Monetary Policy, Employment, and Firm Heterogeneity*

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December 31, 2022

Abstract

The paper presents new empirical evidence that in the U.S., employment by younger and smaller firms responds more to monetary policy shocks than that by older and larger firms. I find that younger and smaller firms rely on pledging personal houses as collateral to obtain bank loans, and thus, these firms are more sensitive to interest rate changes. I build a monetary business cycle model featuring housing collateral constraints that explains 67% of the heterogeneous employment responses found in the data.

Keywords: monetary policy, employment, firm heterogeneity, collateral constraint, housing prices

JEL No. D22, E12, E24, E52, J21, O18

*I am deeply indebted to my advisor Toshihiko Mukoyama for his invaluable advice and enormous support. I am grateful to Behzad Diba, Matthew Canzoneri, Mark Huggett, Dan Cao, Minsu Chang, Margit Reischer, John Rust, Henry Hyatt, Immo Schott, Yoonsoo Lee, Ed Herbst, Sharat Ganapati, Pedro Juarros, Umberto Moratori, and Yangfan Sun for helpful comments and suggestions. I also thank seminar participants at Bank of Canada, Dongbei University of Finance and Economics, Fairfield University, LACEA Conference, SEA Conference, EGSO Seminar, Georgetown Macro Seminar and Conference. I thank Jelena Leathard for her helpful assistance at the Georgetown RDC. Any views expressed are those of the authors and not those of the U.S. Census Bureau. The Census Bureau's Disclosure Review Board and Disclosure Avoidance Officers have reviewed this information product for unauthorized disclosure of confidential information and have approved the disclosure avoidance practices applied to this release. This research was performed at a Federal Statistical Research Data Center under FSRDC Project Number 2483. (CBDRB-FY21-P2483-R9167) This research uses data from the Census Bureau's Longitudinal Employer Household Dynamics Program, which was partially supported by the following National Science Foundation Grants SES-9978093,SES-0339191 and ITR-0427889; National Institute on Aging Grant AG018854; and grants from the Alfred P. Sloan Foundation. Any views expressed are those of the authors and not those of Capital One. This research was supported with a grant from Washington Center for Equitable Growth. All errors are my own.

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1 Introduction

The Federal Reserve uses monetary policy to achieve the goal of maximum employment and price stability. To better understand how to use the federal funds rate to achieve the employment goal, understanding the following question is helpful: Which types of firms are more responsive in employment to changes in monetary policy? Although work has been done to measure the effect of monetary policy on aggregate employment in the U.S., we need further research to better understand its heterogeneous effect across firm types.[1] This paper presents new empirical evidence that smaller, or younger, or smaller and younger firms respond more to monetary policy in their employment.

At the macro level, using a quarterly structural vector autoregression (SVAR) with time series data following Ramey (2016), I find the impulse responses of smaller and younger firms' employment to monetary policy shocks are stronger than those of larger and older firms. The employment information by firm size and age comes from the Census Bureau's Business Dynamics Statistics (BDS) and Quarterly Workforce Indicators (QWI). The data cover the major part of the U.S. private economy. There are two challenges in estimating the firms' employment responses to monetary policy. The first challenge is that neither dataset alone is a good fit for the SVAR model, due to their limited number observations. To deal with this issue, I impute the missing quarterly BDS data with the information from the QWI following Mukoyama, Patterson, and Şahin (2018). The second challenge is that monetary policy endogenously responds to the economic activities. To overcome the challenge, I use the monetary policy shocks identified by Romer and Romer (2004). By regressing the change in the intended funds rate on the Federal Reserve's internal forecasts of inflation and real activity, Romer and Romer (2004) constructs the the monetary shocks with the residuals from the regression. The monetary shocks show changes in the intended funds rate not taken in response to information about future economic developments. My SVAR model specification closely follows Ramey (2016) with quarterly variables including the industrial production, the

1. Ramey (2016) provides a thorough literature review on the effect of monetary policy on the aggregate economy in the U.S.

employment by firm groups, the consumer price index, the commodity price index, and the cumulative Romer and Romer shocks. The model uses the recursiveness assumption that the monetary shock cannot affect the macroeconomic variables within the quarter, placing the Romer and Romer shocks last in the ordering. The estimates show smaller and younger firms respond more to monetary shocks.

At the micro level, I apply a firm-level panel dataset from the Census Bureau to a linear fixed effects model. The fixed effects estimator yields that smaller or younger firms are more responsive than larger or older firms to monetary shocks. Moreover, the firms that are both smaller and younger respond the most. The quarterly firm-level data are from the Census Bureau's Longitudinal Employer-Household Dynamics (LEHD). I use the high-frequency monetary shocks constructed by Gorodnichenko and Weber (2016). Conceptually, these monetary shocks are measured by the difference between the Fed funds futures rate shortly before and after the press release of the Federal Open Market Committee (FOMC). This high-frequency event-study captures the unanticipated monetary policy change not taken in response to the economy. Given that the monetary shocks data is available since 1994, it is not a good candidate for the SVAR method at the macro level. It is a good candidate for the linear fixed effects model with firm-level panel data. The estimation results yield that smaller and younger firms are more responsive to monetary shocks than their respective counterparts. Additionally, firms that are both smaller and younger are the most responsive compared with their counterparts.

Why are smaller and younger firms more responsive to monetary shocks? I hypothesize that these firms are more likely to pledge their personal housing as a collateral, which respond to interest rate fluctuations. In 2016, mortgage constituted over 70% of total debt for partnerships and proprietorships (mostly smaller firms) and less than 6% for nonfinancial corporate business (mostly larger firms), according to Report to the Congress on the Availability of Credit to Small Businesses 2017. To explore this possibility, I rerun the above SVAR specifications by adding a housing prices variable using the Freddie Mac House Price Index. The results indicate the employment of small and medium firms is 50% more correlated with hous-

ing prices than the large firms, and the employment of startups is six times more correlated with housing prices than older firms.[2] More direct evidence would be a comparison of finance structure by firm size and age. Unfortunately, aggregate business finance data broken down by firm size and age are generally not available. Yu (2022) uses the instrumental variable method to identify that a 1% increase in housing prices induces small business loan amounts by 0.54% to 1.78%, using loan data from the Small Business Administration.

How much can the housing collateral channel explain the heterogeneous responses in firms' employment? I build a monetary business cycle model with house collateral constraints to quantify the impact of monetary policy on the heterogeneous employment responses through the transmission channel of housing prices. The model builds heavily on Iacoviello (2005), which incorporates housing collateral constraints into a monetary business cycle model. My model adds a corporate sector in addition to the entrepreneur sector in Iacoviello (2005). The corporate sector represents larger and older firms, and the entrepreneur sector represents smaller and younger firms. The model examines whether and how financial frictions on the firm side may amplify or propagate employment fluctuations in response to aggregate disturbances. The model has the following components. The production sector features two types of agents, namely, entrepreneurs and corporations. Additionally, the model includes a household sector, a retailer to motivate sticky prices, and a central bank that conducts monetary policy. The model features a house collateral constraint on the entrepreneur sector. The model transmission mechanism can work as follows. When a negative monetary shock occurs, monetary actions increase the real rate with sticky prices. The rate increase discourages current consumption and hence output. The effect is propagated by the fall in housing prices, lowering borrowing and housing investment by the entrepreneur sector. The results find housing price and inflation respond negatively to a positive monetary shock (an increase in the interest rate). The decrease in housing price tightens the borrowing constraints of entrepreneurs. As a result, entrepreneurs' employment drop, and corporations' employment

2. Size is measured by total employment and is defined as follows: small (0-19), medium (20-499), and large (500+). Age is measured by the years since a firm's establishment: younger/start-ups (0-1) and older (2+).

change little. The model explains 67% of the heterogeneous employment responses found in the data.

In sum, at macro-level and micro-level, I find that smaller, younger, and smaller and younger firms are more responsive to monetary shocks in employment. Further, these firms reply more on housing collateral to obtain bank loans and are more sensitive to interest rate changes. I use a monetary business cycle model to interpret the empirical findings.

The remainder of the paper is organized as follows. Section 2 provides the literature review. Sections 3 and 4 describe the data, methodology, and estimation results as the empirical motivation at the macro and micro level, respectively. Section 5 illustrates the transmission channel to explain the heterogeneous responses. Section 6 presents a monetary business cycle model features the housing collateral constraints. Section 7 describes the estimation of model parameters. Section 8 analyzes how changes in monetary policy affect disproportionately the employment dynamics of different types of firms. Section 9 concludes and proposes new research area.

