Monetary Policy Effects in Financially Constrained and Unconstrained Firms

Mario Gonzalez

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Abstract

This paper presents a medium-scale DSGE framework to analyze the effects of monetary policy shocks on the economy. The novel feature of the model is that it drops the representative firm assumption by including two distinct groups of firms with different financing structures while keeping the model tractable. The first group of firms, referred to as Unconstrained firms, finance their operation by selling bonds directly to households. The second group of firms obtain loans from financial institutions and face financial constraints. The latter group is referred to as Constrained firms. The results show that financially constrained firms have a stronger response to monetary policy shocks than unconstrained firms. They also show that aggregate dynamics hide the individual dynamics that compensate and can cancel each other. Finally, the results show that total lending shifts away from constrained firms after a contractionary monetary policy shock.

1 Introduction

After the meltdown of the securitized assets market and the Lehman Brothers failure, a full banking panic followed. This event resulted in a substantial increase in the cost of corporate and bank borrowing. During this period, governments promoted liquidity and solvency with a variety of actions. This financial crisis, which led several economies into recession, highlighted the need to understand better the mechanisms through which monetary policy and financial frictions interact.

This paper aims to study the role that financial frictions play in the transmission of monetary policy shocks to the rest of the economy. For this, I develop a New Keynesian general equilibrium model with financial frictions. The novel feature of the model is that it drops the representative firm assumption by including two distinct groups of firms with different financing structures while keeping the model tractable.

In the first group, firms obtain resources directly from households, whereas in the second group, firms need to obtain resources through a financial intermediary and face collateral constraints. This assumption is based on the idea that firms in the first group release more information to the public, so investors have a better understanding of the firm. This allows for these firms to finance their production using cheaper bonds sold directly to the public.

On the other hand, I assume that it is too expensive for the second group of firms to release credible information to the public, so they decide to use bank loans that are more expensive and require collateral. In this context, banks have an advantage in obtaining information and diminishing the asymmetries of information between agents. Monetary models generally base their analysis on the aggregate effects of monetary shocks; however, studying the effects on firms separated by their level of financial access sheds light on the effects of the transmission of monetary policy shocks to the rest of the economy and allow us to answer questions like, do all firms react the same way to monetary policy shocks? Would the policy recommendation change by looking at firms separately?

A vast empirical literature shows that the level of access to external financing varies from firm to firm. Papers within this literature usually divide those firms according to their level of access to financing. One type of firm is characterized by having access to a wide variety of external financing sources, including public trading instruments such as commercial paper and bonds, with a relatively low financial cost. On the other hand, the second group of firms is usually characterized by having access to a limited number of financial instruments, which are generally not publicly traded and relatively expensive. These private instruments are usually required to possess some kind of collateral for their loans, which limits the amount of resources they can borrow.

The fact that firms present different access to financing presents an important challenge to the conduction of monetary policy. Firms with different access to finance will respond differently to monetary policy shocks. Berger and Udell [2002] found that small firms are especially vulnerable to shocks to the financial system. Similarly, Duygan-Bump et al. [2015] found that the decrease in lending to small firms was an important driver of unemployment during the Great Recession. With this feature in mind, I study what are the consequences for monetary policy transmission of having such structure in an economy. For that, I build a theoretical model in which unconstrained firms sell corporate bonds to households to obtain external financing, while constrained firms have to obtain funds from banks and face a collateral constraint.

This paper is organized as follows: Section 2 presents a review of the relevant literature. Section 3 presents the theoretical model, while Section 4 presents the calibration. Finally, Section 5 presents the results and Section 6 concludes and details avenues for further research.

2 Related Literature

The topics dealt with in this paper cover different strands of the macroeconomic literature. First, it studies the transmission of monetary policy shocks to the rest of the economy. As can be expected, this branch of the literature is vast, so doing a comprehensive literature review is beyond the scope of this study. Most papers in this literature follow the works of Christiano et al. [2005], who, in an immensely influential paper, study the mix of nominal rigidities that can account for the inertia in inflation and persistence in output to a monetary policy shock. Another highly cited paper was written by Smets and Wouters [2007], in which the authors estimate a general equilibrium model for the US economy, including several real and nominal frictions. A complete review of medium-sized monetary model literature can be found in Christiano et al. [2010b].

A second topic covered in this paper is the role of financial frictions in business cycles. The literature on financial frictions studies how borrowers cannot obtain unlimited funds from lenders and that various financing sources have different costs for the agents; in other words, the irrelevance theorem by Modigliani and Miller [1958] no longer applies. Two very influential papers in the business cycle literature that relate financial frictions with macroeconomics are Kiyotaki and Moore [1995]. and Bernanke et al. [1999].

