Monetary Policy and Corporate Default

Abolfazl Rezghi*

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Abstract

This paper shows that a contractionary monetary shock would increase the number of defaults and the aggregate liability of defaulted firms in the economy. The adverse effect of firms' default on the balance sheet of banks lowers the supply of credit and forces the interest rate of loans to rise. As a result, the cost of production grows even further, and more firms decide to file for bankruptcy. Using a DSGE framework, I show that Monetary policy can dampen this amplification mechanism by considering financial variables in the policy rule.

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*Department of Economics, University of Texas at Austin. Contact: Rezghi@utexas.edu

1 Introduction

Central banks use Taylor rule to stabilize inflation at low levels and manage the economic fluctuations ((Clarida et al. 2000)). The standard Taylor rule prescribes that interest rates should be adjusted more than one-for-one to an increase in inflation all the while considering real variables like output gap. During the financial crisis of 2008, Federal Reserve deviated from the standard rule by aggressively reducing federal fund rates even though inflation was on the rise and there was no sign of a decline in GDP (Cúrdia and Woodford 2010). This deviation in practice occurred because the Fed was trying to deal with severe problems in the financial sector. Although this happened during a financial crisis, considering variables in the financial sector might be beneficial in the conduct of monetary policy as a general rule, especially when monetary policy shocks are the primary source of aggregate disturbances. The central objective of this research is to see if paying attention to factors in the financial sector, such as aggregate credit, default rate, and credit spread, over applying the standard monetary policy rule would lead to a better response of the economy to monetary policy shocks.

In this study, I consider the adverse effect of monetary shocks on firm default. I show that contractionary monetary shocks increase the number of firms that default and subsequently, the aggregate liability of defaulted firms. The initial effect of monetary shocks then can be reinforced via two different mechanisms and thus leads to a more substantial impact on the economy. One mechanism is the "bank lending channel", and the other is the "competition channel."

If a business fails and its debt becomes past due or nonperforming, the risk weight of the loan increases for the bank. Consequently, the bank has to raise its capital to abide by the capital requirement regulations. Also, the bank will incur a loss if the principal and interest of the loan are not going to be fully repaid. Both increasing the capital and not getting the loan back, raises the bank's cost and lowers the supply of credit. As a result, banks would increase the interest rate on loans, which leads to a rise in the cost of production and forces more firms to fail. If the failed firm decides to cease its operation and leaves the market, the competition among firms will decline due to having a fewer number of firms. As a result, markups will rise, and aggregate output will decrease even further following a contractionary shock.[1]

[1] Contractionary shocks can also decrease the number of entry as documented by Bergin and Corsetti (2008), Lewis and Poilly (2012), and Uusküla (2016). This also leads to an increase in the markups, since Campbell and Hopenhayn (2005) document a negative correlation between markups and entry in many sectors of the US economy.

Based on these two mechanisms, I claim that the financial sector has an essential role in the propagation and reinforcement of monetary shocks throughout the economy. Thus, incorporating an indicator from the financial sector such as aggregate credit, and considering the default rate into the policy rule might alleviate the overall impact of adverse monetary shocks. This Speculation will be investigated in this study.

Depending on the nature of the shock, different studies suggest different modification of Taylor rule. Christiano et al. (2021) answered this question in an environment with news shock on future productivity. They showed that a modified version of monetary policy that does not promote boom and bust is preferred to standard inflation targeting rule. Since credit growth is strongly procyclical in their model, they propose adding aggregate credit growth to the monetary rule to "lean against the wind." Cúrdia and Woodford (2010) find that an adjusted Taylor rule, which includes the credit spread, can reduce the distortions caused by financial disturbances. However, a monetary rule that responds to changes in the aggregate credit is not as effective as a credit-spread-adjusted rule in their model. Cúrdia and Woodford (2016) propose implementing flexible inflation targeting by adjusting the standard Taylor rule for the changes in current and future expected credit spreads to improve the welfare.[2]

The closest paper to this project is Bhamra et al. (2011), where they compare two extreme cases of monetary policy: interest rate peg, and inflation targeting. In their model, passive interest rate peg policy generates procyclical inflation and increases the incentive for corporate default after a negative productivity shock hits. The other policy rule that they investigate is inflation targeting. An inflation targeting policy that eliminates procyclical inflation can dampen the amplification mechanism that causes more default. They show that full inflation targeting requires considering credit market conditions, like default rate, in their policy rule. They assume fixed-rate perpetual debt in their model without any other source of nominal rigidity. In contrast, I allow for short term one-period debt with price stickiness. Moreover, I incorporate the competition and bank lending channels in the model while they ignore.

Tayler and Zilberman (2016) also suggest a modification to the Taylor rule and find the optimum monetary policy for both cases of supply and credit shock. Their model prescribes that the central bank should reduce its inflation response in the Taylor rule,

[2]Other studies propose a combination of credit-augmented Taylor rule with macroprudential policies to minimize the welfare losses. see, e.g., Kannan et al. (2012) , Angelini et al. (2014), Rubio and Carrasco-Gallego (2014) , and Angeloni and Faia (2013)

despite higher inflationary pressures.[3] While they try to answer a similar question, they do not investigate the optimum monetary policy in the presence of monetary shocks. Moreover, bankruptcy in their model does not result in exiting the market, and thus, they assume a fixed number of firms. The banking structure in their model is a competitive one, while I consider monopolistic banking that allows for having nominal rigidities in the financial sector.

The basis of the model is adopted from the seminal paper by Bilbiie et al. (2012) on business cycle with endogenous entry. Their framework replicates several features of the business cycle, and variants of it are widely used in the literature of endogenous entry and exit. Endogenous default is incorporated in the model by following Rossi (2019), and the monopolistic banking sector is based on Gerali et al. (2010). Using the model, I show that including aggregate credit and default rate in the monetary policy rule improves the response of the economy to shocks and brings more stability.

The remainder of this study is structured as follows: In section 2, I provide the empirical evidence on the effect of monetary shocks on corporate default and the liabilities of defaulted firms. Section 3 describes the model, section 4 discusses the results, and section 5 concludes.

2 Empirical Evidence

2.1 Data

The data on *Business Failure* and *Liabilities* come from Dun & Bradstreet (D&B), a company that provides commercial data and analytics for businesses. The D&B dataset covers almost 90 percent of the enterprises in the economy (Uusküla 2016). The monthly data series are available from 1953 to 1994 in the Survey of Current Business.

Business Failure statistics include businesses that ceased operation with losses to creditors after foreclosure or attachment; were involved in court actions such as receivership, reorganization or arrangement; or voluntarily compromised with creditors. It is worth to note that business failure is different from business discontinuance. According to this definition, businesses that discontinue operations and exit the market are not recorded as failures if creditors are paid in full. Also, not all of the business failures necessarily result in exiting the market.

[3] They find that countercyclical banking regulations like Basel III, is much more capable of stabilizing the economy following a credit shock.

Liabilities represents approximately current liabilities. Current liabilities include all accounts and notes payable and all obligations, whether in secured form or not. These liabilities are known to be held by banks, officers, affiliated companies, supplying companies, or the Government. They do not include long-term, publicly held obligations. Offsetting assets are also not taken into account.

Since the D&B dataset does not cover the universe of the firms, data on the business bankruptcy filing is also used as a robustness check. This dataset which is provided by the US bankruptcy court includes all business bankruptcy filing under chapter 7 and 11 of US bankruptcy code and runs from 1960Q3 to 2011Q2.

In Appendix B, I also use the data on establishment exit from *Business Employment Dynamic* dataset to measure the impact of monetary shocks on total exit. All data are seasonally adjusted.

2.2 Empirical Framework

In order to investigate the effect of Romer and Romer (2004) (henceforth R&R) monetary policy shocks, I use the Jordà (2005) local projection method. Local projection allows us to estimate the IRFs to externally-identified shocks. I use the monetary shocks generated in R&R and the updated R&R shock, which is extended to 2008 by Coibion et al. (2017). R&R identify monetary policy shocks as changes to the intended Federal Funds rate that is not predictable by the economic information in the Federal Reserve's "Greenbook" forecasts. The local projection method also allows for non-linearities and sign-dependence. In the baseline model, I assume both linearity and symmetry. In appendix A, these two assumptions are relaxed and tested as a robustness check.

