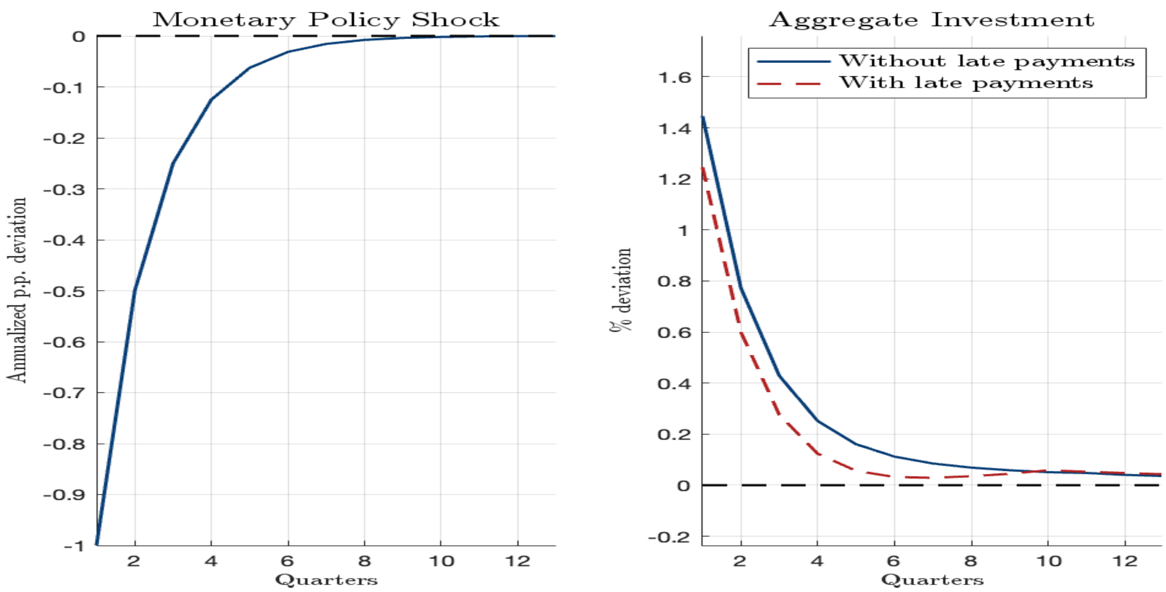
Notes: Results for the estimated coefficient $\beta_{1h}$ from the specifications 3 and 36. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardize $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Dashed lines report 90% error bands.

## B. Policy Experiment

In this section, I study the relevance of delayed payments for aggregate investment response to monetary policy shocks. Following survey evidence from the COVID episode (Atradius, 2023), I calibrate the fraction of firms in the economy subject to delayed payments to 0.5.

Consistent with the evidence on the average duration of delays, I calibrate the magnitude of the delayed payment shock to correspond to a two week payment delay. I assume that this delayed payment shock follows an AR1 process and lasts up to 2 years, based on the duration of the COVID episode. I compare the aggregate investment response of this economy to a counterfactual case economy which is not subject to this delayed payment shock.

**Figure 10. Aggregate Investment Response**




Notes: The dashed line red line shows the aggregate investment response to a monetary policy shock with delayed payments and the solid blue line depicts the aggregate response in the absence of delayed payments.

The results are shown in Figure 10. I find that the aggregate investment response is approximately 17% weaker on impact in an economy subject to delayed payments as compared to a counterfactual economy not subject to delayed payments. This result highlights the quantitative relevance of delayed payments in supply chains. It implies that in the presence of significant payment delays, stronger interventions in policy rates are necessary to bring inflation back to target.

# VII. Conclusion

This paper studies the role of firms' operating cash flows for the transmission of monetary policy. In order to isolate the role of operating cash flows from that of underlying demand, I rely on delayed payments in supply chains. I provide evidence for the relevance of operating cash flows in monetary policy transmission by showing that delayed payments have a significant impact on the investment response of firms. I utilise two distinct empirical approaches as evidence. First, I use panel regressions to study the heterogeneity in investment response to monetary policy shocks. I show that delayed payments dampen the investment response as well as the high frequency stock price response of firms to monetary policy shocks. Second, I examine the impact of a reform which accelerated payments to a subset of suppliers in the economy on the transmission of monetary policy. I use a triple difference specification for this analysis, with the hypothesis that treated firms which observe a decline in delayed payments should respond more to monetary policy shocks after the reform. I find evidence consistent with this hypothesis for both the investment response of firms as well as the stock price response. This natural experiment addresses potential identification concerns with the first approach.

A key determinant of these results is the impact of delayed payments on the borrowing constraints faced by the suppliers. Since a majority of US loans are characterised by cash flow based covenants, a deterioration in operating cash flows on account of delayed payments has a significant impact on a firm's ability to borrow. Using balance sheet and granular loan level data, I show that suppliers exposed to delayed payments for their intermediate inputs face tighter borrowing constraints, as measured through loan amounts and spreads. Tighter borrowing constraints limit the ability of firms to finance additional investment expenditure in response to monetary policy shock. Consistent with the proposed mechanism, I find that delayed payments weaken firms' response of operating cash flows and borrowing to monetary policy.