2 Literature Review

My paper contributes to the following two strands of literature. The first studies the heterogeneous effect of monetary policy on firm dynamics depending on their characteristics. Studies have found the firm-level responses to monetary shocks in the U.S. depend on firms' size (Gertler and Gilchrist (1994), Caglio, Darst, and Sebnem Kalemli-Ozcan (2022), Crouzet and Mehrotra (2020), Singh, Suda, and Zervou (2021)), age (Cloyne, Ferreira, Froemel, and Surico (2021) and Casiraghi, McGregor, and Palazzo (2021)), default risk (Ottonello and Winberry (2020)), liquidity (Jeenas (2019) and Abo-Zaid and Zervou (2020)), and leverage ratio (Ottonello and Winberry (2020) and Lakdawala and Moreland (2021)). The seminal paper of Gertler and Gilchrist (1994) uses the publicly released data of the Quarterly Financial Report for Manufacturing Corporations (QFR) to present evidence that smaller manufacturing firms are more responsive than larger ones to monetary policy in sales, inventories, and short-term

debt. Ottonello and Winberry (2020) uses Compustat data to show default risk generates statistically significant differential responses to monetary policy in investment, whereas size does not. In fact, the point estimates indicate larger firms are more responsive to monetary shocks. Crouzet and Mehrotra (2020) uses confidential microdata underlying the QFR to discover greater cyclical sensitivity among small firms in sales, inventories, and investment. Earlier research focuses on heterogeneous response variables including investment, inventories, and sales in the U.S. Recently, Singh, Suda, and Zervou (2021), Casiraghi, McGregor, and Palazzo (2021), and Bahaj, Foulis, Pinter, and Surico (2022) studies the heterogeneous responses in employment in the context of U.S. and U.K., focusing on either size or age, respectively. This paper supplement the literature by identifying the amplification effects along both size and age dimensions, thanks to the richness of the Census restricted microdata.

The second studies the transmission mechanism of monetary policy. Fisher (1933) argue that a deteriorating credit market can depress the real economy. Bernanke and Gertler (1989) and Bernanke and Gertler (1990) formalizes this idea in a general equilibruium framework. Bernanke, Gertler, and Gilchrist (1999) embeds the financial accelerator mechanism in a representative firm New Keynesian model. Kiyotaki and Moore (1997) build a theoretical model that features collateral that propagate the transmission mechanism. Iacoviello (2005) adds collateral constraints tied to real estate values for entrepreneurs to Bernanke, Gertler, and Gilchrist (1999). Iacoviello (2005), Iacoviello and Pavan (2013), Guerrieri and Iacoviello (2017) studies the housing collateral channel of monetary with a focus on consumption[3]. My model is an extension of Iacoviello (2005) focusing on employment, where a corporate sector is added to extend firm heterogeneity. The model shows housing collateral channel propagates the monetary policy effect disproportionately in smaller or younger firms' employment.

3. Guo (2020), Jermann and Quadrini (2012), Khan and Thomas (2013) study the capital-based collateral channel

3 Empirical Findings: Macro Level

In this section, I present the findings that smaller or younger firms are more responsive to monetary policy, using publicly available macro-level time series data. The empirical method uses the SVAR model. The specification includes industrial production, employment, the consumer price index, the commodity price index, and monetary policy shocks, following Ramey (2016).

3.1 Data

The main datasets for this section, which measure the total employment by firm size or age, are the BDS and the QWI. Both datasets are from the U.S. Census Bureau. BDS provides the annual time series of employment by firm size and age from 1977 to present. It is a publicly available dataset with its micro foundations from Longitudinal Business Database (LBD) that uses the establishment frames of Business Register (BR). QWI provides the quarterly time series of employment by firm size and age from 1993 to present. It is a publicly available dataset with its micro foundations from the LEHD that uses the establishment frames of the Quarterly Census of Employment and Wages (QCEW). Both BDS and QWI cover the comprehensive universe of firms in the U.S. economy[4]. To take advantage of the longer period of the BDS and higher frequency of the QWI, I impute the BDS annual data series into the quarterly frequency with the information from the QWI, following Mukoyama, Patterson, and Şahin (2018). The imputation details are discussed in the Appendix A.1. Figure 1 displays the imputed quarterly BDS employment time series in comparison to the original QWI series. I use the imputed quarterly employment series in the empirical estimation in the next section.

The data series of industrial production, the consumer price index, the commodity index,

4. The coverage and scope of the BDS are based on the Census Bureau's County Business Patterns (CBP) program. It covers the practical totality of the private non–agricultural sector of the economy. The only major exclusions are self–employed individuals, employees of private households, railroad employees, agricultural production employees, and most government employees. The QWI covers UI-covered employment represents 96% of wage and salary civilian jobs in the U.S., including private, state and local, and federal government employment.

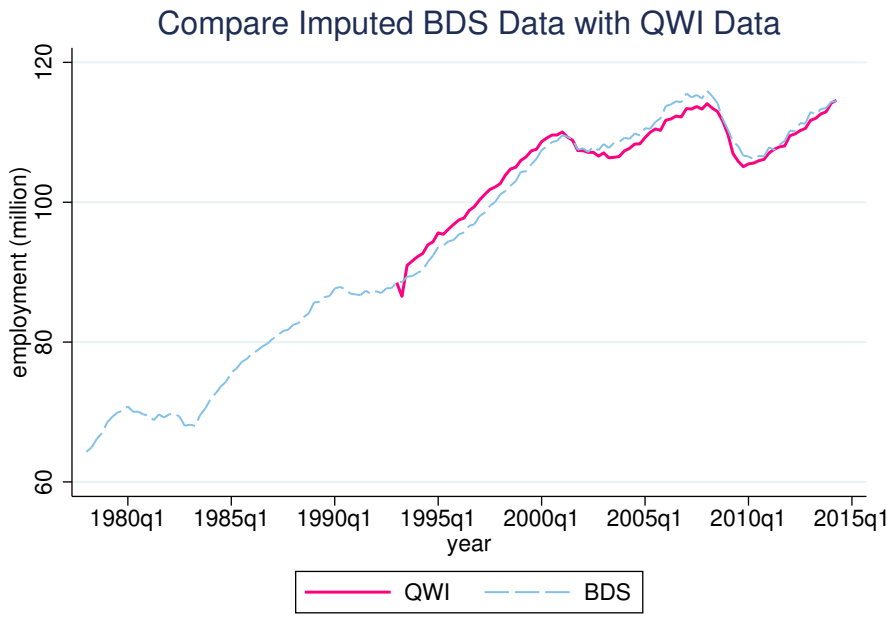


Figure 1: Imputed BDS data and QWI data

and monetary shocks comes from Ramey (2016). The Freddie Mac House Price Index is used to measure house price.

3.2 Empirical approach

My empirical method follows a SVAR model. The reduced-form representation of this model is given by

$$y_t' = x_t'\Phi + u_t', u_t \sim \mathcal{N}(0, \Sigma),$$

where y_t is an $n \times 1$ vector of variables, $x_t = [y_{y-1}', ...y_{y-p}', 1]'$, μ_t is an $n \times 1$ vector of shocks, and Φ is an $n \times n$ matrix of reduced-form parameters. Following Ramey (2016), the variables include industrial production, employment, the consumer price index, the commodity price index and Romer and Romer shocks with four lags. Differently from Ramey (2016), I use the log-transformed employment level by firm groups, for example, total employment of small firms, instead of the aggregate unemployment rate. The reason is that I examine the disproportionate effect of monetary policy on different firms, whereas Ramey (2016) examines its

effect on the aggregate economy.

The model requires more restrictions to identify the coefficients. I adopt the commonly used identification method introduced by Sims (1980). The identification strategy is to triangularize and impose recursive zero restriction on the contemporaneous coefficients. Economically, this strategy assumes the endogenous variables do not respond to the policy shock within the period due to their lagging responses.

The Romer and Romer shock series are monetary shocks constructed by Romer and Romer (2004). I use the Romer and Romer shocks instead of the federal funds rate because they separate the endogenous response of policy to information about the economy from the exogenous shock. Romer and Romer (2004) develops a measure of the U.S. monetary policy shocks that is considered exogenous. By regressing the federal funds rate on the Federal Reserve's internal forecasts and taking the residuals as the monetary policy shocks, it solves the problem that the Federal Reserve may have superior information over the economy, and hence, the fed fund rate can be endogenous. Newer monetary shocks constructed using high-frequency event-study approach are considered to be more exogenous than the Romer and Romer shocks. However, those shocks are only available since the 1990s when the federal funds futures became available. A quarterly frequent times series between the 1990s and 2007 includes too few observations for the systems of equations of five variables in the specification. These newer monetary shocks are useful for the micro-level analysis in the next section given that the micro panel data have abundant observations.

The firms are grouped by size or age. The size is measured by total employment and is defined as: small (0-19), medium (20-499), and large (500+). The age is measured by the years since a firm's establishment and is defined as: start-ups/younger (0-1) and older (2+).

The resulting specifications are estimated over the 1977Q1 to 2007Q4 period using four lags. The results are a set of impulse responses that are reported with 90% confidence bands following Ramey (2016).

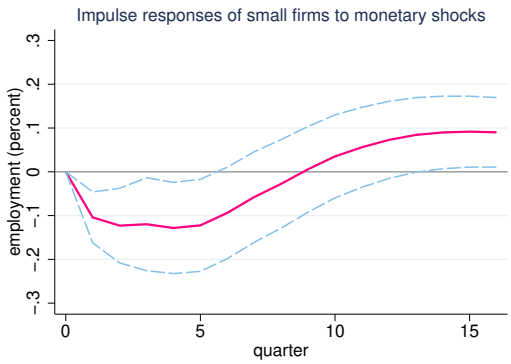
3.3 Empirical estimates

Figures 2 and 3 show the employment response of different firms after a monetary shock by size and age, respectively. The horizontal axis denotes the quarter and the vertical axis denotes the percentage change of employment by the firms. At time 0, a monetary shock of one standard deviation occurs. In the following quarters, we see the responses of different firm groups vary based on the firms' size or age.