The effect of 1 unit monetary policy shock, which corresponds to 1 percent R&R monetary shock, on the variable of interest y_t, h period after shock s_t hits can be estimated using the following regression:

$$y_{t+h} - y_t = \boldsymbol{\beta_h'} \boldsymbol{X_t} + \gamma_h s_t + \epsilon_{t,h} \tag{1}$$

$\boldsymbol{X_t}$ is the vector of controls that might affect the variation in the dependent variable. The control variables are one year of lags for the shocks and the dependent variable, a constant and a time trend. According to Jordà (2005), the impulse response of y_t to the shock s_t after h period is given by γ_h. The standard error of the estimate is the standard error of γ_h itself.

2.3 Results

Since D&B broadened the scope of businesses that included in their dataset after 1984, the total number of failures before and after this period are not directly comparable. Also, there is a steep increase in the number of business failures after 1980, which can affect the trend term in equation 1. Here I use the data from 1966M1-1979M12 to estimate the IRFs.

Figure 1 and 2 show the impulse response function of business failure and total liability of defaulted firms to 1 percent R&R contractionary monetary shock. The number of business failure rises by more than 18 percent almost two years after the shock hits. This result is qualitatively in line with Uusküla (2016) in which the monetary shocks are identified by using a VAR model. The total liability of defaulted firms also increases with approximately the same magnitude. The data on liability is highly noisy, even after seasonally adjusting. Thus the IRF of liability is not as smooth as the IRF of business failure.[4] The shaded area represents the 90 percent confidence interval. The confidence interval is calculated by using the standard deviation of γ_h in the equation 1, which is adjusted as in Newey and West (1987) to deal with serial correlation.

US court data on the business bankruptcy filing, which reports total bankruptcies in each quarter from 1960 to 2011, enables us to use the updated R&R shocks. Figure 3 shows the IRF of the bankruptcy filing to one percent R&R contractionary monetary shock. The effect of monetary shocks on the bankruptcy filing provided by US court is qualitatively the same as its effect on business failure data by D&B. These results recommend that monetary policy shocks lead to disturbances in the financial sector through their impact on business failure and the aggregate liabilities of defaulted firms.

3 The Model

In the previous section, I showed that monetary shocks could cause disturbances in the financial sector through impacting bankruptcy and liabilities of defaulted firms. These disturbances propagate throughout the economy due to the tight relationship between businesses and the financial sector. This observation leads us to question the effectiveness of standard Taylor rule, which ignores the financial sector, in stabilizing the economy following a monetary shock.

In this section, I closely follow Rossi (2019) and present a model with endogenous

[4] Appendix A shows that the assumptions of symmetry and linearity in shocks can be rejected at 90 percent confidence interval for total liabilities.

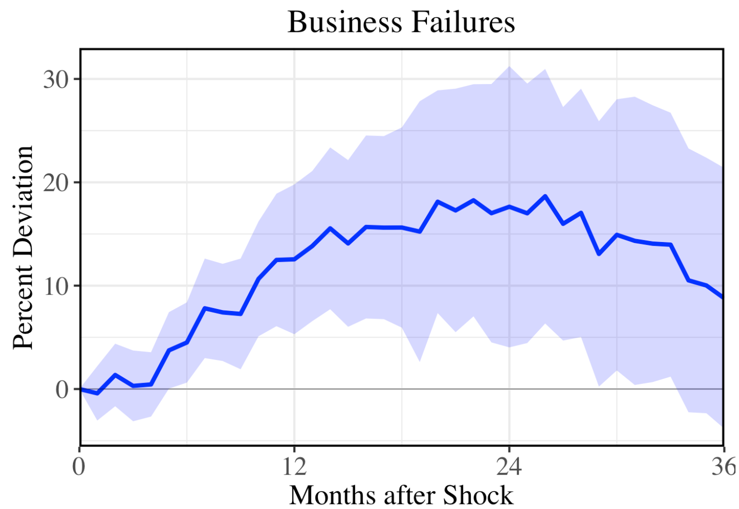

Figure 1: IRF of business failure to 1 percent contractionary monetary shock

Notes: The shaded area represents 90 percent confidence interval.

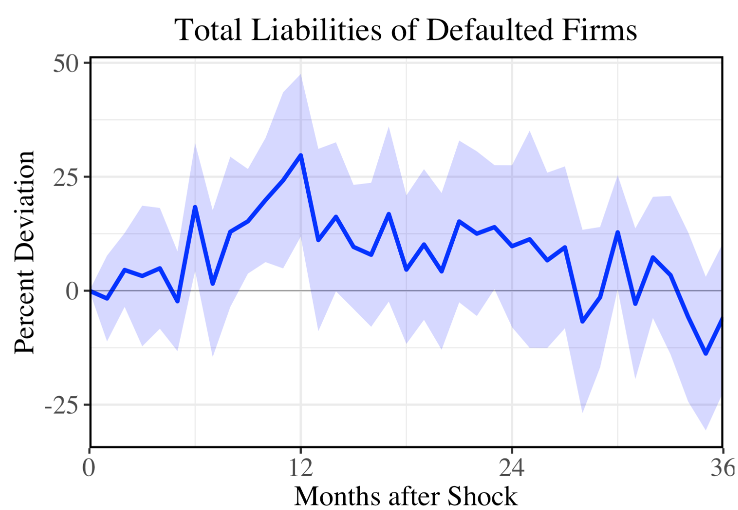

Figure 2: IRF of aggregate liabilities of defaulted firms to 1 percent contractionary monetary shock

Notes: The shaded area represents 90 percent confidence interval.

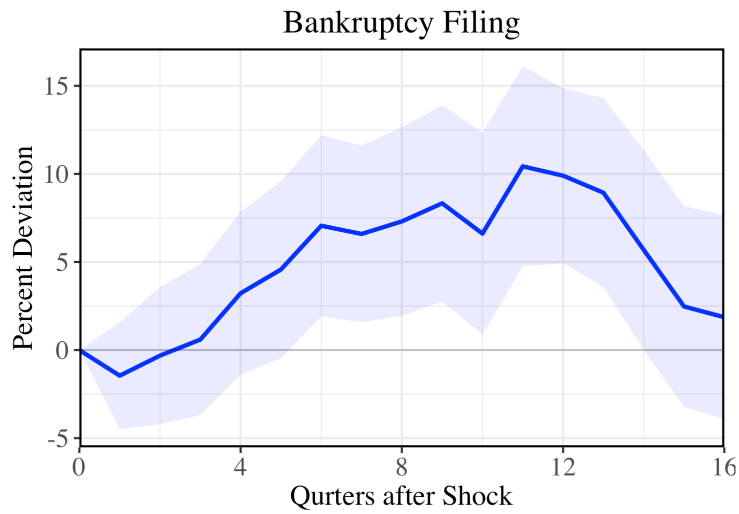

Figure 3: IRF of business bankruptcy filing to 1 percent contractionary monetary shock

Notes: The shaded area represents 90 percent confidence interval.

default to investigate if incorporating variables from the financial sector like aggregate credit in the monetary rule results in a better response of the economy to monetary shocks. The basis of the model is adopted from Melitz and Ghironi (2005) and Bilbiie et al. (2012). Endogenous default is incorporated in the model by following Rossi (2019) , and the monopolistic banking sector is based on Gerali et al. (2010). There are four types of agents in the model that I explain in following sections: firms, households, banks, and central bank.

3.1 Firms

Firms in the economy produce three types of goods: final good , industry good, and intermediate good.