Based on this mechanism, I develop a heterogeneous firm New Keynesian model to rationalise the empirical findings and derive aggregate quantitative implications of delayed payments for monetary policy. Calibrating the model to match relevant moments in the data, I show that the model is successful in replicating the persistence and magnitude of heterogeneity in investment response. Finally, simulating the steep deterioration in payment behaviour during COVID-19, I find that the response of aggregate investment to a monetary policy shock is 17% weaker than it would be in the absence of delayed payments, highlighting the quantitative relevance of the proposed channel. As next steps, I seek to study the implications of these findings for cross-border transmission of US monetary policy. Extending the findings of this paper to cross-border trade is important because delayed payments are even more widespread in these transactions, particularly those involving emerging or lower income economies.

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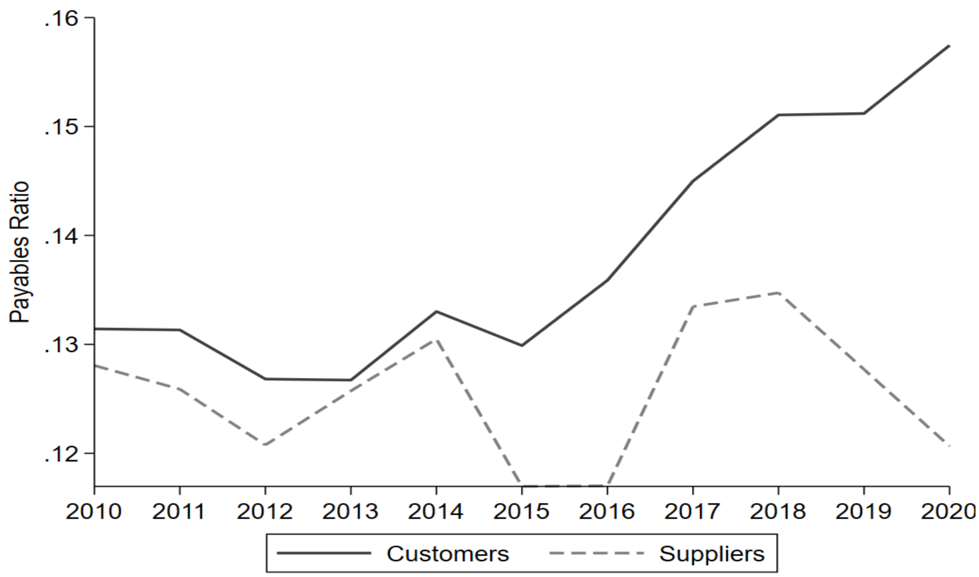
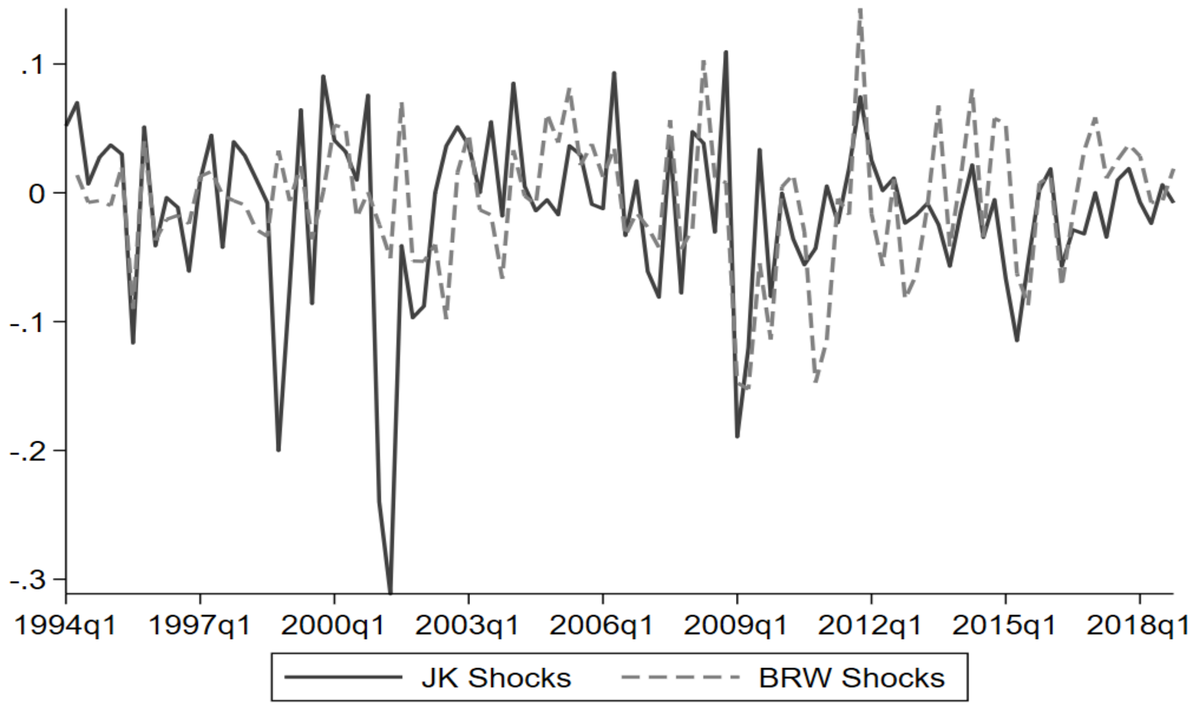
# Online Appendix

## A. Payment Behaviour of Suppliers and Major Customers in the Compustat Sample




Notes: Median payment behaviour of US suppliers and major customers in the Compustat sample. Solid black line shows the accounts payable to COGS ratio for major customers, while the dashed grey line shows the accounts payable to COGS ratio for the suppliers.