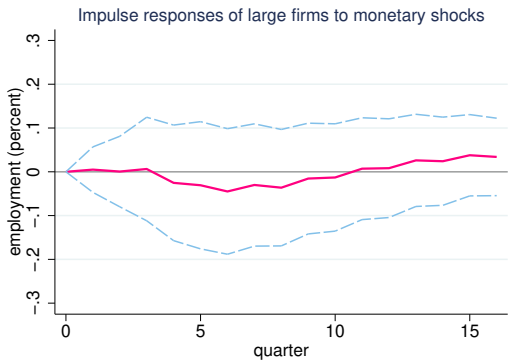
Figure 2a illustrates the responses of smaller firms to a monetary shock. In the next quarter, we observe a statistically significant negative response of smaller firms that lasts for five quarters. At its peak, it reduces employment of small firms by 0.13% during that period. And by its peak, the cumulative reduction of employment of the small firms reaches 0.60%. By contrast, Figure 2b shows that larger firms' response is much smaller and not statistically significant. This set of impulse responses provide evidence that smaller firms are more responsive to monetary shocks than larger firms.

Figure 3a displays the responses of younger firms (startups) to a monetary shock. In the next quarter, we observe statistically significant negative responses of smaller firms that last for two quarters a shock. At its peak, the contractionary monetary shock reduces employment of startups by 0.35% during the second quarter. Cumulatively, it induces a 0.63% drop in the employment of startups by the third quarter. By contrast, Figure 3b shows the older firms' responses are smaller and not statistically significant. This set of impulse responses provide evidence that younger firms are more responsive to monetary shocks than older firms.

The time series data I use in the SVAR model have limitations. The number of observations are limited, which may explain the wide confidence interval, especially for the start-ups. The natural way to deal with the challenge is to examine the empirical evidence with micro-level data. I discuss the method and results in section 4.

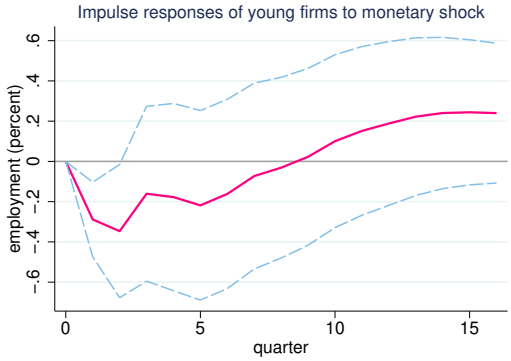


(a) Small

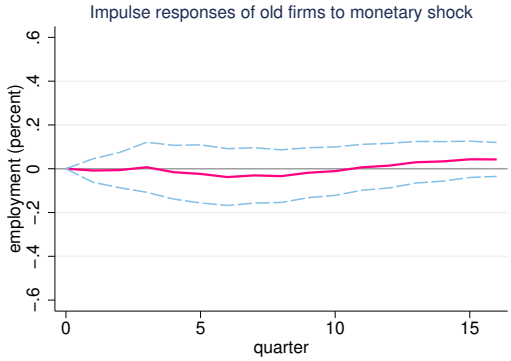


(b) Large

Figure 2: Firms' responses to monetary shocks by size



(a) Start-ups



(b) Older

Figure 3: Firms' responses to monetary shocks by age

Note. Light blue bands are 90% confidence bands.

4 Empirical Findings: Micro Level

In this section, I present the findings that smaller or younger firms are more responsive to monetary policy, using restricted micro-level panel data. Additionally, firms that are smaller and younger are the most responsive ones. The empirical method uses the linear fixed effect model. The specification includes firm employment, firm fixed effect, sector by time fixed effect, a dummy indicating firm category, and monetary policy shock, following Ottonello and Winberry (2020) and Bahaj, Foulis, Pinter, and Surico (2022).

4.1 Data

The quarterly longitudinal firm-level data are from the LEHD, which cover 95% of U.S. private sector jobs, primarily collected via the Local Employment Dynamics (LED) partnership, which is a federal-state data-sharing collaboration. Partner states voluntarily provide data from existing administrative record systems. LEHD staff combine these data with a range of other data sources to generate data products. Each state approves user requests for data access independently. The paper has approval from 24 states to access its data. The data start in the 1990s and the exact beginning dates vary by states. Firm employment data come from the QWI. Firm age information comes from the LEHD-Employer Characteristic Files (ECF). Haltiwanger, Hyatt, Mcentarfer, Sousa, and Tibbets (2014) discuss details about the LEHD data.

I use high-frequency monetary shocks identified using federal funds futures as Gorodnichenko and Weber (2016) for the micro-level analysis. The reason goes two-folded. First, the shocks data start in the 1994, around the same time as the micro-level employment data. While this shock series are too short for the macro-level analysis, it is long enough for the estimation using firm panel data. Second, the raw shocks data are at the daily frequency, making them ideal candidates for unanticipated or exogenous shocks.

Table 1 provides summary statistics of the variables described above. The monetary shock series, either average or weighted average, has a zero mean. The average firm age is slightly

over 11 years old. The average firm employment is around 24 employees.

Table 1: Summary statistics

Variables	Mean
Monetary shocks (average)	−0.02
Monetary shocks (weighted average)	−0.02
Firm age	11.72
Firm employment	23.55

4.2 Empirical approach

The empirical specification is as follows:

$$\Delta ln(emp)_{i,t} = \alpha_i + \alpha_{st} + \delta D_{gi,t-1} + \beta D_{gi,t-1}\xi_t^m + \epsilon_{i,t}$$

The dependent variable $\Delta ln(emp)_{i,t}$ is the change in log employment for firm i in a quarter between t and $t-1$, α_i is the firm fixed effect α_{st} is the sector-time fixed effect, $D_{gi,t-1}$ is a dummy for firm groups (small, young, small and young, etc.), and ξ_t^m is monetary shocks.

The size is measured by total employment and is defined as: small (0-19), large (20+). The age is measured by the years since a firm's establishment and is defined as: start-ups/young (0-1) and old (2+). The micro data allow us to define firm groups with the combination of size and age: small (0-19) and young (0-1), small (0-19) and old (2+), large (20+) and young (0-1), large (20+) and old (2+).

4.3 Empirical estimates

Consistent with the macro evidence, the micro results show smaller or younger firms are more responsive to monetary shocks than larger or older firms. Table 2 summarizes the estimation results. Column (1) indicates smaller firms decrease employment 0.28% more than larger ones, with a 100-basis-point contractionary interest rate shock. Column (2) shows

Table 2: Heterogeneous Responses of Employment to Monetary Policy

Variables	(1)	(2)	(3)
Small	0.190		
	0.000233		
Small × shocks	−0.278		
	0.126		
Young		0.0342	
		0.000209	
Young × shocks		−0.875	
		0.218	
Small and young			0.0610
			0.000226
Small and young × shocks			−2.376
			0.238
Small and old			0.0483
			0.00014
Small and old × shocks			−0.0569
			0.106
Large and young			−0.0102
			0.000855
Large and young × shocks			−1.795
			0.887
Observations	86390000	86390000	86390000
R^2	0.069	0.061	0.063
Firm FE	Yes	Yes	Yes
Time industry FE	Yes	Yes	Yes

The table reports the estimation results of heterogeneous responses of employment to monetary shocks. Column (1) displays the estimation results by firm size, column (2) displays the estimation results by firm age, column (3) displays the estimation results by firm size and age. The sample period is between 1994 and 2007. Size is measured by total employment and is defined as: small (0-19), large (20+). Age is measured by the years since a firm's establishment and is defined as: start-ups/young (0-1) and old (2+). Shocks refer to the weighted average of monetary shocks.

younger firms decreases employment 0.88% more than older firms. Thanks to the richness of the Census microdata, I can present the amplification effects when combining the size and age dimension. Column (3) shows that firms that are both smaller and younger decreases employment 2.38% more than larger and older firms. It also shows that smaller and older firms decreases employment 0.057% more than larger and older ones. In addition, larger and younger firms decrease employment -1.80% more than larger and older firms.

4.4 Robustness

The Census Bureau's microdata allows for flexible definition of firm groups. I use alternative definitions of size to test the robustness of the micro-level results. In this set of results, age definition is kept the same to help us examine the amplication effect.

The firm groups are redefined as the following. Size is measured by total employment and is defined as: smaller (0-4), and larger (5+). The age is measured by the years since a firm's establishment and is defined as: start-ups/younger (0-1) and older (2+). In addition, I define firm groups with the combination of size and age: smaller (0-4) and younger (0-1), smaller (0-4) and older (2+), larger (5+) and younger (0-1), large (5+) and older (2+).

Table 3 summarize the main results. Consistent with the previous results, I find that smaller or younger or smaller and younger firms are more responsive to monetary shocks. Furthermore, smaller firms defined with fewer employees demonstrate even stronger results relative to the benchmark Table 2. Column (1) indicates smaller firms decrease employment 0.59% more than larger ones, with a 100-basis-point contractionary interest rate shock. Column (2) remains the same as in Table 2 so that I can present amplification effect in column (3). Column (3) shows that firms that are both smaller and younger decreases employment 4.68% more than larger and older firms. The magnitude of the heterogeneous responses are twice as those in the benchmark Table 2.