3.1.1 Final Good

The final good producer bundles the differentiated industry goods $Y_t^I(i)$, taking as given their price $P_t^I(i)$ and sells the output Y_t at the competitive price P_t. The final good firm's optimization problem is:

$$\max_{Y_t^I(i)} \left\{ P_t Y_t - \int_0^1 Y_t^I(i) P_t^I(i) di \right\} \tag{2}$$

Subject to the CES production function:

$$Y_t = \Big(\int_0^1 Y_t^I(i)^{\frac{\theta_i - 1}{\theta_i}} di \Big)^{\frac{\theta_i}{\theta_i - 1}} \tag{3}$$

Where θ_i is the elasticity of substitution between industry goods. The first order conditions give the demand functions for industry goods:

$$Y_t^I(i) = \left(\frac{P_t^I(i)}{P_t} \right)^{-\theta_i} Y_t \tag{4}$$

And the aggregate price in terms of industry good prices will be:

$$P_t = \left(\int_0^1 P_t^I(i)^{1-\theta_i} di \right)^{\frac{1}{1-\theta_i}} \tag{5}$$

Solving the model for symmetric equilibrium results in $Y_t^I(i) = Y_t$ and $P_t^I(i) = P_t$ for all sectors i.

3.1.2 Industry Goods

Industry good producers buy the intermediate goods from the firms, bundle them and sell them to the final good producer. The Industry good producers compete against each other in a monopolistic way and set the price in a Calvo (1983) Calvo (1983) fashion. The only reason for introducing the industry good producer in the model is to have nominal rigidities while the intermediate goods producers are setting price flexibly. The optimization problem of the firms consists of two stages. First, they minimize their expenditures on intermediate goods:

$$\min_{y_t(\omega)} \int_{\omega \in \Omega_t} p_t(\omega) y_t(\omega) d\omega \tag{6}$$

s.t.

$$Y_t^I = \left(\int_{\omega \in \Omega_t} y_t(\omega)^{\frac{\theta_f - 1}{\theta_f}} d\omega \right)^{\frac{\theta_f}{\theta_f - 1}} \tag{7}$$

Where Ω is the set of operating firms and θ_f is the elasticity of substitution between intermediate goods. Solving this problem results in:

$$\int_{\omega \in \Omega_t} p_t(\omega) y_t(\omega) d\omega = \lambda_t Y_t^I \tag{8}$$

and

$$y_t(\omega) = (\frac{p_t(\omega)}{\lambda_t})^{-\theta_f} Y_t^I \tag{9}$$

Where

$$\lambda_t = \left(\int_{\omega \in \Omega_t} p_t(\omega)^{1-\theta_f} d\omega \right)^{\frac{1}{1-\theta_f}} \tag{10}$$

In the second stage, industry good firms set the price P_t^I to maximize their expected sum of discounted profit, while facing a Rotemberg (1982) price adjustment cost:

$$\max_{P_{t+i}^I} \mathbb{E}_t \sum_{i=0}^{\infty} \Lambda_{t,t+i} \left[(\frac{P_{t+i}^I}{P_{t+i}} - \frac{\lambda_{t+i}}{P_{t+i}})(\frac{P_{t+i}^I}{P_{t+i}})^{-\theta_i} Y_{t+i} - \frac{\kappa_p}{2}(\frac{P_{t+i}^I}{P_{t-1+i}^I} - 1)^2 Y_{t+i} \right] \tag{11}$$

Where κ_p determines the level of price rigidity in the model. $\Lambda_{t,t+i}$ is the stochastic discount factor that comes from the household side in the general equilibrium. Using first order condition and imposing symmetry result in:

$$1 - \theta_i(1 - \frac{\lambda_t}{P_t}) - \kappa_p \frac{P_t}{P_{t-1}}(\frac{P_t}{P_{t-1}} - 1) + \mathbb{E}_t \Lambda_{t,t+1} \left(\kappa_p \frac{P_{t+1}}{P_t}(\frac{P_{t+1}}{P_t} - 1)\frac{Y_{t+1}}{Y_t} \right) = 0 \tag{12}$$

3.1.3 Intermediate Goods

The model is populated by unit mass of sectors. In each sector, there are N_t measure of firms, indexed by i, which are competing against each other in a monopolistic way. Firms have a linear production function and only use labor l_{it} as their input: $y_{it} = z_{it} l_{it}$. z_{it} is the productivity of firm i that will be drawn from a Pareto distribution in each period. The CDF of the distribution is given by $G(z_t) = 1 - (\frac{z_m}{z_t})^{\alpha}$.

Following Rossi (2019), I assume that each firm has to pay a fixed production cost of f^F in terms of final good in each period. This fixed cost needs to be financed at the beginning of each period by borrowing b_{it} from the financial sector prior to drawing the productivity. Firms have to pay the loan back at the end of the same period. Therefore, the real profit d_{it} of firm i in time t can be written as:

$$d_{it} = \frac{p_{it}}{P_t} y_{it} - w_t l_{it} - f^F + b_{it} - b_{it}(1 + r_t^b) \tag{13}$$

where p_{it} is the price of the intermediate good, P_t is the price of final good, w_t is the real wage, and r_t^b is the interest rate.

A firm given staying in the market will solve the following static problem:

$$\max_{p_{it}} \left(\frac{p_{it}}{P_t} - \frac{w_t}{z_{it}}\right) y_{it} - f^F(1 + r_t^b) \tag{14}$$

s.t.

$$y_{it} = \left(\frac{p_{it}}{\lambda_t}\right)^{-\theta_f} Y_t^I \tag{15}$$

Assuming that firm's pricing decision does not affect the industry prices, the FOC results in:

$$p_{it} = \frac{\theta_f}{\theta_f - 1} \frac{w_t}{z_{it}} P_t \tag{16}$$

$\tilde{v}_t$, the average value of the entrants and incumbents after production, will be defined as follows:

$$\tilde{v}_t = \mathbb{E}_t \sum_{i=1}^{\infty} \Lambda_{t,t+i} \tilde{d}_{t+i} \tag{17}$$

In other words, the average value equals the present value of the expected future stream of the average real profits $\tilde{d}_t$.

3.1.4 Entry and Default Decisions

In each period and for each sector, there is an unbounded measure of prospective firms which consider entering the market. Prior to entry, firms are identical and face an exogenous sunk entry cost of $f^E N_t^E$ in terms of final good. This assumption captures the fact that the cost of entry increases in the entry rate due to congestion (Savagar and Dixon 2017). The number of entrants N_t^E will be pinned down by free entry condition: $\tilde{v}_t = f^E N_t^E$. The prospective firms that pay the sunk entry cost, will enter the market in the next period.[5]

After borrowing from the banks, incumbent and entrant firms draw their productivity from a Pareto distribution. Then they calculate their expected present value of the flow of their profit and decide if it is profitable to operate in the economy or default on the loan. Defaulting on the loan results in leaving the market. In this framework, the firms that have a productivity higher than $\underline{z}_t$ will stay in the market and firms with $\underline{z}_t$ earns zero net present profit:

$$d_t(\underline{z}_t) + \tilde{v}_t = 0 \tag{18}$$

[5] This one period lag is a way to consider the time-to-build period as in BGM (2012).

By having the number of entrants and incumbents and the probability of default, the law of motion of the number of operating firms will be:

$$N_t = \eta_t \big(N_{t-1} + N_{t-1}^E \big) \tag{19}$$

Where $1 - \eta_t$, the probability of default, is equal to $1 - (\frac{z_m}{\underline{Z}_t})^{\alpha}$.

3.2 Households

There is a continuum of representative households h that live forever, consume final good C_t, supply labor $L_{h,t}$ to a CES labor aggregator in a monopolistic competition by setting wage $w_{h,t}$, and maximize the sum of expected discounted utility given the budget constraint that face in each period. Households deposit $D_{h,t}$ in banks and earn interest with the rate r_t^d. Also, they invest in the stock of mutual fund of operating firms by buying share s_{t+1} of the fund. Households maximization problem is:

$$\max_{C_{h,t}, w_{h,t}, D_{h,t}, s_{t+1}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Big(\frac{C_{h,t}^{1-\sigma}}{1-\sigma} - \frac{L_{h,t}^{1+\phi}}{1+\phi} \Big) \tag{20}$$

Subject to Household's budget constraint:

$$\begin{aligned} C_{h,t} + D_{h,t} + (N_t + N_t^E)\tilde{v}_t s_{t+1} + \frac{\kappa_w}{2}\Big(\frac{w_{h,t}}{w_{h,t-1}} - 1\Big)^2 Y_t = w_{h,t} L_{h,t} + \\ (1 + r_{t-1}^d)\frac{D_{h,t-1}}{\pi_t} + N_t(\tilde{d}_t + \tilde{v}_t)s_t + T_t \end{aligned} \tag{21}$$