## B. Monetary Policy Shocks




This figure shows the monetary policy shocks used for the analysis in this paper. The solid black line depicts the monetary policy shocks derived in Jarociński and Karadi (2020) and the dashed grey line depicts the monetary policy shocks derived in Bu et al. (2021). The units are in percentage points.

## C. Private equity and delayed payments

It is useful to discuss potential reasons for the sharp recent rise in payment delays by large US firms shown in Figure 1. I propose that increased private equity activity in the recent years may be one of the driving factors behind this change. Transactions such as leveraged buyouts, management buyouts, and private placements are financed primarily through debt. Private equity investors rely on cash flows from these investments to service this debt. Therefore, optimisation of firm cash flows is one of the core tenets of private equity. This was observed in the case of 3G Capital, which purchased Anheuser-Busch in 2008. According to a report in NYtimes[17], Anheuser-Busch extended its payment terms to 120 days after this acquisition. Similar instances of extended payment terms after leveraged buyouts have been reported in Europe[18]. Given the aggressive cash management policies of PE firms, even public firms tend to follow suit in extending payment terms so as not to be at a competitive disadvantage. In a letter to suppliers on 5th April 2013, the CEO of Procter & Gamble wrote the following: "Through an extensive analysis we have determined that in order to remain competitive, reflect current industry standards, and drive world-class growth, we need to change our payment terms", which reflects the need to match the payment terms of other firms in their industry.

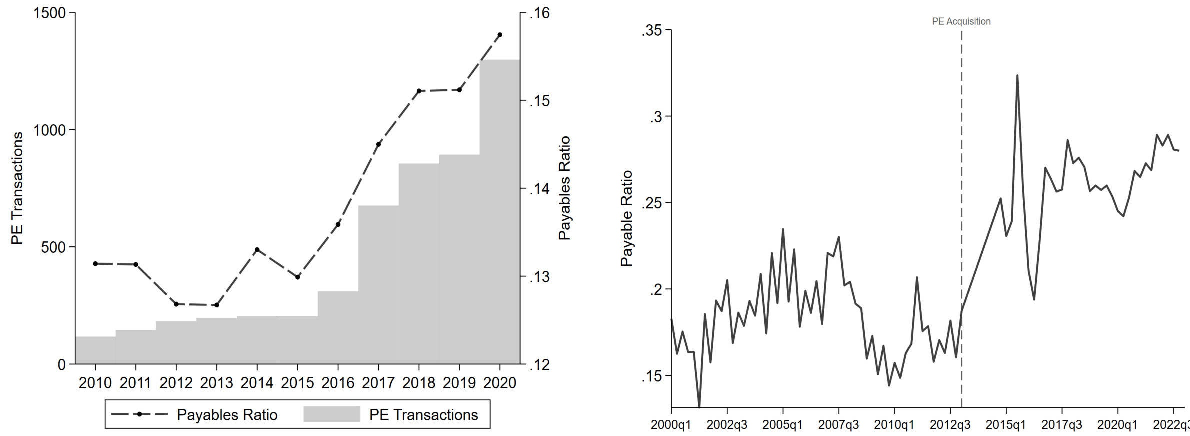
Given the importance of these firms in the supply chain and the associated bargaining power, suppliers are left with little choice but to accept the revised terms. In this paper, I provide preliminary evidence that the aggregate rise in delayed payments is strongly correslowd with the rise in private equity transactions. I collect a sample of private equity deals from Capital IQ by searching for events which include the terms "going private", "leveraged buyout", or "management buyout". Following Bernstein et al. (2020), I exclude "growth buyouts," "venture capital," and "expansion capital" investments as these deals usually involve little to no leverage.

Figure 11a shows the correlation between delayed payment behaviour and the number of private equity transactions by year. We find that the sharp rise in private equity post 2015 is associated with a corresponding rise in delayed payments. In Figure 11b, I provide a representative example of this link by plotting the payable ratio for The Kraft Heinz Company. HJ Heinz was acquired by 3G Capital and Berkshire Hathaway in 2013 in a deal valuing $23 billion dollars and subsequently merged with Kraft Foods Group Inc to create one of the largest North American food companies. After the acquisition, payable ratio increases

[17] https://www.nytimes.com/2015/04/07/business/big-companies-pay-slowr-squeezing-their-suppliers.html

[18] https://www.ft.com/content/15ce002a-9ffd-11e4-9a74-00144feab7de

## Figure 11. Private equity and payment behaviour




(a) PE transactions and payable ratio

(b) Kraft Heinz Company

Notes: Left panel shows the ratio of accounts payable to COGS alongside the total number of Private Equity transactions by year. Private equity refers to leveraged buyouts, management buyouts, and private placements, excluding growth buyouts, venture capital, and expansion capital since these include little to no leverage. Right panel shows that ratio of accounts payable to COGS for 'The Kraft Heinz Company' along with the timing of its acquisition by 3G Capital and Berkshire Hathaway. Due to missing data for Kraft Heinz immediately after acquisition, payable ratio from 2013 Q2 to 2014 Q3 is imputed.

by close to 10 percentage points.