In Kiyotaki and Moore [1995] the authors study how credit constraints interact with aggregate economic activity over the business cycle. The authors study how small temporary shocks are able to generate large and persistent fluctuations in output and asset prices. In this case lenders demand collateral for the funds they provide, so the borrower's credit limit is affected by the price of collateral assets that in turn is affected by the size of the credit limits.

In Bernanke et al. [1999], the authors present a framework to study the role of financial frictions in business cycles. In particular they study how the interaction between credit limits and assets prices ends up creating a transmission mechanism by which the effects of the shocks persist, amplify and spread out. Ther main financial friction is of the form of a costly state verification with default in equilibrium. The authors find that under reasonable parametrization of the model, the financial accelerator channel has a significant influence over the monetary policy shocks, by increasing the effects on output, investment and the nominal rate. Finally, the authors do not find important differences when they include heterogenous firms, hence they conclude that the propagation of shocks in the one or two sector versions of the model is roughly the same.

More recent studies include Iacoviello [2005], who developed a monetary business cycle model with nominal loans and collateral constraints tied to housing values. The novel feature in his paper is the inclusion of nominal debt, which further increases the effects of monetary policy shocks. Iacoviello [2005] imposes the collateral constraint on the fixed asset used in production. Quadrini [2011] presents a simple two-period model in which he describes the business cycle implication of a general equilibrium model with collateral constraints. He finds that financial frictions, through the investment channel, have a limited impact on labor. Taking this factor into account, the model presented in this paper introduces a working capital channel. By introducing working capital into the model, he is able to increase the amplification effects of productivity shocks of the model. Despite several similarities with this study, these models do not consider the role of financial intermediaries and heterogenous agents in the propagation of monetary shocks, as is being done in this paper.

In the context of the latest financial crisis, Gertler and Kiyotaki [2010] develop a framework to understand how disruptions in financial intermediation can induce a crisis. Similarly, Christiano et al. [2010a] augment a monetary DSGE model to include a banking sector and financial markets with agency problems in financial contracts. These models differ from what is presented here in that they focus more on the business cycles implications of financial constraints, while this paper is more focused on the implications for monetary policy.

In the context of implications of financial frictions on monetary policy, Kiyotaki and Moore [2012] present a model characterized by differences in liquidity across assets. In their model, agents choose to hold money because of a speculatory motivation, i.e., to buy assets in case an opportunity arises. The model is used to study the role of government policy through open market operations which change the mix of assets held by the private sector. Therefore, monetary policy acts by changing the bundle of financial assets held by private agents.

More recently Curdia and Woodford [2015] extend the basic New Keynesian model for monetary transmission by allowing a varying spread between the interest rates available for lenders and borrowers. Their results suggest that New Keynesian models do not need to have any fundamental modification to account for the observed varying interest rate spread that exists in the economy, hence the fundamental lessons of the traditional New Keynesian model still apply.

Other papers closer to what is presented in this study include the works of Fisher [1999] and Fiore and Uhlig [2014]. In Fisher [1999], the author develops a general equilibrium model with a costly state verification to assess the lending view of monetary transmission. His paper is very similar to this study in that it separates big firms from small firms and analyses the effects of monetary policy on them. However, several differences arise from the structure of the model. First, his model uses the limited participation assumption to model monetary policy shocks, while I make a richer model by incorporating new and modern techniques and frictions into the model, making it better suited to analyze the dynamics of the variables in the model. In addition, he focuses on studying the validity of the lending view for the US, while I try to understand the propagation of monetary policy shocks through different channels.

In Fiore and Uhlig [2014], the authors develop a model in which heterogeneous firms endogenously choose the best capital structure. The main focus of their paper is to understand the main determinants of firms' capital structure. They find that differences in capital structure between US and European firms can result from lower levels of information disclosure about a firm's credit risk in Europe relative to the US. In the model presented in this paper, heterogenous firms choose whether to finance production using bonds or bank loans, and the focus is to understand how monetary policy shocks are propagated through heterogeneous firms.

3 A Monetary Policy Model of Financial Frictions with Heterogeneous Agents

The model takes as a starting point a medium sized monetary model as shown in Smets and Wouters

[2007], Christiano et al. [2005] and Christiano et al. [2010b], and modifies it to analyze the behavior of the economy with heterogeneous firms. The novelty of the model is that it separates the firms in the economy into two groups. In the first group, firms are assumed to release enough information so that investors fully understand all aspects of the firm. This feature allows them to finance their production directly from households by selling bonds. This group is denominated as *Unconstrained* firms.