To summarize, the estimates at macro-level and micro-level consistently show smaller or younger or smaller and younger firms are more responsive to monetary shocks, which naturally

Table 3: Heterogeneous Responses of Employment to Monetary Policy

Variables	(1)	(2)	(3)
Small	0.224		
	0.000143		
Small × shocks	−0.594		
	0.0841		
Young		0.0342	
		0.000209	
Young × shocks		−0.875	
		0.218	
Small and young			0.111
			0.000246
Small and young × shocks			−4.684
			0.255
Small and old			0.137
			0.000123
Small and old × shocks			−0.595
			0.0844
Large and young			−0.00363
			0.000391
Large and young × shocks			−2.486
			0.411
Observations	86390000	86390000	86390000
R^2	0.09	0.061	0.076
Firm FE	Yes	Yes	Yes
Time industry FE	Yes	Yes	Yes

The table reports the estimation results of heterogeneous responses of employment to monetary shocks. Column (1) displays the estimation results by firm size, column (2) displays the estimation results by firm age, column (3) displays the estimation results by firm size and age. The sample period is between 1994 and 2007. Size is measured by total employment and is defined as: smaller (0-4), and larger (5+). Age is measured by the years since a firm's establishment and is defined as: start-ups/younger (0-1) and older (2+). Shocks refer to the weighted average of monetary shocks.

prompts the question why these firms respond more to monetary policy in their employment.

5 Transmission Channel

To explore the transmission channels through which monetary policy has these heterogeneous effects on employment, I examine the following financial friction theory. When a contractionary monetary policy shock occurs, housing prices and its collateral value would decrease, and the firms that collateralize against their housing value could borrow less money and hire fewer people. I provide three pieces of empirical evidence to explore the role of the housing collateral constraint.

First, the financing structure of small and young businesses rely on loans, which partially collateralised with personal residence. Using a proxy for organization type, smaller firms are shown to rely much more on mortgage debt than larger ones. Figure 4 shows mortgage constitutes over 60% of total debt for partnerships and proprietorships and less than 20% for nonfinancial corporate business, according to the Report to the Congress on the Availability of Credit to Small Businesses. Figure 5 shows that over 70% of bank loans to small and medium enterprises in the U.S. are collateralised, based on a survey conducted by Financial Stability Board. Meisenzahl (2014) identifies that in 2003, 29% of small businesses pledge personal residences to obtain loans. Figure 6 shows that the primary source of finance for startups is outsider debt and bank loans is the mostly commonly used instrument for finance, as described by Kobe (2007). More direct evidence would be a comparison of finance structure by firm size and age. Unfortunately, aggregate business finance data broken down by firm size and age are generally not available.

Second, I revisit the SVAR model by adding a variable for the house price index as discussed in section 3.2. The purpose is to test whether the employment of smaller and younger firms is more strongly correlated with a house price shock. If the theory holds, we would expect house price to be more correlated with the change of employment of smaller and younger firms. As Figure 7a shows, the employment of small and medium firms is 50%

more correlated with house price than the large firms. Figure 7b shows the employment of startups is six times more correlated with house price than older firms.

Third, using loan data from the Small Business Administration, Yu (2022) applies the instrumental variables method and identify 1% increase in housing prices raises 0.54%-1.78% increase in loan amount to small and young businesses, as shown in Table 4. Brown and Earle (2017) links the Small Business Administration loan data to the Census Bureau's employer and non-employer business registers. It finds that 75% of the businesses are startups. In addition, for the remaining 25% non startups, their average firm size is 12.46 employees and average age is 6.74 years old. I use the Census Bureau's restricted microdata to find the average firms size is 23.55 employees and average firm age is 11.72 years old. That is to say, the firms in the sample of the Small Business Administration are smaller and younger compare to the population.

In summary, I find supportive evidence that smaller and younger firms rely on pledging personal residence as collateral to obtain loans empirically.

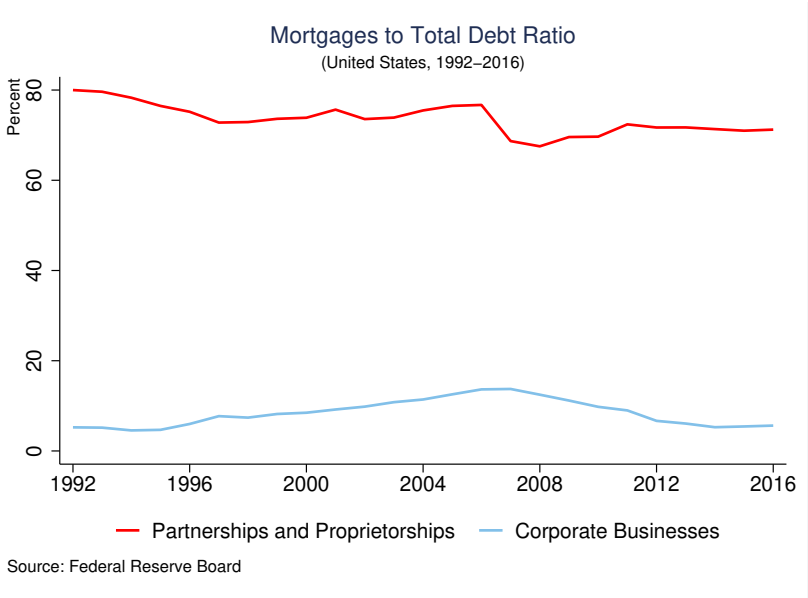


Figure 4: Mortgages to to total debt ratio by firm types

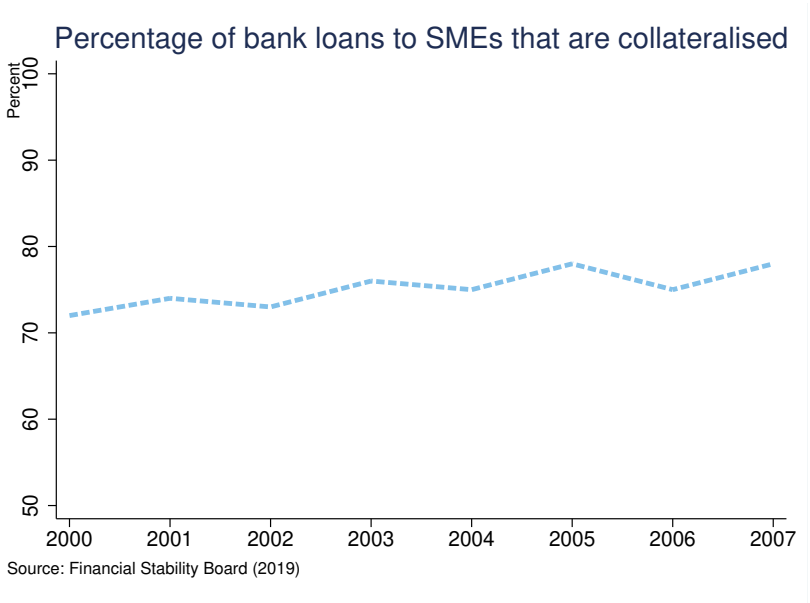


Figure 5: Percentage of bank loans collateralised to small and medium enterprises

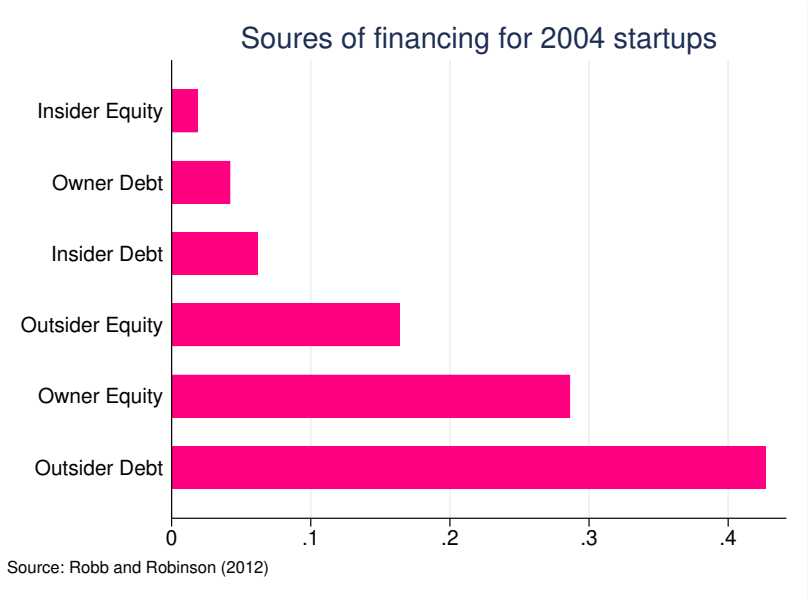
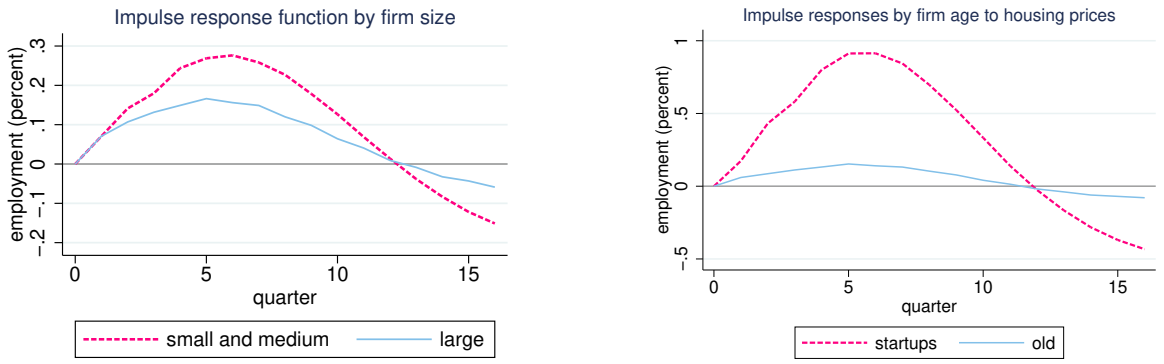