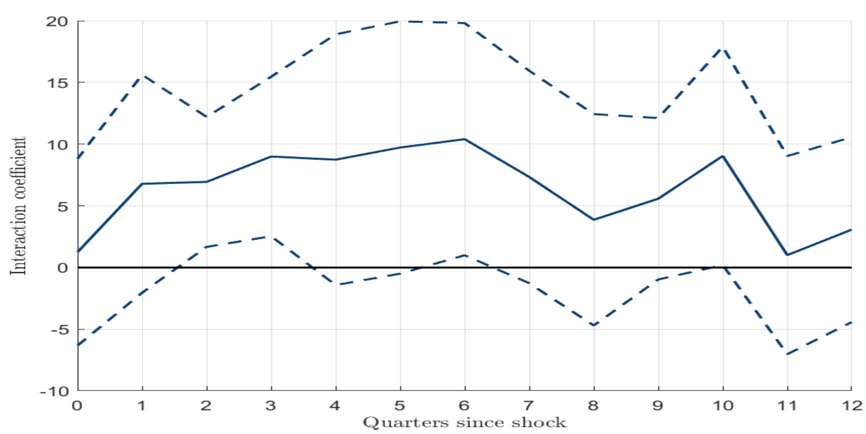
## D. Delayed payments and share repurchases

I show in Figure 4 that customers with varying payment behaviours do not exhibit heterogeneity in investment response to monetary policy. This raises the question of how the additional cash generated through delayed payments is employed by the customers. In this section, I propose that customers use the additional cash to carry out share repurchases. This is consistent with recent evidence on the sharp rise in share repurchases (Aramonte, 2020). In this section, I examine whther customers delaying payments to their suppliers show stronger response of share repurchases to monetary policy. I employ the following regression specification:

$$sh_{it+h} - sh_{it-1} = \alpha_{ih} + \alpha_{sth} + \beta_{1h}(pay_{it-1} - E_i[pay_{it}])\epsilon_t^m + \beta_{2h} pay_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h}) Z_{it-1} + e_{ith} \quad (37)$$

where $sh_{it+h}$ denotes the share repurchases for firm i at time horizon t+h, while the rest of the notations follow the description in Equation 7. The results for this are shown in Figure 12

**Figure 12. Heterogeneous Dynamic Response of Share Repurchases**




Notes: Reports the coefficient $\beta_{1h}$ over quarters 0 to 12 for the specification $sh_{it+h} - sh_{it-1} = \alpha_{ih} + \alpha_{sth} + \beta_{1h}(pay_{it-1} - E_i[pay_{it}])\epsilon_t^m + \beta_{2h} pay_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h}) Z_{it-1} + e_{ith}$, where $sh_{it+h}$ denotes share repurchases of firm i in period t+h, $\alpha_{ih}$ is a firm fixed effect, $\alpha_{jh}$ is a customer fixed effect, $\alpha_{sth}$ is a sector-by-quarter fixed effect, $pay_{it-1} - E_i[pay_{it}]$ is the demeaned measure of payables to COGS ratio, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls containing demeaned leverage, default probability, sales growth, size, and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardize $pay_{it-1} - E_i[pay_{it}]$ over the entire sample. Dashed lines report 90% error bands.

# E. Model

## E.1. Equilibrium:

**Distribution of firms:** The distribution of firms $\mu_t(z,k,b,\chi)$ evolves in the following way:

$$
\begin{aligned}
\mu_{t+1}(z',k',b',\chi') = & \int (1-\pi_d)\mathbb{1}\{k_t'(z,n_t(z,k,b,\chi)) = k'\} \\
& \times \mathbb{1}\Big\{\frac{b_t'(z,n_t(z,k,b,\chi))}{\Pi_{t+1}} = b'\Big\} p(\varepsilon | e^{\rho \log z + \varepsilon} = z') p(\varepsilon_\chi | \rho_\chi \chi + \varepsilon_\chi X = \chi') d\varepsilon d\varepsilon_\chi d\mu_t(z,k,b,\chi) \\
& + \overline{\mu}_t \int (1-\pi_d)\mathbb{1}\{k_t'(z,n_t(z,k_0,0,\chi)) = k'\} \\
& \times \mathbb{1}\Big\{\frac{b_t'(z,n_t(z,k_0,0,\chi))}{\Pi_{t+1}} = b'\Big\} p(\varepsilon | e^{\rho \log z + \varepsilon} = z') p(\varepsilon_\chi | \rho_\chi \chi + \varepsilon_\chi X = \chi') d\varepsilon d\varepsilon_\chi d\mu_t^{ent}(z,k_0,0,\chi)
\end{aligned}
\tag{38}
$$

where $p(\varepsilon | e^{\rho \log z + \varepsilon} = z')$ is the density of draws of $\varepsilon$ for which $e^{\rho \log z + \varepsilon} = z'$, while $p(\varepsilon_\chi | \rho_\chi \chi + \varepsilon_\chi X = \chi')$ is the density of draws of $\varepsilon_\chi$ for which $\rho_\chi \chi + \varepsilon_\chi X = \chi'$. Note that parameter defining the magnitude of the delayed payment shock $X$ is 0 in steady state and takes a positive value for the period in which the monetary policy shock is realized.