Where $\pi_t = \frac{P_t}{P_{t-1}}$, $L_{h,t} = (\frac{w_{h,t}}{w_t})^{-\theta_w} L_t$, and T_t is the transfer from firms' fixed cost, entry cost, and adjustment cost payments to households. $\frac{\kappa_w}{2}(\frac{w_{h,t}}{w_{h,t-1}} - 1)^2 Y_t$ is the wage adjustment cost to generate real wage rigidity in the model. Using FOCs and imposing symmetry result:

$$\theta_w \frac{L_t^{\phi}}{C_t^{-\sigma}} + (1 - \theta_w) w_t - \kappa_w (\pi_t^w - 1)\pi_t^w \frac{Y_t}{L_t} + \beta \Big(\frac{C_{t+1}}{C_t}\Big)^{-\sigma} \kappa_w (\pi_{t+1}^w - 1)\pi_{t+1}^w \frac{Y_{t+1}}{L_t} = 0 \tag{22}$$

$$1 = \beta(1 + r_t^d)\mathbb{E}_t \Big[\Big(\frac{C_{t+1}}{C_t}\Big)^{-\sigma} \frac{1}{\pi_{t+1}} \Big] \tag{23}$$

$$\tilde{v}_t = \beta \mathbb{E}_t \Big[\Big(\frac{C_{t+1}}{C_t}\Big)^{-\sigma} \eta_{t+1} (\tilde{d}_{t+1} + \tilde{v}_{t+1}) \Big] \tag{24}$$

Forward iteration of the FOC for share holdings and the absence of speculative bubbles yield the asset price given in equation 17, And the stochastic discount factor:

$$\Lambda_{t,t+i} = \beta^i (\frac{C_{t+i}}{C_t})^{-\sigma} \prod_{s=1}^{i} \eta_{t+s} \tag{25}$$

3.3 The Banking Sector

The structure of banking sector is adopted from Gerali et al. (2010). Each bank has three different branches, two retail branches and one wholesale branch. The retail branches are responsible for raising differentiated deposits and giving out differentiated loans. The wholesale unit manages the capital position of the group. Retail branches in this framework can have monopolistic power and set the rates for loans and deposits, while the wholesale branches compete in a competitive market.

3.3.1 Wholesale Branch

Wholesale branch combines bank capital K_t and wholesale deposits D_t and issue wholesale loans B_t. The balance sheet identity has to hold for the banks. The total amount of loans equals the sum of deposits and banks' capital :

$$B_t = D_t + K_t \tag{26}$$

The bank capital adjusts slowly through accumulation of banks earnings:

$$\pi_t K_t = (1 - \delta) K_{t-1} + J_{t-1} \tag{27}$$

where J_t is overall real profits made by three branches of each bank and δ measures resources used up in managing bank capital.

Also banks have to abide by banking regulations on capital requirements. I assume that banks target an exogenous capital adequacy ratio ν, which is set by the policymaker and any deviation from this target is costly. Banks use the risk weights that are also determined by the regulator to calculate the capital adequacy ratio[6]. In order to see the effect of this regulation in this framework I make another simplifying assumption. In

[6]According to Basel III guidelines, risk weight of a loan changes from 100 percent to 150 percent if the loans becomes past due. In contrast, Risk weight of a loan generally does not change if the loan becomes past due according to Basel I, except for certain residential mortgage loans.

periods that more default occurs, the risk-weighted asset of a bank is larger. I define $B_t^W = \zeta B_t + (1-\zeta) w^b B_t$ as the risk weighted asset of a bank in time t. ζ is the share of the loans that firms do not default on, and w^b is the risk weight associated with defaulted loans.

I assume that banks have access to unlimited finance at the policy rate r_t. The optimization problem of wholesale branch is to choose loans and deposits so to maximize the discounted sum of real cash flows:

$$\max_{B_t, D_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \Big[(1+R_t^b) B_t - B_{t+1}\pi_{t+1} + D_{t+1}\pi_{t+1} - (1+r_t) D_t + (K_{t+1}\pi_{t+1} - K_t) - \frac{\kappa}{2} \Big(\frac{K_t}{B_t^W} - \nu\Big)^2 K_t \Big] \tag{28}$$

Subject to a balance sheet constraint. The FOC results in:

$$R_t^b = r_t - \kappa \Big(\frac{K_t}{B_t^W} - \nu\Big)\Big(\frac{K_t}{B_t^W}\Big)^2 \tag{29}$$

3.3.2 Retail Banking: Loan Branch

I assume that households offer a basket of differentiated deposits that is bundled using a CES aggregator. Likewise, each firm demands a basket of differentiated loan bundled using a CES aggregator.

Retail loan branch j borrows $B_t(j)$ from the wholesale branch and sells them to the firms charging a markup. Since firms borrow before drawing their productivity, bank j charges all of them with the same rate r_{jt}^b. Each firm demands a CES bundle of loans from all banks and the banks compete in a monopolistic way to supply the loans. Given the demand of a firm for the bundle of loans b_t, the demand for loans of bank j will be:

$$b_{jt} = \Big(\frac{r_{jt}^b}{r_t^b}\Big)^{-\epsilon^b} b_t \tag{30}$$

Where ϵ^b is the elasticity of substitution between banks, and $r_t^b = \big(\int_0^1 {r_{jt}^b}^{1-\epsilon^b} dj\big)^{\frac{1}{1-\epsilon^b}}$.

The profit maximization problem of the retail loan branch j, assuming flexible rates, is:

$$\max_{r_{jt}^b} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \Big[\eta_t r_{jt}^b b_{jt} - R_t^b B_{jt} - \gamma (1-\eta_t) b_{jt} \Big] \tag{31}$$

subject to $B_{jt} = b_{jt}$ and equation 30.

Assuming symmetric equilibrium results in $b_{jt} = b_t$, and $B_{jt} = B_t$. From the FOC and imposing symmetry the rate of loans will be:

$$r_t^b = \frac{\epsilon_b}{(\epsilon_b - 1)\eta_t}\left(R_t^b + \gamma(1 - \eta_t)\right) \tag{32}$$

Where γ is the ratio of loans of defaulted firms that are not going to be repaid to the bank.

3.3.3 Retail Banking: Deposit Branch

The retail deposit branch j collects the deposit from households and passes the raised funds D_{jt} to the wholesale branch and earn interest with rate of r_t. Household offers a CES bundle of deposits to all retail banks, seeking to maximize his revenue from total saving. The retail deposit banks compete with each other on rates that they offer to the household. Given the total unit of bundled deposit D_t^h that a household wants to save, bank j's demand of deposit d_{jt} from the household will be:

$$d_{jt} = (\frac{r_{jt}^d}{r_t^d})^{-\epsilon^d} D_t^h \tag{33}$$

Where ϵ^d is the elasticity of substitution between banks and $r_t^d = (\int_0^1 {r_{jt}^d}^{1-\epsilon^d} dj)^{\frac{1}{1-\epsilon^d}}$.

The optimization problem of retail deposit branch j will be:

$$\max_{r_{jt}^d} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[r_t D_{jt} - r_{jt}^d d_{jt} \right] \tag{34}$$

Subject to 33 and $D_{jt} = d_{jt}$. From the FOC and imposing symmetry condition the interest rate on deposits will be:

$$r_t^d = \frac{\epsilon^d}{\epsilon^d - 1} r_t \tag{35}$$

The aggregate profit of the branch is sum of the profit of these three branches. Deleting intragroup transaction yields:

$$J_t = \eta_t r_t^b b_t - r_t^d D_t - \frac{\kappa}{2}(\frac{K_t}{B_t^W} - \nu)^2 K_t - \gamma(1 - \eta_t) b_t \tag{36}$$

3.4 Market Clearing

The equilibrium is symmetric across industries. In the equilibrium, all markets should clear. The clearing condition for the deposit market is $D_t^h = D_t$, for the loan market is $b_t = B_t = N_t f^F$, and for the labor market is $\int_{\omega \in \Omega} l_t(\omega) d\omega = L_t$.