Figure 6: Sources of financing for startups



(a) By size

(b) By age

Figure 7: Firms' responses to housing prices

VARIABLES	(1) OLS	(2) FE	(3) IV_1	(4) IV_2
house price	0.305	0.329	1.775	0.540
	(0.0885)	(0.0950)	(0.582)	(0.136)
unemployment rate	-0.0266	-0.0270	-0.00788	-0.0176
	(0.0107)	(0.0108)	(0.0128)	(0.0105)
population	0.416	0.0977	-2.169	0.168
	(0.308)	(0.634)	(1.553)	(0.681)
Observations	6,020	6,020	6,020	6,020
Number of msanecma	215	215	215	215
Year FE	YES	YES	YES	
MSA FE	NO	YES	YES	YES
F-test			76.03	891.8
Division year FE				YES

Table 4: Effect of housing prices on small business borrowing

The table reports the estimation results of housing prices on small business borrowing. Column (1) is OLS, column (2) is fixed effects, column (3) is IV using the Saiz instrument interacting with the local unemployment rate, column (4) is IV using the sensitivity instrument interacting with the regional housing prices. The sample period is between 1991 and 2019. Standard errors are clustered at the MSA level.
Source: Yu (2022)

6 Model

How much can the housing collateral channel explain the heterogeneous responses in firms' employment? I build a monetary business cycle model with house collateral constraints to quantify the impact of monetary policy on the heterogeneous employment responses through the transmission channel of housing prices. Using this model, I conclude the housing collateral channel explains 67% of the heterogeneous responses that we see in the empirical analysis, which I interpret as the upper bound for the role of housing collateral channel.

The model builds heavily on Iacoviello (2005), which incorporates housing collateral constraints into a monetary business model. My model adds a corporate sector in addition to the entrepreneur sector. The corporate sector represents large or old firms, and the entrepreneur sector represents small or young firms. The model examines whether and how financial frictions on the firm side may amplify or propagate employment fluctuations in response to aggregate disturbances.

The model is a discrete-time, infinite-horizon economy. It includes the production sectors, the retailers, the households, and the central bank. The production sectors feature two types of agents: the noncorporate/entrepreneur sector representing smaller/younger firms and the corporate sector representing larger/older firms. Both the entrepreneur and corporate sector produce intermediate goods and sell them to the retailer sector. The retailer sector purchases the intermediate goods and transforms them into the final goods. It is where the nominal rigidity comes from. The household sector supplies labor to both the entrepreneurs and corporations and consumes final goods and invests in housing. They lend money to the entrepreneurs and own the corporations and retailers. The central bank conducts monetary policy. The model features house collateral constraints on the noncorporate sector. The model transmission mechanism can work as follows and is illustrated in Figure 8. When a contractionary monetary shock occurs, the real interest rate increases and it discourages current consumption and hence output. The effect is propagated by the fall in housing prices lowering borrowing, labor demands and housing investment by the noncorporate sector that

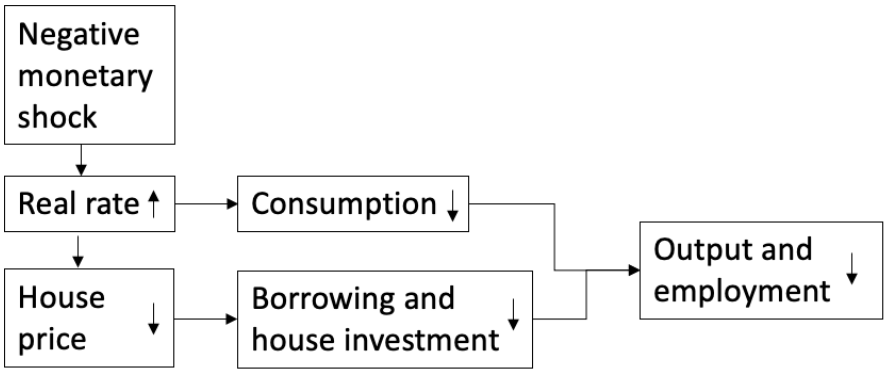


Figure 8: Transmission channel

collateralized against house value. As a result, the entrepreneur sector's employment responds negatively to the monetary shocks.

6.1 Households

Households maximize a lifetime utility function discounted by β, which values consumption c_t^h and housing h_t^h, and dislikes labor l_t^h, subject to a budget constraint. The budget constraint is satisfied when the expenditure comprising consumption c_t^h, housing investment h_t^h at housing price q_t, and lending $-b_t^h$ is no more than total income comprising of labor income $w_t L_t^h$ by working for entrepreneurs and corporations, receipt of debt repayment $-\frac{R_{t-1}b_{t-1}^h}{\pi_t}$ from entrepreneurs, dividends from corporations d_t, and lump-sum profits F_t from retailers. Households solve the following problem 1:

$$\text{P1} \quad \max_{c_t^h, b_t^h, h_t^h, L_t^h} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \big(\ln c_t^h + \rho \ln h_t^h - \frac{(L_t^h)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \big)$$

$$s.t. \; c_t^h + q_t \triangle h_t^h - b_t^h = w_t L_t^h - \frac{R_{t-1}b_{t-1}^h}{\pi_t} + d_t + F_t$$

Solving the problem yields the first-order conditions for consumption (c_t^h), labor supply (L_t^h), and housing demand (h_t^h):

$$\frac{1}{c_t^h} = \beta \frac{R_t}{\pi_{t+1} c_{t+1}^h}$$

$$w_t = (l_t^h)^{\eta-1} c_t^h,$$

$$and \ \frac{q_t}{c_t^h} = \frac{\rho}{h_t^h} + \beta \frac{q_{t+1}}{c_{t+1}^h}$$

6.2 Firms

Two types of representative firms exist, namely, entrepreneurs and corporations. They both produce homogeneous intermediate goods and sell them to retailers. The main feature of the entrepreneurs is that they collateralize against their housing values to borrow, whereas corporations do not have this feature. The purpose of distinguishing between the entrepreneurs and corporations is that entrepreneurs represent the smaller and younger firms whereas corporations represent the larger and older ones in the empirical analysis. This difference allows us to examine the role of housing collateral in the transmission mechanism of monetary policy.

Entrepreneurs

The entrepreneurs represent smaller/younger firms that we see in the empirical analysis. In this paper, I define entrepreneurs as those who design, launch, and run a business, which is often similar to a small business.

Entrepreneurs produce homogeneous intermediate goods Y_t^e at wholesale price P_t^w with an input demand for labor L_t^e and house h_{t-1}^e, using a Cobb-Douglas constant returns-to-scale technology. Entrepreneurs maximize a lifetime utility function discounted by γ, which values consumption c_t^e, subject to the production technology above, a budget constraint, and a borrowing constraint. The budget constraint is satisfied when the revenue of the goods plus borrowing amounts to the expenditure comprising consumption, housing investment, debt repayment, and wage payment. The borrowing constraint is satisfied when the amount of borrowing is no more than a limit of the collateralized house value parameterized by m, the

loan-to-value ratio. Entrepreneurs solve the following problem 2:

$$\text{P2} \quad \max_{c_t^e, b_t^e, h_t^e, L_t^e} \mathbb{E}_0 \sum_{t=0}^{\infty} \gamma^t \ln c_t^e$$

$$s.t. \; Y_t^e \frac{P_t^w}{P_t} + b_t^e = c_t^e + q_t \triangle h_t^e + \frac{R_{t-1} b_{t-1}^e}{\pi_t} + w_t L_t^e$$

$$b_t^e \leq m \mathbb{E}_t (q_{t+1} h_t^e \pi_{t+1} / R_t)$$

$$Y_t^e = (h_{t-1}^e)^{\upsilon} (L_t^e)^{1-\upsilon}$$

The main feature here is the borrowing constraint that is tied to the housing value against which the entrepreneurs borrow money. The parameter m measures the tightness of the borrowing constraints that can be anywhere between 0 and 1. Another way to look at the constraints is as follows: $b_t^e R_t \leq m \mathbb{E}_t (q_{t+1} h_t^e \pi_{t+1})$. In other words, the total amount of debt repayment with interest and principle $b_t^e R_t$ shall not exceed m fraction of the expected housing value $E_t (q_{t+1} h_t^e \pi_{t+1})$[5].

I assume entrepreneurs have a lower discount factor than households, that is, $\gamma < \beta$, to ensure a binding borrowing constraint.