Firms that belong to the second group, named as *Constrained* firms, are assumed to be informationally opaque, which means that it is too costly for them to release information to the public. This assumption leads to investors avoiding financing this type of firm. To obtain financing, these firms need to borrow from commercial banks, which are assumed to collect all the necessary information, allowing them to diminish the informational asymmetry with constrained firms. These assumptions rely on contemporary theories on financial intermediation, which have shown that banks are more efficient than the market in solving informational problems. Among other reasons, banks have economies of scale in the production of information, and they have access to inside information of firms, De Fiore and Uhlig [2011]. In addition, financial firms can use several technologies based on 'hard' and 'soft' information to reduce the information wedge present in small firms, Berger and Frame [2007].[1]

Despite the ability of banks to decrease informational asymmetry, some firms of this group will not be able to pay back their debts, and banks know that they will not be able to recover their loans fully. Therefore, to provide loans, banks demand collateral against the future value of the firm's capital, so capital has an additional role besides being a factor of production. This assumption follows the results of Avery et al. [1998], who found that personal commitment and collateral are essential to firms seeking loans. Secured lending is very common in the US; according to Berger and Udell [1990], nearly 70 percent of all commercial and industrial loans in the United States are secured by collateral assets.

The need for firms to have collateral motivates another modification from the traditional models. Firms to be the owners of the capital, which they use as collateral, instead of the traditional assumption that firms rent capital from households.

Constrained firms as well as unconstrained firms face a working capital constraint, produce differentiated final goods and buy capital from capital producers. The need to finance their production

[1] Hard information technologies include 'small business credit scoring' (which is similar to consumer credit scoring), asset-based lending, factoring, fixed asset lending and leasing. Soft lending technology refers to "relationship lending". Under relationship lending banks are able to obtain information over time through contact with the firms and their owners.

comes from the working capital constraint, i.e they receive the proceeds from sales of their production at the end of each period, so they borrow resources to pay for operating costs.

The rest of the model is populated by households, financial intermediaries and a central bank. The model includes a number of frictions that are now standard in the monetary literature such as, external habit formation, cost of investment, cost of adjusting prices and wage adjusting frictions. The model includes monetary policy shocks, so it can be used to understand the response of heterogeneous firms in the presence of this type of shocks. The model also includes an aggregate technology shock that affects both type of firms. The objectives and constraints of the agents in the model are described in the following subsections.

Households

Households are utility-maximizing agents who supply labor, save in corporate bonds or bank deposits, and consume a basket of final goods produced by firms. Calvo-style wage-setting frictions are modeled by assuming there is a continuum of households indexed by $i \in [0,1]$. Each of these households are assumed to provide a specialized labor input, $h_{i,t}$ to a labor packer who in turn offers this service to a good producing firm. Assuming that household utility depends on its consumption of the composite good, which presents external habit formation, and leisure, then its utility function is given by

$$U\left(C_t^i, H_t^i\right) = \ln\left(C_t^i - \tau C_{t-1}\right) - \chi \frac{\left(H_t^i\right)^{1+\eta}}{1+\eta} \tag{1}$$

where C_t^i is the consumption made by household i at period t, C_{t-1} is the average lagged consumption level of the economy, τ is a measure of external habit formation, η is the inverse of labor price elasticity and χ is a parameter that affects the relative valuation of utility from consumption and labor and is constrained to be positive. Given the additive separability of consumption and employment in utility, the efficient allocation of consumption within households imply $C_t^i = C_t$. On the other hand, they receive profits from firms and banks and principal plus interest payments from the savings assets, deposits and bonds. Taking all into account the households maximize (1) subject to and the budget constraint of the form revisar timming

$$P_t C_t^i + B_t^i + D_t^i = W_t H_t^i + \left(1 + r_{t-1}^d\right) D_{t-1}^i + \left(1 + r_{t-1}^b\right) B_{t-1}^i + \Pi_t^{i,u} + \Pi_t^{i,c} + \Pi_t^{i,b} + \Pi_t^{i,k} \tag{2}$$

where r_t^b is the nominal interest earned by lending funds to unconstrained firms, r_t^d is the nominal interest payed by banks. The variables $\Pi_t^{i,u}$, $\Pi_t^{i,c}$, $\Pi_t^{i,b}$ and $\Pi_t^{i,k}$ are the dividends that households receive from unconstrained firms, constrained firms, banks, and capital producers, respectively. The part of the problem that is not related to the labor market has the following optimality conditions:

$$\lambda_t = \frac{1}{C_t - \tau C_{t-1}} \tag{3}$$

$$\lambda_t = \beta \mathbb{E}_t \left(\frac{1 + r_t^b}{1 + \pi_{t+1}} \right) \lambda_{t+1} \tag{4}$$

$$\lambda_t = \beta \mathbb{E}_t \left(\frac{1 + r_t^d}{1 + \pi_{t+1}} \right) \lambda_{t+1} \tag{5}$$

Equation (3) shows that households care about the consumption path. Equations (4) and (5) are the Euler equations, these state that households will be indifferent between holding corporate bonds or bank deposits as long as $r_t^b = r_t^d$.