The final good will be consumed by consumers and accumulated as bank capital. Firms use final good to pay for the sunk entry costs and the fixed cost of production. Also, banks, households, and the industry good producers use it to pay for their adjustment costs. The market clearing condition for final good is:

$$Y_t = C_t + J_t + WAC_t \tag{37}$$

where WAC_t is the wage adjustment cost in the model. Since I assume that the fixed cost of production and firms' adjustment costs will be paid to the households, it does not enter the market clearing equation of final good.

3.5 Central Bank

To close the model, I assume that central bank follows an adjusted Taylor rule:

$$ln(\frac{1+r_t}{1+r}) = \phi_r ln(\frac{1+r_{t-1}}{1+r}) + (1-\phi_r)\big(\phi_\pi ln(\frac{\pi_t}{\pi}) + \phi_x ln(\frac{x_t}{x})\big) + \epsilon_t \tag{38}$$

x_t is a variable from the financial sector like aggregate credit or default rate, and x is its steady state value. r and π are the steady state values for interest rate and inflation. ϕ_π and ϕ_x are the elasticity of the nominal interest rate with respect to the deviation of inflation and credit variable from their steady states. ϕ_r is the degree of persistence in the interest rate rule. Following Tayler and Zilberman (2016), I do not include output in the policy rule, as a response to output in the Taylor rule results in negligible welfare gains (see also Schmitt-Grohé and Uribe 2007). ϵ_t is an AR(1) monetary policy shock with persistence ρ_ϵ and standard error σ_ϵ. Appendix B summarizes all the log linearized equations of the model.

3.6 Calibration

I set $\beta = 0.99$ and $\sigma = 2$ which are standard choices for quarterly business cycle models. The Frisch elasticiy of labor supply ϕ is set at 0.25 as in Bilbiie et al. (2012). Following

Gerali et al. (2010), I choose the elasticity of substitution between deposit $\epsilon_d = -1.46$, the elasticity of substitution between loan banks $\epsilon_b = 3.12$, and the leverage deviation cost parameter $\kappa = 11.49$. The bank capital adequacy ratio ν is set at 0.08, which represents a floor value under Basel III. Risk weight of past due loans ω^b is set at 1.5, according to Basel III. δ is set at 0.20 which ensures that the ratio of bank capital to risk weighted loans is 0.08.

The steady state default rate $1 - \eta = 0.0293$ as in Rossi (2019). I set the rate of defaulted loans that will not be recovered to $\gamma = 0.16$ which results in 13 percent annual rate for bank loans. I assume $\theta_i = \theta_f = \theta$ and use Bernard et al. (2003) to set $\theta = 3.8$, which was calibrated to fit U.S. plant and macro trade data. Following Melitz and Ghironi (2005), Z_m and $F_E N_E$ are normalized to one and the productivity distribution parameter $\alpha = 3.4$. f^F is set to 1.184 resulting in dividend to output ratio of 0.0567.

κ_p is set to 30.08 which is equivalent to having a Calvo parameter of 0.75. κ_w, which determines the level of wage rigidity in the model, is set to 1054.24, equivalent to an implied Calvo wage duration of 4 quarters. The wage-elasticity of demand for a specific labor variety θ_w is set to 21 following Schmitt-Grohe and Uribe (2006). I set the interest rate smoothing parameter $\phi_r = 0.18$, the persistence of the shock $\rho_\epsilon = 0.83$, and the standard deviation of the shock $\sigma_\epsilon = 0.16$ following Lewis and Poilly (2012). Table 1 summarizes all of the parameters.

4 Impulse Response Functions

This section compares two different monetary policy rules, namely the benchmark policy rule (Policy I) and an alternative policy (Policy II). The former only takes into account the inflation rate when setting the policy rate, with $\phi_\pi = 1.5$ and $\phi_x = 0$ in equation (38). On the other hand, the latter incorporates the survival rate η_t in the policy rule, with $\phi_\pi = 1.5$ and $\phi_x = 2$ for this exercise.

Figure 4 displays the impulse response functions (IRFs) of several variables in the model to a 1-standard deviation contractionary monetary shock. When the central bank adopts Policy I, it reacts only to inflation, but inflation does not respond significantly to monetary shocks due to nominal rigidities. Consequently, the interest rate increases following the shock. Higher interest rates incentivize savings and decrease demand for final goods, leading to a decline in output, labor demand, and real wages. The reduced demand for output and higher borrowing costs also lower firms' profits, resulting in a

Table 1: Parametrization

Parameter	Description	value	Source
ϕ	Frisch elasticity	0.25	Bilbiie et al. (2012)
ϵ_d	Deposit elasticity	-1.46	Gerali et al. (2010)
ϵ_b	Loan elasticity	3.12	Gerali et al. (2010)
κ	Leverage deviation cost	11.49	Gerali et al. (2010)
$\theta_i = \theta_f$	Demand elasticity	3.8	Bernard et al. (2003)
α	Productivity distribution	3.4	Melitz and Ghironi (2005)
θ_w	Labor elasticity	21	Schmitt-Grohe and Uribe (2006)
ϕ_r	Interest rate smoothing	0.18	Lewis and Poilly (2012)
ρ_ϵ	Shock persistence	0.83	Lewis and Poilly (2012)
σ_ϵ	s.d. of shock	0.16	Lewis and Poilly (2012)
Calibrated:			
β	Discount factor	0.99	
σ	Risk aversion	2	
ν	Capital adequacy ratio	0.08	Basel III
ω_b	Risk weight of past due loans	1.5	Basel III
η	Survival rate	0.9707	
γ	Loan loss rate	0.16	13% bank loan annual rate
δ	Capital to loans ratio	0.08	
κ_p	Price rigidity	3.08	
κ_w	Wage rigidity	1054.24	
f_F	Fixed production cost	1.18	

higher rate of default. A higher default rate negatively affects the balance sheet of firms, leading to a decline in the supply of credit, which can contribute to an increase in interest rates. However, in the current calibration, this factor is not the primary determinant of interest rate dynamics.

In contrast, when policymakers implement Policy II and consider the effect of contractionary shocks on default rates, the dynamics of the economy change. When a shock occurs and default rates rise, monetary policy authority reduces the interest rate to mitigate the adverse impact of the shock on firms' survival. In this scenario, the impact of the shock on firms' profits is mitigated because the cost of borrowing decreases due to the central bank's response to the increase in default rates. As a result, the number of business failures is lower than in the previous case. The initial decline in the real interest rate can help mitigate the decline in consumption, output, and demand for labor, but the aggregate variables still exhibit persistent dynamics.

5 Conclusion

In this chapter, I demonstrated that contractionary monetary shocks can lead to an increase in the number of defaults and the aggregate liability of defaulted firms in an economy with endogenous default. I developed a model that incorporates endogenous default and explored the propagation mechanisms of monetary shocks. Using this model, I compared the effectiveness of two different monetary policies in responding to these shocks.

My findings suggest that a monetary policy that takes into account the default rate can significantly reduce the number of defaults induced by contractionary monetary shocks. Specifically, my analysis reveals that a policy that responds to default rates can help mitigate the negative impact of such shocks on firms' balance sheets, which in turn helps to prevent a decline in the supply of credit. In this scenario, a reduction in the interest rates results in a stabilization of output and employment.