Solving the problem yields first-order conditions for the consumption Euler equation (c_t^e), housing demand (h_t^e), and labor demand (L_t^e):

$$\frac{1}{c_t^e} = \frac{r R_t}{\pi_{t+1} c_{t+1}^e} + \lambda_t R_t,$$

$$\frac{q_t}{c_t^e} = \frac{\gamma}{c_{t+1}^e} (\upsilon \frac{Y_{t+1}^e}{X_{t+1} h_t^e} + q_{t+1}) + \lambda_t m \pi_{t+1} q_{t+1},$$

$$and \; w_t = (1 - \upsilon) \frac{Y_t^e}{X_t l_t^e}$$

Corporations

Corporations represent those larger/older firms that we see in the empirical analysis. In

5. This collateral feature originates from Kiyotaki and Moore (1997). I follow Iacoviello (2005) to embed the collateral feature into a quantitative model.

this parsimonious setting, corporations do not face financial constraints.

Corporations produce homogeneous intermediate goods Y_t^c at wholesale price P_t^w with an input demand of labor L_t^c. Corporations pay dividends to their owners, which are households. Corporations maximize lifetime dividends, where dividends are the remaining part of revenue $\frac{P_t^w}{P_t} Y_t^c$ after deducting wage payment $w_t L_t^c$. $\Lambda_{t,k} = \beta^k (\frac{c_t^h}{c_{t+k}^h})$ is the household relevant discount factor. Corporations solve the following problem 2:

$$\text{P2} \quad \max_{d_t, Y_t^c, L_t^c} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{t,k} d_t$$

$$s.t. \; d_t = \frac{P_t^w}{P_t} Y_t^c - w_t L_t^c$$

$$Y_t^c = A(L_t^c)^{\mu}$$

Solving the problem yields the first-order condition for labor:

$$\mu (l_t^c)^{\mu - 1} \frac{A}{X_t} = w_t$$

6.3 New Keynesian Block

This part of the model serves the purpose of motivating sticky price and generating a New Keynesian Phillips curve which connect the nominal variables with the real economy. The New Keynesian block includes the retailers, who are the final good producers, and the central bank, who is the monetary authority that sets the nominal interest rate according to the Taylor Rule.

Retailers

Retailers buy homogeneous intermediate goods at wholesale price P_t^w from entrepreneurs and corporations, differentiate goods without cost into $Y_t(z)$, and sell it at price $P_t(z)$. Final goods are $Y_t = (\int_0^1 Y_t(z)^{\epsilon - 1/\epsilon} dz)^{\epsilon/\epsilon - 1}$, where $\epsilon > 1$. Hence, the price index is $P_t = (\int_0^1 P_t(z)^{1-\epsilon} dz)^{1/1-\epsilon}$ and each retailer's demand curve is $Y_t(z) = (P_t(z)/P_t)^{(-\epsilon)} Y_t^f$. Retailers

are monopolistic competitors indexed by z, and change price with probability $1-\theta$. Aggregate price evolves: $P_t = (\theta P_{t-1}^{1-\epsilon} + (1-\theta)(P_t^*)^{1-\epsilon})^{\frac{1}{1-\epsilon}}$. Retailers maximize lifetime profits discounted by $\Lambda_{t,k}$, by choosing to change the sale price in every period, subject to the given demand curve. Let $P_t^*(z)$ denote the reset price. Retailers solve the following problem 3:

$$\text{P3} \quad \max_{P_t^*} \sum_{t=0}^{\infty} \theta^k \mathbb{E}_{t-1} \left[\Lambda_{t,k} \frac{P_t^* - P_{t+k}^w}{P_{t+k}} Y_{t+k}^* \right]$$

$$s.t. \; Y_{t+k}^*(z) = \left(\frac{P_{t+k}^*(z)}{P_{t+k}} \right)^{-\epsilon} Y_{t+k}^f,$$

where $\Lambda_{t,k} = \beta^k (\frac{c_t^h}{c_{t+k}^h})$ is the household relevant discount factor and $X_t = \frac{P_t}{P_t^w}$ is the markup of final goods over intermediate goods. Profits $F_t = (1 - 1/X_t)Y_t$ are rebated to households.

Central bank

The central bank implements the Taylor rule:

$$R_t = (R_{t-1})^{r_R} \left(\pi_{t-1}^{1+r_\pi} \left(\frac{Y_{t-1}}{Y} \right)^{r_Y} \bar{rr} \right)^{1-r_R} e_{R,t}$$

where $\bar{rr}$ and Y are the steady-state real rate and output. The current interest rate responds to the past interest rate, inflation, and output. r_R, r_π, and r_Y indicate the weight that the central bank puts on the past interest rate, inflation, and output, respectively, when making decisions for the current interest rate. $e_{R,t}$ follows a white noise process with zero mean and variance σ_e^2.

6.4 Equilibrium

An equilibrium is an allocation $\{h_t^e, h_t^h, L_t^e, L_t^c, L_t^h, c_t^e, c_t^h, b_t^e, b_t^h, Y_t\}_{t=0}^{\infty}$, together with the sequence of price $\{W_t, R_t, P_t, P_t^w, P_t^*, q_t, \}_{t=0}^{\infty}$, such that, given the sequence of monetary shocks $\{e_{R,t}\}$:

1. Entrepreneurs optimize: $\{c_t^e, b_t^e, h_t^e, L_t^e\}$ solves P1.
2. Corporations optimize: $\{d_t, Y_t^c, L_t^c\}$ solves P2.
3. Retailers optimize: $\{P_t^*\}$ solves P3.
4. Households optimize: $\{c_t^h, b_t^h, h_t^h, L_t^h\}$ solves P4.
5. Labor market clears: $L_t^e + L_t^c = L_t^h$.
6. Housing market clears: $h_t^e + h_t^h = H$.
7. Goods market clears: $c_t^e + c_t^h = Y_t$.
8. Loans market clears: $b_t^e + b_t^h = 0$.

7 Estimation of Model Parameters

The model parameters are set in two ways: externally set with the values in the literature and internally set to target data moments. The majority of the externally set parameter follows Iacoviello (2005). One deviation is the loan-to-value(LTV) ratio, which is selected from Chang (2022), based on the mean LTV ratio for prime mortgages from Freddie Mac. I calibrate the rest of the parameters using the steady-state equilibrium to target moments found in the data. The following section describes the details of the parameters.

7.1 Externally set parameters

Preferences. The household discount factor is set at 0.99, and the entrepreneur discount factor is set at 0.98, following Iacoviello (2005). The assumption that $\gamma < \beta$ ensures the borrowing constraints hold with equality at the steady state. $\beta = 0.99$ and $\gamma = 0.98$ translate

to a steady-state annual return of 8% on entrepreneurs' assets and 4% on households' asset. The households labor supply aversion η is set at 0.18, as in Brown (2013).

Sticky Prices. The degree of price rigidity θ, that is the probability of not changing prices, is set at 0.75; and the steady-state gross markup X is set at 1.05. Both parameters are taken from Iacoviello (2005).

Borrowing Constraints. Entrepreneurs can borrow by collateralizing against housing values. $m = 0.75$ is set as Chang (2022), based on the mean LTV for prime mortgages from Freddie Mac.

7.2 Calibrated parameters

Four parameters are calibrated in the model to target data moments, which are υ, the elasticity of output to entrepreneurial real estate, ρ, housing preference in the utility function of households, μ, the elasticity of output to labor in corporate production function, and the A, technology parameter in corporate production.

The parameter υ, the elasticity of output to entrepreneur real estate, governs the steady-state value of entrepreneur real estate quantity over total housing quantity. I calibrate υ to 0.026, which yields 17% for the steady-state value of entrepreneur real estate quantity over total housing quantity. I target the moment of business owner share of households at 17% as in Salgado (2020). The assumption here is that the housing distribution is same between entrepreneurs and households.

The parameter ρ mainly controls the stock of residential housing over annual output. I calibrate ρ to 0.041 such that the ratio of residential housing value over annual output is 1.28%. I target the average residential housing value over GDP from the flow-of-Funds accounts between 1977 and 2007.

The parameter μ mainly determines the share of the employment by the corporate sector in the model. I calibrate μ to 0.76 such that it matches the large firms employment share of

Table 5: Externally set parameters

Description	Parameter	Value	Source
Preferences			
Households discount factor	β	0.99	Iacoviello (2005)
Entrepreneurs discount factor	γ	0.98	Iacoviello (2005)
Households labor supply aversion	η	0.18	Brown (2013)
Sticky prices			
Steady-state gross markup	X	1.05	Iacoviello (2005)
Probability fixed price	θ	0.75	Iacoviello (2005)
Borrowing constraint			
Loan-to-value ratio	m	0.75	Chang (2022)

Table 6: Calibrated parameters

Description	Param	Value	Target	Model	Data
HH weight on housing	ρ	0.041	Residential Housing Value over GDP	1.28	1.28
Ent. housing share	υ	0.026	Business Owners Share of Households	0.17	0.17
Corp. labor elasticity	μ	0.76	Share of Employment of large firms	0.51	0.52
Corp. technology	A	1.06	Share of Output of large firms	0.55	0.53

52%, an average between 1977 and 2007 using the BDS data.