**Equilibrium Definition:** Given an initial distribution of firms $\mu_0$, a perfect foresight equilibrium is given by the set of functions, quantities, and price paths $V_{0,t}(z,n,\chi), n_t(z,n,\chi), k_t'(z,n,\chi), b_t'(z$ $\mu_t(z,n,\chi), c_t, l_t, \lambda_{t+1}(z',n',\chi')$, such that:

1. Production firms optimization: $v_t(z,n,\chi)$ solves 13-15 with decision rules for investment $k_t'(z,n,\chi)$ and financing $b_t'(z,n,\chi)$
2. The financial intermediary earns zero profits, solving 28 while satisfying 29
3. New Keynesian Block: Retailers and final good producers generate NK Phillips Curve. The prices $p_t$, $q_t$, and $\Pi_t$ satisfy 30 and 32
4. The distribution of firms evolves according to 38
5. Monetary authority follows Taylor rule $\log R_t^{nom} = \log\frac{1}{\beta} + \varphi_\pi \log(1+\pi_t) + \epsilon_t^m$
6. Household chooses labor supply $N_t$ and generates SDF: $\Lambda_{t+1} = \beta\frac{C_t}{C_{t+1}}$. The wages satisfy $w_t = \Psi C_t$.
7. Market Clearing: Aggregate investment is characterized by $K_{t+1} = \Phi\big(\frac{I_t}{K_t}\big)K_t + (1-\delta)K_t - (1-(1-\delta))k_0\overline{\mu}_t$, where $K_t = \int k d\mu_t(z,k,b,\chi)$, and aggregate consumption is defined by $C_t = Y_t - I_t$.

### E.2. Transition Path

In this section, I briefly describe my approach to solving the perfect foresight transition path of the economy in response to the monetary policy and delayed payment shocks. The economy starts from a stationary distribution, which is then subject to a sequence of monetary policy shocks, modelled as innovations to the Taylor Rule, $\varepsilon = (\varepsilon_0, ...., \varepsilon_T)'$, and a sequence of delayed payment shocks affecting a fraction of firms in the economy $\chi = (\chi_0, ...., \chi_T)'$. Following Ottonello and Winberry (2020), I characterize the equilibrium of the model as a system of equations which are expressed as a function of two prices: the price of capital $\mathbf{q} = (q_0, ...., q_T)'$ and the marginal utility of consumption $\lambda = (\lambda_0, ...., \lambda_T)'$, where $\lambda = \frac{1}{C_t}$. Denoting $\mathbf{p} = (\mathbf{q;}\lambda)$ as the 2T $\times$ 1 vector of the two price sequences, the market clearing conditions can then be expressed as function of this vector.

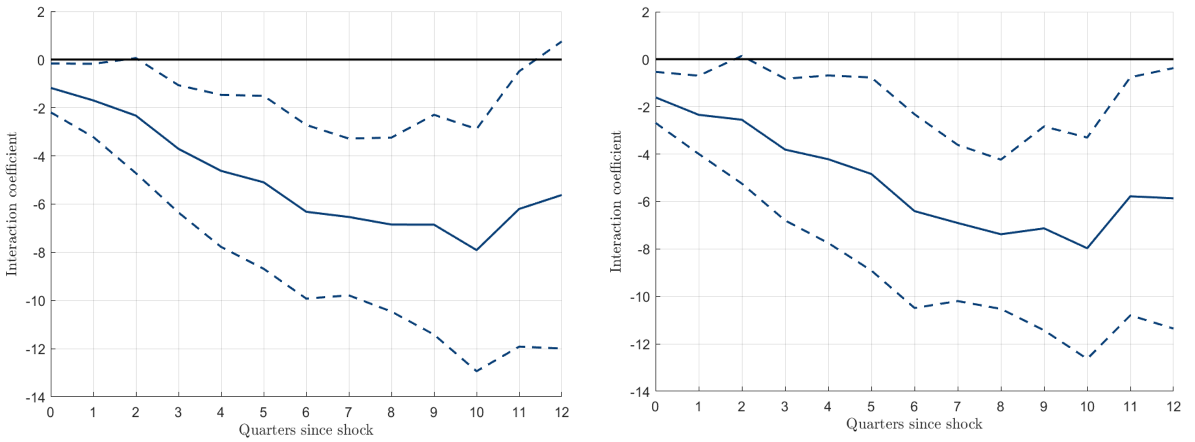
$$F(\mathbf{p}; \varepsilon, \chi) = 0 \tag{39}$$