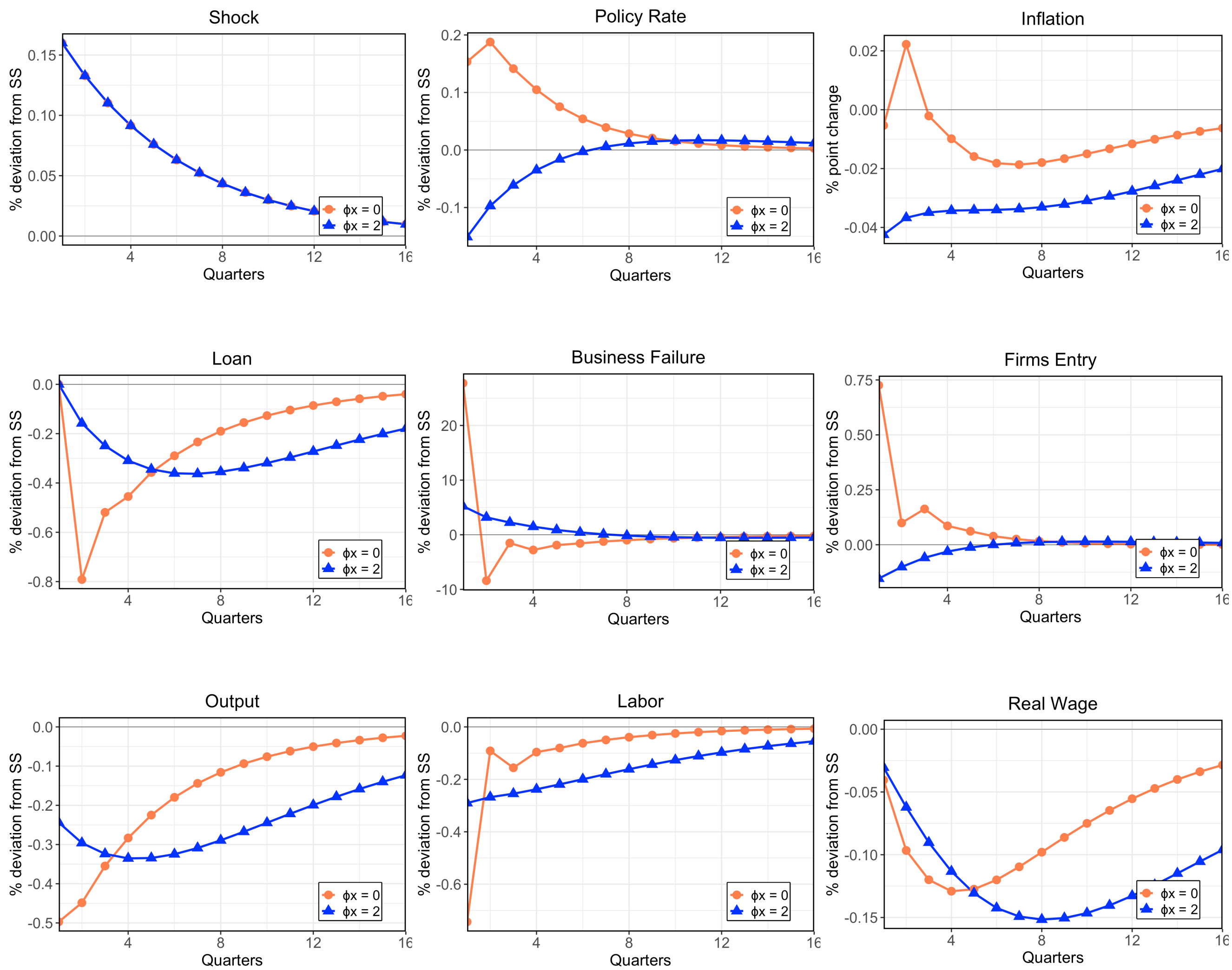

Figure 4: IRFs of aggregate variables to 1 s.d. contractionary monetary shock

Notes: This figure compares the IRFs to contractionary shock under two different monetary policy rule of equation 38.

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A Testing Symmetry and Linearity

of the assumptions behind the equation 1 is that responses to positive and negative shocks are identical except for their sign. In other words, positive and negative shocks affect y_t in a symmetric way. We can test the assumption of symmetry using the following specification, as used in Tenreyro and Thwaites (2016) and Wong (2015). This specification allows for responses to differ condition on the sign of shocks:

$$y_{t+h} - y_t = \boldsymbol{\beta_h' X_t} + \gamma_h^+ s_t^+ + \gamma_h^- s_t^- + \epsilon_{t,h} \tag{39}$$

Where $s_t^+ = max\{0, s_t\}$ and $s_t^- = min\{0, s_t\}$. s_t^+ represents the contractionary shocks and s_t^- the expansionary ones. Then we can simply test the null hypothesis of $H_0: \ \gamma_h^+ = \gamma_h^-$ for all $h : 1, 2, ..., T$. This time $\boldsymbol{X_t}$ includes lags of both positive and negative shocks, as well as lags of y_t, a trend term and a constant.

We can also incorporate a quadratic form in the regression to see if this kind of non-linearity can have any explanatory power. Since the added term is always positive for positive and negative shocks, it generates another form of non-symmetry in our specification:

$$y_{t+h} - y_t = \boldsymbol{\beta_h' X_t} + \gamma_h s_t + \delta_h s_t^2 + \epsilon_{t,h} \tag{40}$$

In order to test the quadratic form against the linear one, the null hypothesis will be $H_0: \ \delta_h = 0$ for all $h : 1, 2, ..., T$.

Figure 5 and figure 7 show the IRF of business failure to monetary shocks. Figure 5 tests the null hypothesis of symmetry of shock and figure 7 tests the null hypothesis of linearity of shocks. As we see, the null hypothesis cannot be rejected using 90 percent confidence interval.

Figure 6 and figure 8 repeats the same exercises for the total liability. We can reject the null hypothesis of symmetry for some periods and the null hypothesis of linearity for most of the periods.

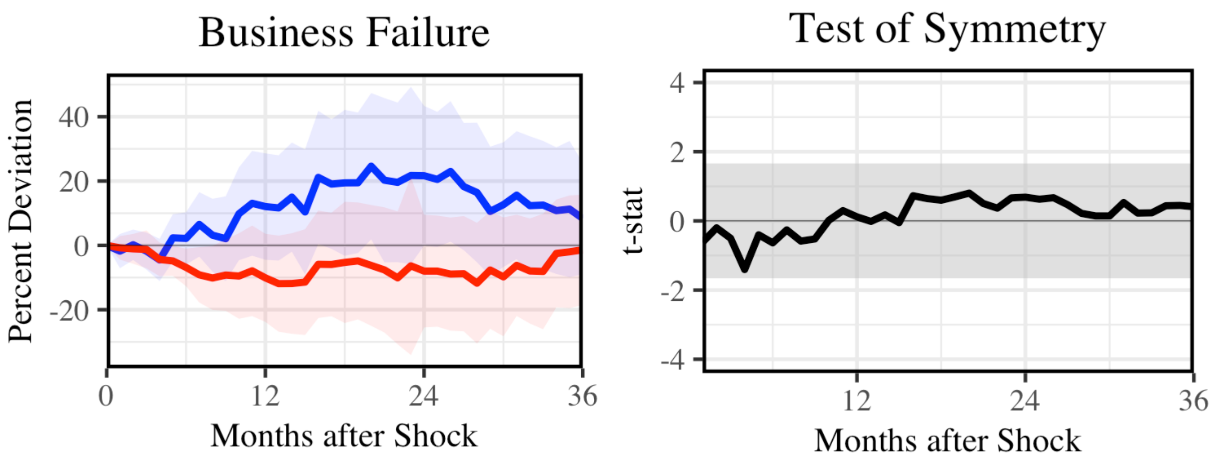

Figure 5: Testing the assumption of symmetric effects of monetary shocks on business failure

Notes: Left: IRFs of business failure to 1 percent contractionary (blue) and expansionary (red) monetary policy shock, using equation 39. *Right:* Testing the null hypothesis of having symmetry respect to negative and positive shocks. 6 lags of both positive and negative shocks have been used as control. The shaded areas represent 90 percent confidence interval.