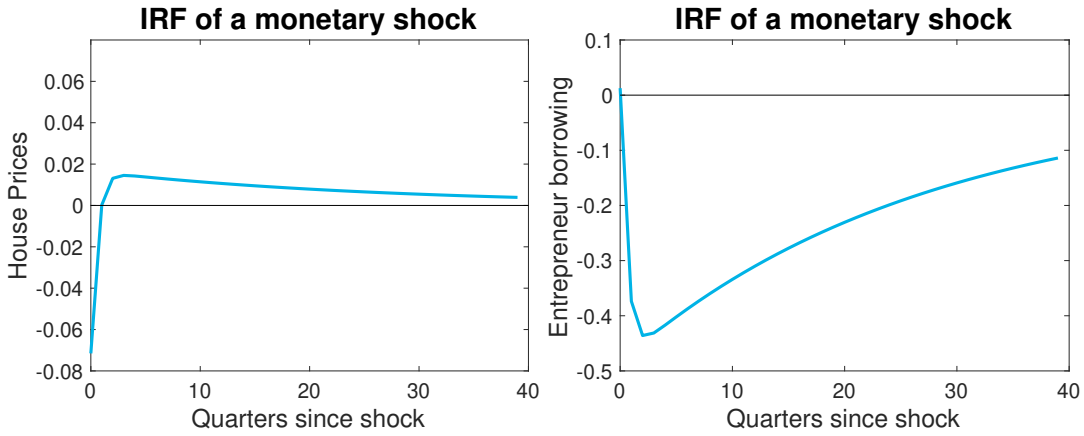
The parameter A mainly determines the share of the output by the corporate sector in the model. I calibrate A to 1.06 such that it matches relatively close to the large firms output share of 0.53, an average between 1998 and 2007 using data from Kobe (2007).

8 Model Analysis

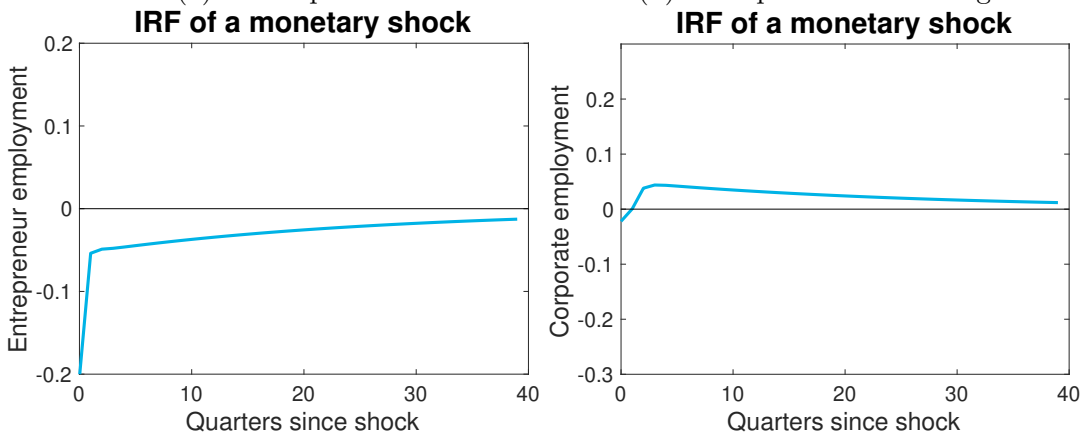
My hypothesis is that younger and smaller firms rely more on pledging personal house as collateral, and thus, these firms are more sensitive to interest rate changes. Specifically, when a contractionary monetary shock occurs, the real interest rate increases and it discourages current consumption and hence output. The effect is propagated by the fall in house prices lowering borrowing, labor demand, and housing investment by the noncorporate sector that collateralized against house value. As a result, the entrepreneur sector's employment responds negatively to the monetary shocks. To test the hypothesis, I generate impulse re-

sponse functions to a monetary shock of the endogenous variables including housing prices, entrepreneurs' borrowing, and employment by entrepreneurs and corporations. The main results are as follows.

Figure 9a shows housing prices respond negatively to a positive monetary shock (an increase in the interest rate). In Figure 9b, the decrease in housing prices reduces entrepreneurs' housing holdings and tightens the borrowing constraints of entrepreneurs. As a result, we observe a significant drop in entrepreneurs employment in Figure 9c, along with a negligible increase in corporations' employment in Figure 9d. In summary, the model produces heterogeneous employment responses of entrepreneurs and corporations to a monetary shock.



(a) House price (b) Entrepreneur borrowing



(c) Entrepreneur's employment (d) Corporate employment

Figure 9: Endogenous variables' responses to monetary shocks

To compare the model and the data, I set the standard deviation of monetary shock in

the model such that it generate the same deviation as in the data for the federal funds rate. Figure 10 displays the impulse responses functions generated in the data and in the model. Considering that corporations' responses being negligible, I then calculate the ratio of the cumulative responses of the entrepreneur sector in the model to that of the small firms in the data. Overall, the model is able to explain 67% cumulative responses of the small firms.

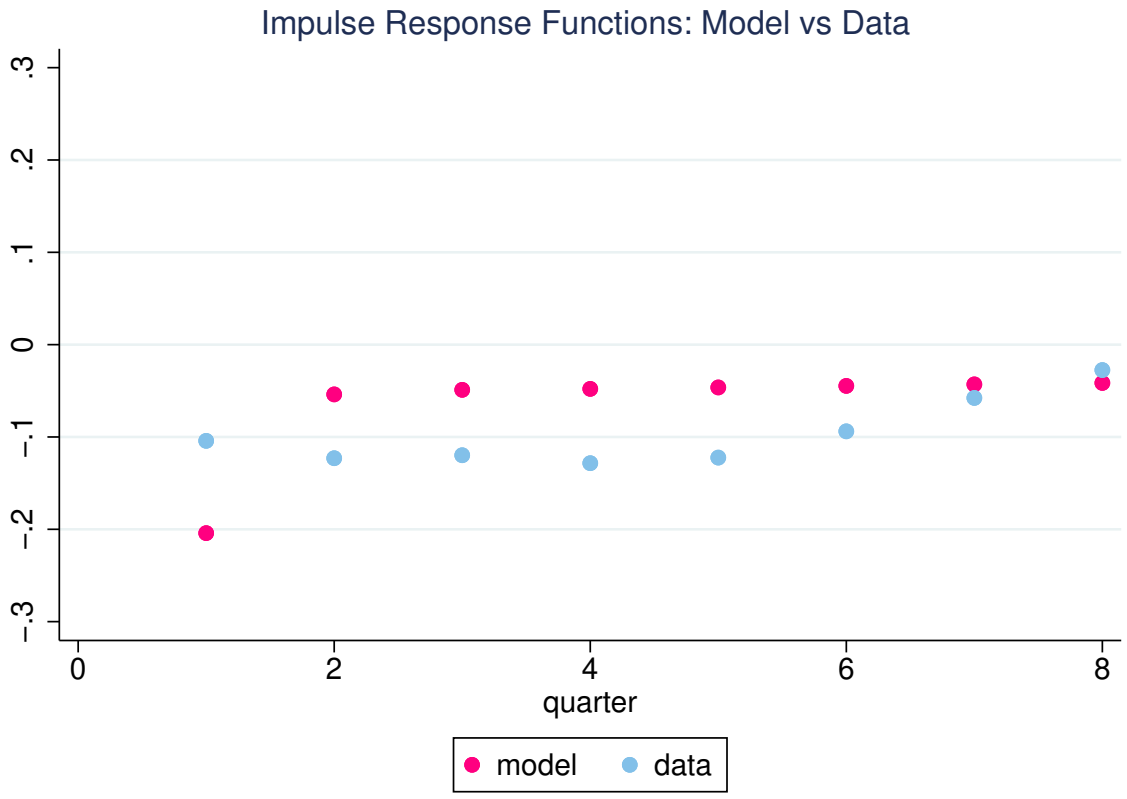


Figure 10: Compare model and data

9 Conclusion

Using data covering the U.S. economy, this paper presents empirical evidence, both at macro-level and micro-level, that smaller or younger firms responds more to monetary shocks in employment. Further, it documents that firms that are smaller and younger are the most responsive groups among others using Census Bureau's restricted microdata. To examine

the role of housing collateral constraints in explaining the heterogeneous responses, I find smaller or younger firm's responses are more strongly correlated with housing prices. Yu (2022) identifies that 1% increase in housing prices raises loan amount to small and young businesses by 0.54%-1.78%. Motivated by this evidence, I use a monetary business cycle model to show that housing collateral channel explains a fair part of the heterogeneous employment responses to monetary policy shocks.

An interesting question can be further explored: Do heterogeneous responses exist based on the employer or employees characteristics, for example, by race, gender, and ethnicity? Are certain groups of individuals more likely to choose housing collateral as a means of finance during entrepreneurship? If so, to what extent could the housing collateral channel explain these heterogeneous responses? The LEHD data provide employer and employee characteristics and therefore, are ideal for examining the topic. The project is approved for access to employer-employee matching files. Hence, a possible extension of the project would be to examine the heterogeneous responses to monetary shocks by employer-employee characteristics and the transmission mechanism of monetary policy.

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A Appendix

A.1 Macro Empirical Evidence: Time Series Imputation

The BDS data are annually starting in 1977 and the QWI data are quarterly starting in 1993. I impute the missing quarterly BDS data with the information from the QWI following Mukoyama, Patterson, and Şahin (2018). The following steps describes the details of the imputation process. Figure 11 illustrate the unscaled imputation results. The gap between the BDS and the QWI originates from their different establishment framework.