In order to solve for the transition path, I guess a path for price of capital q and marginal utility of consumption $\lambda$. Given this guess, I obtain the sequence of inflation, nominal interest rate, real interest rate, and the intermediate input price. Having obtained all the relevant prices for the model, I solve for a firm's value function and decision rules using backward iteration. Finally, I use the decision rules to compute the distribution of firms in the economy and the aggregate variables. The final system of equations needs to satisfy Equation 39. In order to achieve this, I generate the next iteration of prices using Quasi-Newton method

$$\mathbf{p}^{(n+1)} = \hat{F}_1(\mathbf{p}^{(n)}; \varepsilon, \chi)^{-1} F(\mathbf{p}^{(n)}; \varepsilon, \chi) \tag{40}$$

. where $\hat{F}_1(\mathbf{p}^{(n)}; \varepsilon, \chi)$ is an approximation of the 2T$\times$2T Jacobian matrix of the market clearing conditions. Under the Quasi-Newton method, this approximation is obtained by deriving the Jacobian matrix for the representative firm model. I iterate over the above steps until the market clearing condition is satisfied.

## F. Granular Industry Classifications

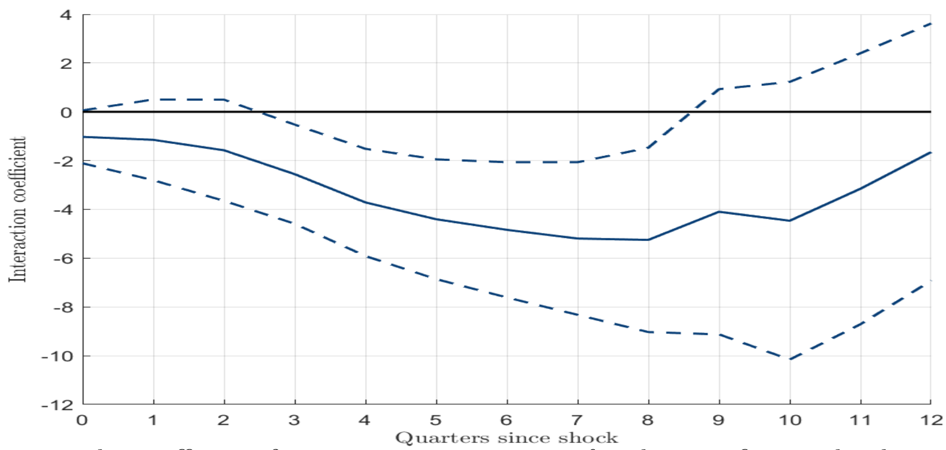



(a) 3-digit NAICS

(b) 4-digit NAICS

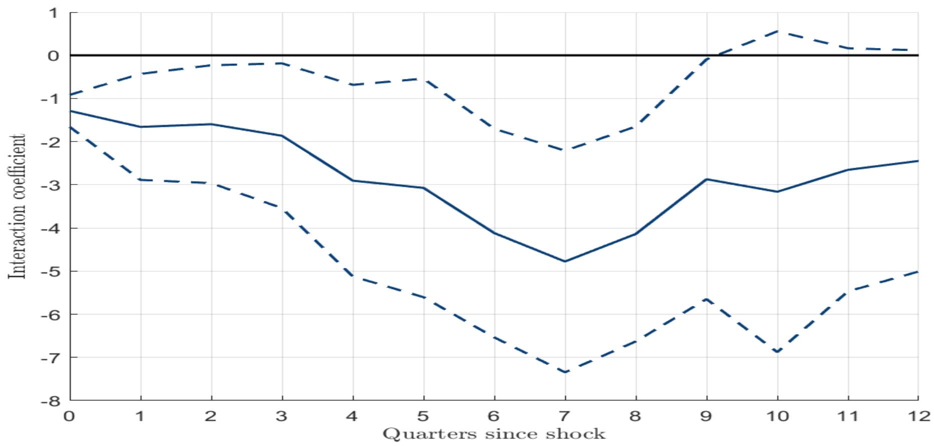
Notes: Reports the coefficient $\beta_{1h}$ over quarters 0 to 12 for the specification $\log k_{it+h} - \log k_{it} = \alpha_{ih} + \alpha_{jh} + \alpha_{sth} + \beta_{1h}(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_{2h}cp_{it-1} + (\Gamma'_{1h} + \epsilon_t^m \Gamma'_{2h})Z_{it-1} + e_{ith}$, where y is the capital stock, $\alpha_{ih}$ is a firm fixed effect, $\alpha_{jh}$ is a customer fixed effect, $\alpha_{sth}$ is a sector-by-quarter fixed effect, $cp_{it-1} - E_i[cp_{it}]$ is the demeaned measure of customer payables, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls containing demeaned leverage, default probability, sales growth, size, and an indicator for fiscal quarter. The left panel uses 3 digit NAICS classification of industries for the industry fixed effects while the right panel uses the 4 digit classification. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardise $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Dashed lines report 90% error bands.

## G. Heterogeneous Investment Response to BRW Shocks (Bu et al., 2021)




Notes: Reports the coefficient $\beta_{1h}$ over quarters 0 to 12 for the specification $\log k_{it+h} - \log k_{it} = \alpha_{ih} + \alpha_{jh} + \alpha_{sth} + \beta_{1h}(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_{2h}cp_{it-1} + (\Gamma'_{1h} + \epsilon_t^m\Gamma'_{2h})Z_{it-1} + e_{ith}$, where y is the capital stock, $\alpha_{ih}$ is a firm fixed effect, $\alpha_{jh}$ is a customer fixed effect, $\alpha_{sth}$ is a sector-by-quarter fixed effect, $cp_{it-1} - E_i[cp_{it}]$ is the demeaned measure of customer payables, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls containing demeaned leverage, default probability, sales growth, size, and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardise $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Dashed lines report 90% error bands.