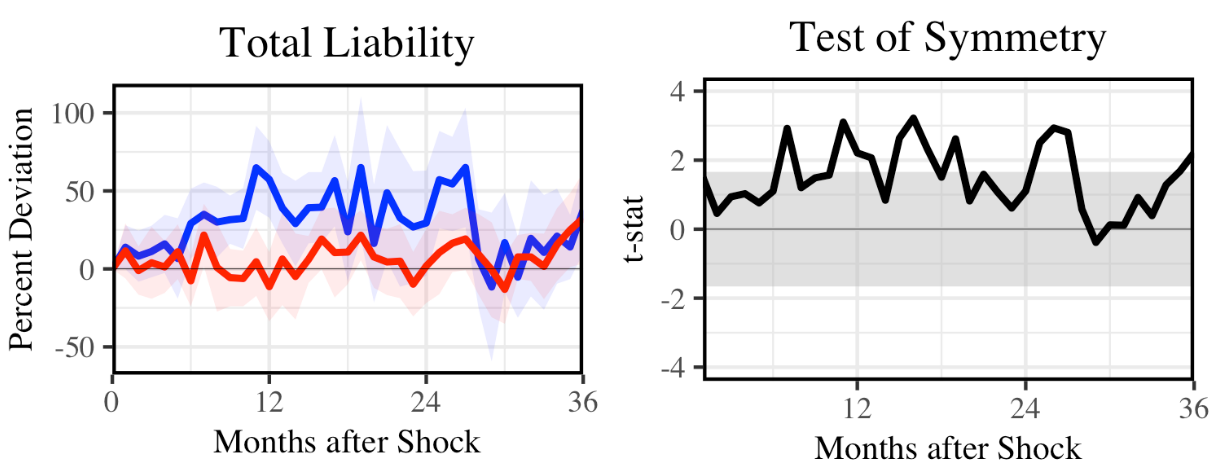

Figure 6: Testing the assumption of symmetric effects of monetary shocks on total liability

Notes: Left: IRF of business failure to 1 percent contractionary (blue) and expansionary (red) monetary policy shock, using equation 39. *Right:* Testing the null hypothesis of having symmetry respect to negative and positive shocks. 6 lags of both positive and negative shocks have been used as control. The shaded areas represent 90 percent confidence interval.

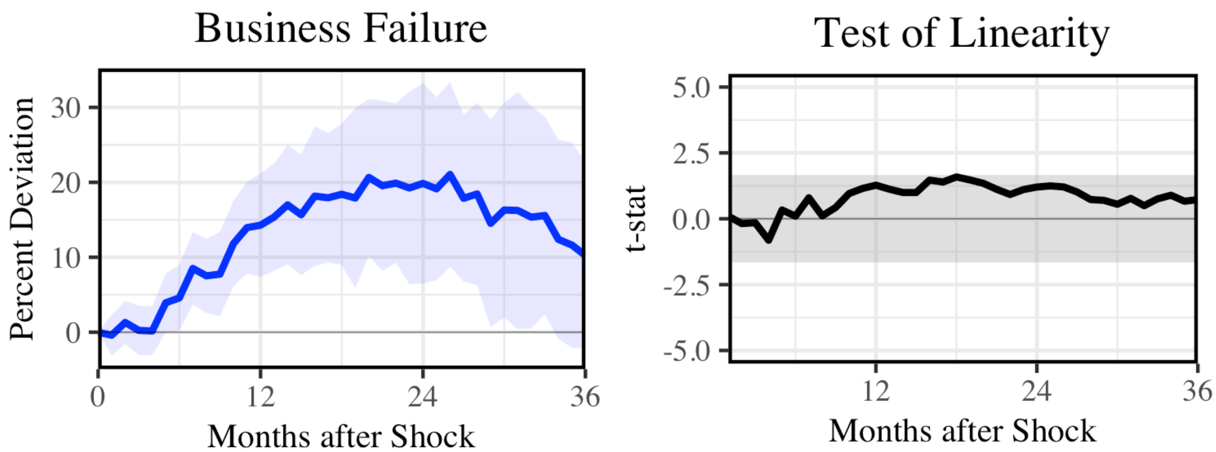

Figure 7: Testing the assumption of linear effects of monetary shocks on business failure

Notes: IRF of business failure to 1 percent contractionary monetary shock, using equation 40. *Right:* Testing the null hypothesis of having linear specification respect to shocks. The shaded area represents 90 percent confidence interval.

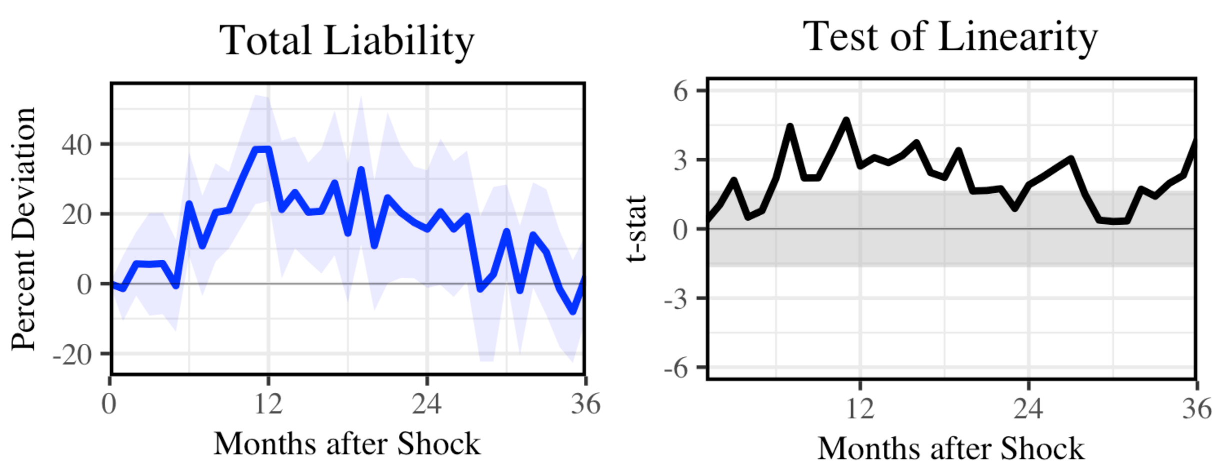

Figure 8: Testing the assumption of linear effects of monetary shocks on total liability

Notes: Left: IRF of total liabilities of defaulted firms to 1 percent contractionary monetary shock, using equation 40. *Right:* Testing the null hypothesis of having linear specification with respect to shocks. The shaded area represents 90 percent confidence interval.

B First-Order Conditions

B.1 Households:

$$\hat{\pi}_t^w = \beta \mathbb{E}_t \hat{\pi}_{t+1}^w + \frac{\theta_w - 1}{\kappa_w} \frac{\bar{w}\bar{L}}{\bar{Y}} \left(M\hat{R}S_t - \hat{w}_t \right) \tag{41}$$

$$\hat{w}_t - \hat{w}_{t-1} = \hat{\pi}_t^w - \hat{\pi}_t \tag{42}$$

$$-\sigma \left(\mathbb{E}_t \hat{C}_{t+1} - \hat{C}_t \right) + \hat{r}_t^d - \mathbb{E}_t \hat{\pi}_{t+1} = 0 \tag{43}$$

$$M\hat{R}S_t = \phi \hat{L}_t + \sigma \hat{C}_t \tag{44}$$

B.2 Firms, Entry, and Default:

$$\hat{\bar{v}}_t = -\sigma * \left(\mathbb{E}_t \hat{C}_{t+1} - \hat{C}_t \right) + \hat{\eta}_{t+1} + \frac{\bar{\bar{d}}}{\bar{\bar{d}} + \bar{\bar{v}}} \mathbb{E}_t \hat{\bar{d}}_{t+1} + \frac{\bar{\bar{v}}}{\bar{\bar{d}} + \bar{\bar{v}}} \mathbb{E}_t \hat{\bar{v}}_{t+1} \tag{45}$$

$$\hat{\lambda}_t - \hat{P}_t = \hat{w}_t - \hat{\underline{z}}_t + \frac{1}{1 - \theta_f} \hat{N}_t^* \tag{46}$$

$$\hat{\pi}_t = \frac{\theta_i - 1}{\kappa_p} (\hat{\lambda}_t - \hat{P}_t) + \beta \bar{\eta} \mathbb{E}_t \hat{\pi}_{t+1} \tag{47}$$

$$\hat{\pi}_t = \hat{P}_t - \hat{P_{t-1}} \tag{48}$$

$$\hat{\bar{v}}_t = \hat{N}_t^E \tag{49}$$

$$\hat{N}_t = \hat{\eta}_t + \hat{N}_t^* \tag{50}$$

$$\hat{N}_t^* = \frac{\bar{N}}{\bar{N} + \bar{N}^E} \hat{N}_{t-1} + \frac{\bar{N}^E}{\bar{N} + \bar{N}^E} \hat{N}_{t-1}^E \tag{51}$$

$$\hat{\eta}_t = -\alpha \hat{\underline{z}}_t \tag{52}$$

$$\frac{f^F(1 + \bar{r}_b)}{f^F(1 + \bar{r}_b) - \bar{\bar{v}}} \hat{r}_t^b - \frac{\bar{\bar{v}}}{f^F(1 + \bar{r}_b) - \bar{\bar{v}}} \hat{\bar{v}}_t = \hat{w}_t + \hat{Y}_t - \hat{\underline{z}}_t + \frac{\theta_f}{1 - \theta_f} \hat{N}_t^* \tag{53}$$

$$\bar{d}\hat{d}_t = (\bar{d} + f^F(1 + \bar{r}^b))(\hat{w}_t + \hat{Y}_t - \hat{\underline{z}}_t + \frac{\theta_f}{1 - \theta_f} \hat{N}_t^*) - f^F(1 + \bar{r}_b) \hat{r}_t^b \tag{54}$$