Step 1. Construct $\eta = \frac{QWI - Q\tilde{W}I}{QWI}$, $e = \frac{emp - e\tilde{m}p}{emp}$

Step 2. Regress $\eta = \alpha + \beta_1 Q + \beta_2 e$ (for 1993Q1-2017Q2)

Step 3. Predict $\eta = \alpha + \beta_1 Q + \beta_2 e$ (for 1977Q1-1992Q4)

Step 4. Construct $BDS = \frac{B\tilde{D}S}{1-\eta}$

Figure 11: Imputed BDS data with QWI data

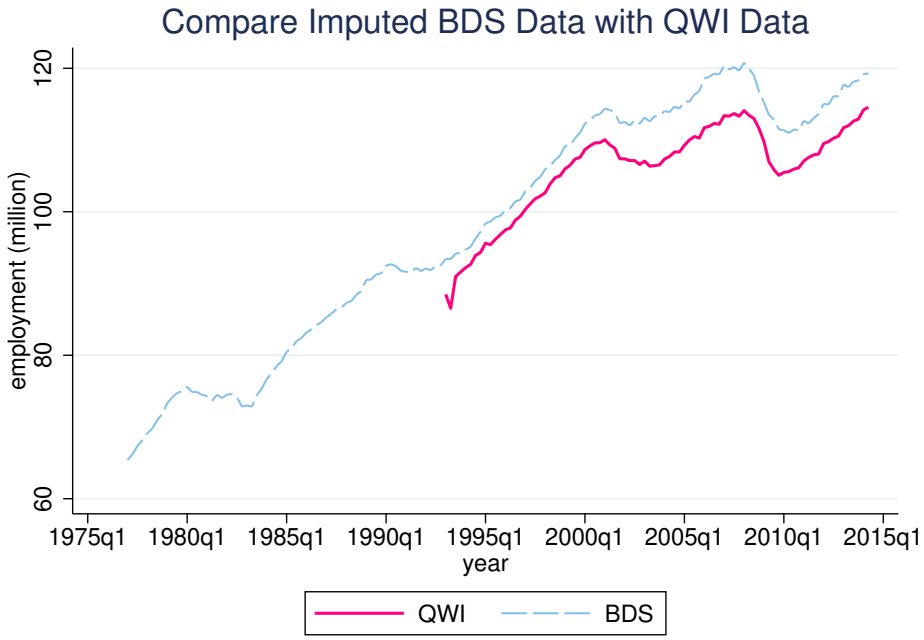
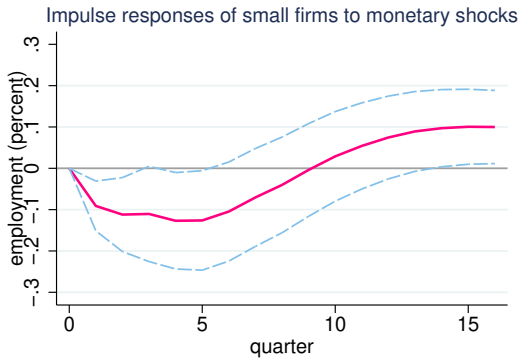
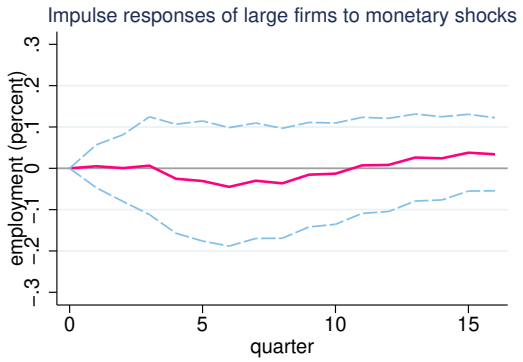


Figure 11.–Imputation results. Note: The blue line denotes the raw QWI quarterly data. The red line denotes the imputed BDS quarterly time series data.

A.2 Macro Empirical Evidence: Robustness



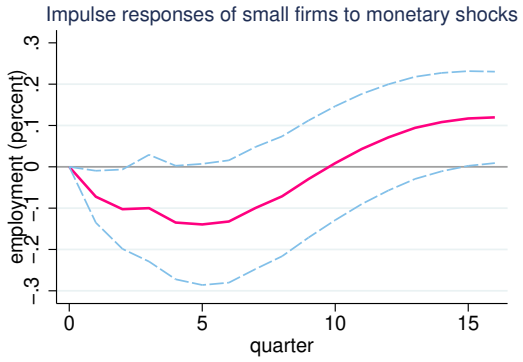
(a) Small



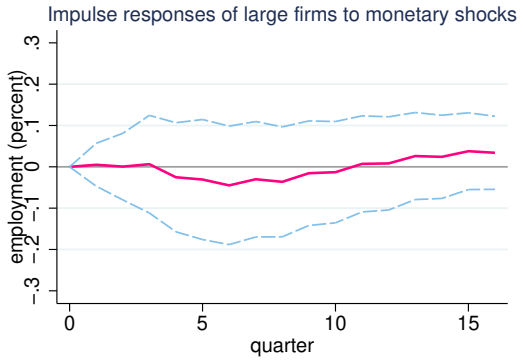
(b) Large

Figure 12: Firms' responses to monetary shocks by size

Note. Light blue bands are 90% confidence bands. Size is measured by total employment and is defined as follows: small (0-49), medium (50-499), and large (500+)



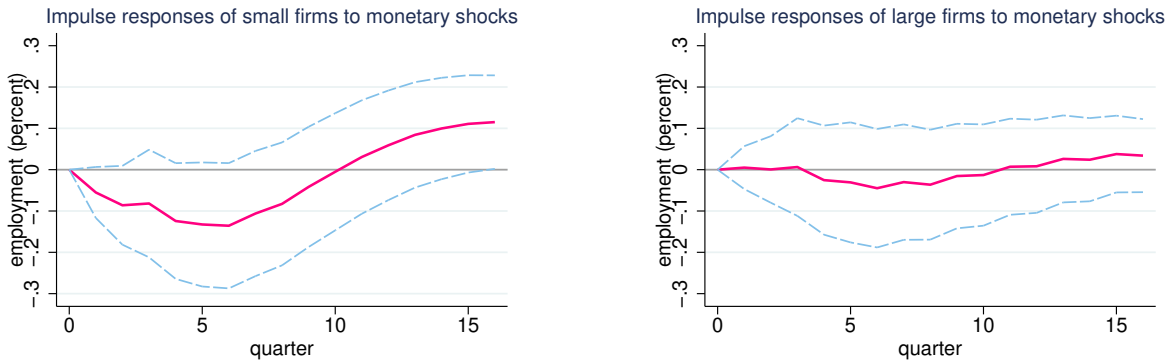
(a) Small



(b) Large

Figure 13: Firms' responses to monetary shocks by size

Note. Light blue bands are 90% confidence bands. Size is measured by total employment and is defined as follows: small (0-249), medium (250-499), and large (500+)



(a) Small (b) Large

Figure 14: Firms' responses to monetary shocks by size

Note. Light blue bands are 90% confidence bands. Size is measured by total employment and is defined as follows: small (0-499), and large (500+)

A.3 Micro Empirical Evidence: Robustness

Table 7: Heterogeneous Responses of Employment to Monetary Policy

Variables	(1)	(2)	(3)
Small	0.190		
	0.000232		
Small × shocks	−0.277		
	0.100		
Young		0.0342	
		0.000205	
Young × shocks		−1.385	
		0.171	
Small and young			0.0611
			0.000222
Small and young × shocks			−2.192
			0.188
Small and old			0.0483
			0.000138
Small and old × shocks			0.0176
			0.0842
Large and young			−0.0102
			0.000834
Large and young × shocks			−1.788
			0.675
Observations	86390000	86390000	86390000
R^2	0.069	0.061	0.063
Firm FE	Yes	Yes	Yes
Time industry FE	Yes	Yes	Yes

The table reports the estimation results of heterogeneous responses of employment to monetary shocks. Column (1) displays the estimation results by firm size, column (2) displays the estimation results by firm age, column (3) displays the estimation results by firm size and age. The sample period is between 1994 and 2007. Size is measured by total employment and is defined as: smaller (0-19), and larger (20+). Age is measured by the years since a firm's establishment and is defined as: start-ups/younger (0-1) and older (2+). Shocks refer to the average of monetary shocks.

Table 8: Heterogeneous Responses of Employment to Monetary Policy

Variables	(1)	(2)	(3)
Small	0.224		
	0.000143		
Small × shocks	-0.498		
	0.0668		
Young		0.0342	
		0.000205	
Young × shocks		-1.385	
		0.171	
Small and young			0.111
			0.000242
Small and young × shocks			-3.448
			0.201
Small and old			0.137
			0.000122
Small and old × shocks			-0.511
			0.0671
Large and young			-0.00371
			0.000383
Large and young × shocks			-2.726
			0.32
Observations	86390000	86390000	86390000
R^2	0.09	0.061	0.076
Firm FE	Yes	Yes	Yes
Time industry FE	Yes	Yes	Yes

The table reports the estimation results of heterogeneous responses of employment to monetary shocks. Column (1) displays the estimation results by firm size, column (2) displays the estimation results by firm age, column (3) displays the estimation results by firm size and age. The sample period is between 1994 and 2007. Size is measured by total employment and is defined as: smaller (0-4), and larger (5+). Age is measured by the years since a firm's establishment and is defined as: start-ups/younger (0-1) and older (2+). Shocks refer to the average of monetary shocks.