## H. Heterogeneous Investment Response 1990-2020 Sample




Notes: Reports the coefficient $\beta_{1h}$ over quarters 0 to 12 for the specification $\log k_{it+h} - \log k_{it} = \alpha_{ih} + \alpha_{jh} + \alpha_{sth} + \beta_{1h}(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_{2h}cp_{it-1} + (\Gamma'_{1h} + \epsilon_t^m\Gamma'_{2h})Z_{it-1} + e_{ith}$, where y is the capital stock, $\alpha_{ih}$ is a firm fixed effect, $\alpha_{jh}$ is a customer fixed effect, $\alpha_{sth}$ is a sector-by-quarter fixed effect, $cp_{it-1} - E_i[cp_{it}]$ is the demeaned measure of customer payables, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls containing demeaned leverage, default probability, sales growth, size, and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and quarter. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I standardise $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Dashed lines report 90% error bands.

## I. Heterogeneous Response of Stock Prices to Monetary Policy: One-day Window

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Customer Payable × FFR shock | -0.23 | -0.45** | -0.28* | -0.40** |
| | (0.20) | (0.20) | (0.15) | (0.16) |
| MP shock | 6.13*** | | | |
| | (1.45) | | | |
| Observations | 56619 | 56619 | 56619 | 56619 |
| $R^2$ | 0.042 | 0.088 | 0.058 | 0.090 |
| Sector-Date FE | no | yes | yes | yes |
| Firm Controls | yes | no | yes | yes |
| Firm FE | yes | yes | no | yes |
| Buyer FE | yes | yes | no | yes |

Notes: Results from estimating $\Delta p_{it} = \alpha_i + \alpha_j + \alpha_{st} + \beta(cp_{it-1} - E_i[cp_{it}])\epsilon_t^m + \beta_2 cp_{it-1} + (\Gamma_1' + \epsilon_t^m \Gamma_2')Z_{it-1} + e_{it}$, where $\Delta p_{it}$ refers to stock returns on the day of the FOMC announcement, $\alpha_i$ is a firm fixed effect, $\alpha_j$ is a customer fixed effect, $\alpha_{st}$ is a sector-by-quarter fixed effect, $cp_{it-1} - E_i[cp_{it}]$ is the demeaned measure of customer payable, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls consisting of uninteracted customer payabale, default risk of the supplier along with its interaction with monetary shock, sales growth, size, and an indicator for fiscal quarter. Standard errors are two-way clustered by firms and date. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. I have standardised $cp_{it-1} - E_i[cp_{it}]$ over the entire sample. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

## J. Impact of Quickpay Reform on Stock Price Response

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| $\mathbb{1}\{QP\} \times$ MP shock $\times$ $\mathbb{1}\{Post\}$ | 24.58 | 52.68** | 52.90** | 53.96** |
| | (21.45) | (23.02) | (21.88) | (21.76) |
| Observations | 71897 | 71897 | 71897 | 71897 |
| $R^2$ | 0.178 | 0.073 | 0.141 | 0.180 |
| Firm controls | no | yes | yes | yes |
| Sector-Date FE | yes | no | yes | yes |
| Firm FE | yes | yes | no | yes |

Notes: Results from estimating $\Delta p_{it} = \alpha_i + \alpha_{st} + \beta_1 \ \mathbb{1}\{QP\} * \epsilon_t^m * \mathbb{1}\{Post\} + \Gamma' Z_{it-1} + e_{it}$ where $\Delta p_{it}$ refers to stock returns in percentages, $\alpha_i$ is a firm fixed effect, $\alpha_{st}$ is a sector-by-quarter fixed effect, $\mathbb{1}\{QP\}$ is a dummy variable which takes the value of 1 for treated firms and 0 for control firms, 1{Post} is a dummy variable which takes the value 1 for quarters after the reform and 0 for the quarters before, $\epsilon_t^m$ is the monetary shock, and $Z_{it-1}$ is a vector of firm-level controls consisting of uninteracted terms, (log) size, and leverage, with each control also interacted with the post dummy and the monetary policy shock. Standard errors are two-way clustered by firms and date. I normalise the sign of the monetary shock $\epsilon_t^m$ so that a positive shock corresponds to a decrease in interest rates. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

## K. Data Construction

In this section, I explain the steps undertaken in constructing the sample used in this paper. I begin by explaining the criteria for inclusion of a Compustat firm in the sample, and then explain how the variables used in the analysis are constructed.