B.3 Banks:

$$\bar{B}\hat{B}_t = \bar{D}\hat{D}_t + \bar{k}\hat{k}_t \tag{55}$$

$$\bar{\pi}\bar{k}(\hat{\pi}_t + \hat{k}_t) = (1 - \delta) * \bar{k}\hat{k}_{t-1} + \bar{J}\hat{J}_{t-1} \tag{56}$$

$$\hat{R}^b_t = \hat{r}_t - \kappa(\frac{\bar{k}}{\bar{B}^W})^3(\hat{k}_t - \hat{B}^W_t) \tag{57}$$

$$\frac{1}{\bar{r}^b}\hat{r}^b_t = -\hat{\eta}_t + \frac{1}{\bar{R}^b + \gamma(1-\bar{\eta})}(\hat{R}^b_t - \gamma\bar{\eta}\hat{\eta}_t) \tag{58}$$

$$\hat{r}^d_t = \hat{r}_t \tag{59}$$

$$\bar{J}\hat{J}_t = \bar{\eta}\bar{r}^b\bar{b}(\hat{\eta}_t + \frac{1}{\bar{r}^b}\hat{r}^b_t + \hat{b}_t) - \bar{r}_d\bar{D}(\frac{1}{\bar{r}^d}\hat{r}^d_t + \hat{D}_t) - \gamma(1-\bar{\eta})\bar{b}(-\frac{\bar{\eta}}{1-\bar{\eta}}\hat{\eta}_t + \hat{b}_t) \tag{60}$$

$$\hat{B}_t = \hat{b}_t = \hat{N}^*_t \tag{61}$$

$$\bar{B}^W\hat{B}^W_t = \bar{\eta}\bar{B}(\hat{\eta}_t + \hat{B}_t) + \gamma(1-\bar{\eta})\omega_b\bar{B}(\hat{B} + \frac{-\bar{\eta}}{1-\bar{\eta}}\hat{\eta}_t) + (1-\gamma)(1-\bar{\eta})\bar{B}(\hat{B}_t + \frac{-\bar{\eta}}{1-\bar{\eta}}\hat{\eta}_t) \tag{62}$$

B.4 Market Clearing and Monetary Policy Rule

$$\bar{Y}\hat{Y}_t = \bar{C}\hat{C}_t + \bar{J}\hat{J}_t \tag{63}$$

$$L = \frac{1}{1-\theta_f}\hat{N}^*_t + \hat{Y}_t - \hat{\underline{z}}_t \tag{64}$$

$$\hat{r}_t = \phi_r\hat{r}_{t-1} + (1-\phi_r)\left(\phi_\pi\hat{\pi}_t + \phi_x\hat{\eta}_t\right) + \epsilon_t \tag{65}$$

$$\epsilon_t = \rho_\epsilon\epsilon_{t-1} + \hat{s}_t \tag{66}$$

C VAR Evidence

Since not all of the business failures result in exiting the market, here I provide additional evidence on the effect of monetary shock on exit. The data on the number of establishment exit comes from BED. It has universal coverage and extends from 1992Q3-2018Q3. Since R&R monetary shocks are not available after 2008Q4, utilizing R&R shocks for estimating IRFs results in losing almost half of the observations from 2008Q4-2018Q3. Therefore, I follow Uskula (2016) and estimate the impulse response function by using a VAR model.

The variables that are included in the model are Real GDP, GDP deflator, Establishment exit[7], and federal fund rates. I use the shadow interest rate of Wu and Xia (2016) for periods from 2009Q3-2015Q3, to account for the unconventional measures.

Monetary policy shocks are identified by using the recursive approach, which is popular in the empirical literature. This approach assumes that the monetary shocks cannot have a contemporaneous impact on the variables that are inside the information set of the central bank. In the VAR model, I assume that all variables are inside the policymaker's information set. Thus, the federal fund rate is placed at the end.

Figure 9 presents the IRFs of variables of the model to one standard deviation contractionary monetary shock. The interest rate rises by around 0.3 percent after the shock hits. The number of establishment exit increases following the contractionary shock by 1 percent, and the effect is statistically significant. The results of real GDP and inflation are similar to other VAR models such as Altig et al. (2011). The inflation rate rises for a couple of periods and then falls. Real GDP also falls following the shock.

[7] Uusküla (2016) uses establishment death, a subset of establishment exit, instead of the overall number of establishment exit in his VAR model. Other than this difference, this section follows Uusküla (2016) closely.

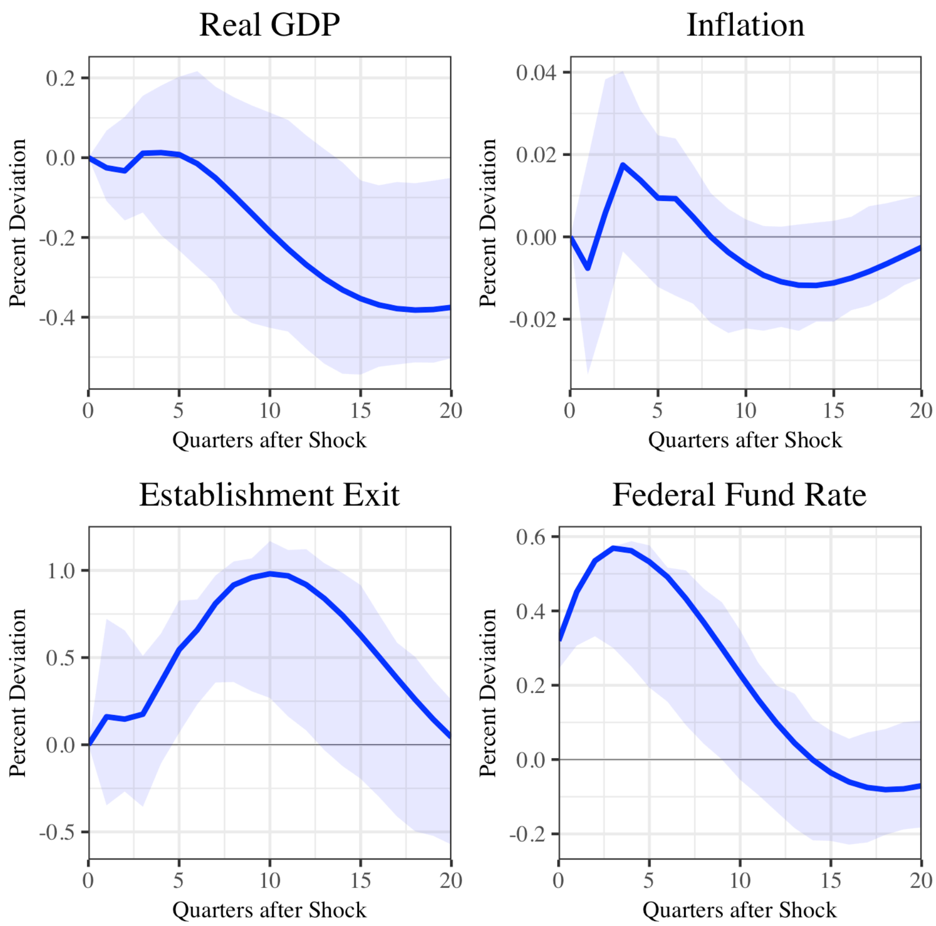

Figure 9: IRFs of variables in the VAR model to 1 s.d. contractionary monetary shock.

Notes: Shaded area represents the 90 percent confidence interval.