**Sample Selection-** I use the firm-quarter level sample from Compustat and exclude the firms which:

1. Firms not incorporated in the United States
2. Firms without a major customer or firms which do not specify the value of bilateral sales to the customers. The latter step is important because some firms disclose the identity of non-major customers as well. When bilateral sales information is not available, it is impossible to distinguish between major and non-major customers. In order to ensure comparison between otherwise similar customers, I drop firms which do not provide any bilateral sales information.
3. Firms belonging to finance or insurance sector with SIC between 6000 and 6799, and firms belonging to the utilities sector with SIC codes between 4900 and 4999.
4. I exclude firms-quarter observations which satisfy any one of these conditions:
   - Negative physical capital or total assets
   - Acquisitions exceeding 5% of total assets
   - Available spell of investment less than 40 quarters
   - Outlier investment behaviour in the top or bottom 0.5% of distribution
   - Negative leverage or leverage exceeding 10
   - Negative liquidity or sales
   - Ratio of net current assets to total assets $\notin [-10, 10]$

Consistent with Ottonello and Winberry (2020), I also exclude the subsequent quarters for the firms which satisfy any of these conditions. All relevant dependant and explanatory variables used in the empirical analysis are winsorized at the top 0.5% and the bottom 0.5% of their distributions. The sample begins from 1990, but since formal FOMC announcements were initiated in 1994, I consider that as the starting year for the main results in the paper.

**Variable Construction-** The raw data for the constructed variables is obtained from Compustat (including Customer Segment):

1. Investment $I_t$ is defined as the accumulation of capital $\Delta\log\,(k_{t+1})$, where $k_{t+1}$ denotes the stock of capital at the end of period t+1. Following Ottonello and Winberry (2020), I consider the beginning value of capital stock as the variable PPEGTQ, which denotes gross plant, property, and equipment of a firm. Beyond the first period, I measure inflation as the log change in the variable PPENTQ, which denotes the net plant, property, and equipment of a firm. This variable deducts depreciation and is significantly better populated than the gross measure of capital stock. In case a value for capital stock is missing, I linearly interpolate it based on the preceding and subsequent values of capital stock. The underlying logic for this is that capital stock is a slow moving variable, and hence linear interpolation should provide a good approximation. However, if either the preceding or succeeding value is also missing, I do not carry out any interpolation.
2. Payables: The payment behaviour of customers is measured as the ratio of accounts payable (APQ in Compustat) to cost of goods sold (COGSQ in Compustat) $p_j = \frac{AP_j}{COGS_j}$
3. Customer Payables: For each supplier, customer payables is constructed as the weighted average of the payables of each major customer: $cp_i = \frac{1}{n}\sum_{j=1}^{n}(\%Sales_{ij} \times p_j)$
4. Operating Cash flows: The measure of operating cash flows in Compustat (OANCFY) is recorded on an year-to-date basis. Therefore, I convert it into a quarterly measure as follows: For the first quarter of each year, quarterly operating cash flows OANCFQ = OANCFY. For the subsequent quarters, the debt issuance can be measured as OANCFQ = OANCFY - L.OANCFY.
5. Net Debt Issuance: The net debt issuance is computed as the difference between debt issuance and debt reduction. Debt issuance is measured using the variable DLTISY from Compustat. Since this measure is recorded on an year to date basis, we first need to convert it to the quarterly frequency. For the first quarter of each year, quarterly debt issuance = DLTISY. For the subsequent quarters, the debt issuance can be measured as DLTISQ = DLTISY - L.DLTISY. This similarly holds for the computation of the quarterly measure of debt reduction DLTRQ = DLTRY - L.DLTRY. Finally, the net debt issuance is computed as the difference between debt issuance and debt reduction, Net Debt = DLTISQ - DLTRQ.
6. Interest Expense Rate: This measure as constructed as the ratio of total interest

expenses (XINTQ) to the lag of total liabilities (LTQ).

7. Debt: This measure is constructed as the sum of current debt (DLCQ) and long term debt (DLTTQ)

8. Leverage: I control for demeaned leverage of a firm in the regressions. The measure of leverage is constructed as the ratio of total debt (DLCQ+DLTTQ) to total assets (ATQ)

9. Expected Frequency of Default (EDF) measures the probability of default of any given firm with the next year. I control for demeaned EDF of a firm in the regressions. This measure is constructed as the $N(-\text{DTD})$, where N is the cumulative distribution function of a standard normal distribution and DTD denotes the distance to default. The distance to default is computed as $\text{DTD} \equiv \frac{\log (V/D)+(\mu_V-0.5\sigma_V^2)}{\sigma_V}$, where V denotes the value of the firm, D denotes the total debt, $\mu_V$ denotes expected annual return and $\sigma_V$ is the annual volatility of V. The value of V is estimated following the iterative procedure described in Gilchrist and Zakrajšek (2012).

10. Size: The regressions also control for the size of a firm which is computed as the log of total assets.

11. Sales growth is measured as the log change in sales.

12. Sector dummies: These are employed in the regressions to construct the sector-time fixed effects. The one-digit sectors are defined as:

    (a) Agriculture, forestry, and fishing (SIC¡999)

    (b) Mining (SIC∈[1000,1499]

    (c) Construction (SIC∈[1500,1799]

    (d) Manufacturing (SIC∈[2000,3999]

    (e) Transportation, communication, electricity (SIC∈[4000,4999])

    (f) Wholesale trade (SIC∈[5000,5199])

    (g) Retail trade (SIC∈[5200,5999])

    (h) Services (SIC∈[7000,8999])