Now, regarding the part of the household problem that deals with wage setting, each period a randomly selected fraction, $(1 - \omega_w)$, of households is given the opportunity to adjust their wage according to market conditions to a wage $W_t^*(l)$, the rest ω_w of the households are only able to index last period wages according to inflation. It is assumed that non-adjusting households index their nominal wage according to inflation at a rate $\nu \in [0, 1]$. This means that non-updating households receive a wage of $(1 + \pi)^\nu W_{t-1}(l)$. Analyzing the case that household l is not able to adjust its wage since period t, at $t + 1$ and at $t + 2$ its wage would be

$$W_{t+1} = (1 + \pi_t)^\nu W_t^*(l)$$
$$W_{t+2} = ((1 + \pi_{t+1})(1 + \pi_t))^\nu W_t^*(l) = \left(\frac{P_{t+1}}{P_{t-1}} \right)^\nu W_t^*(l),$$

respectively. Then for any period $t + s$ where household have not been able to adjust their wages for the last s periods the non updated wage can be expressed as

$$W_{t+s}(l) = \left(\frac{P_{t+s-1}}{P_{t-1}} \right)^\nu W_t^*(l) \tag{6}$$

Recalling that households offer their labor service to a labor packer, who aggregates all of households labor into one service using the following technology

$$H_t = \left(\int_0^1 H_t\left(l\right)^{\frac{\theta_w - 1}{\theta_w}} dl \right)^{\frac{\theta_w}{\theta_w - 1}}, \quad \theta_w > 1. \tag{7}$$

Then the demand of the labor packer for $H_t\left(l\right)$ is given by

$$H_t(l) = \left(\frac{W_t\left(l\right)}{W_t} \right)^{-\theta_w} H_t \tag{8}$$

which states that demand for household (l) services depends on their wage relative to the aggregate wage level, given by

$$W_t^{1-\theta_w} = \int_0^1 W_t\left(l\right)^{1-\theta_w} dl \tag{9}$$

In addition, note that the labor packer must provide labor services to all firms in the economy, then the labor is dividing among the firms following

$$H_t^{\frac{\theta_w - 1}{\theta_w}} = \left(1 - \omega_{cu}\right) \left(H_t^c\right)^{\frac{\theta_w - 1}{\theta_w}} + \omega_{cu} \left(H_t^u\right)^{\frac{\theta_w - 1}{\theta_w}} \tag{10}$$

where H_t is the total time worked by the individual, H_t^c is the time worked by the individual in the constrained firm, H_t^u is the time worked by the individual in the unconstrained firm. Households then solve their wage decision problem taking into account the decisions made by the labor packer. More formally, by replacing the labor demand, (8), the indexation of wages, (6), and the aggregate wage level, (9), into the utility function and budget constraint, (2) the wage setting problem becomes

$$\begin{aligned} \mathcal{L} = \mathbb{E}_t \textstyle\sum_{s=0}^{\infty} \left(\beta\omega_w\right)^s \Bigg\{ & - \chi \frac{\left(\left(\frac{P_{t+s-1}}{P_{t-1}} \right)^{\nu} \frac{W_t^*(l)}{W_{t+s}} \right)^{-\theta_w(1+\eta)} H_{t+s}^{1+\eta}}{1+\eta} \\ & + \left(\lambda_{t+s} + \mu_{t+s}\right) \left(\left(\left(\frac{P_{t+s-1}}{P_{t-1}} \right)^{\nu} W_t\left(l\right) \right)^{1-\theta_w} W_{t+s}^{-\theta_w} H_t \right) \Bigg\} \end{aligned}$$

where λ_t is the Lagrangean multiplier of the budget constraint and μ_t is the Lagrangean multiplier of the CIA constraint. The first order conditions of this problem, after some algebraic manipulation, are given by

$$w_t^* = \frac{\theta_w}{\theta_w - 1}\chi\frac{G_{1t}}{G_{2t}} \tag{11}$$

$$G_{1,t} = \left(\frac{w_t^*}{w_t}\right)^{-\theta_w(1+\eta)} H_t^{1+\eta} + \mathbb{E}_t\beta\omega_w\left(1+\pi_t\right)^{-\nu(1+\eta)\theta_w}\left(1+\pi_{t+1}\right)^{\theta_w(1+\eta)}\left(\frac{w_{t+1}^*}{w_t^*}\right)^{-\theta_w(1+\eta)} G_{1,t+1} \tag{12}$$

$$G_{2,t} = \left(\frac{w_t^*}{w_t}\right)^{-\theta_w} H_t\left(\lambda_t + \mu_t\right) + \mathbb{E}_t\beta\omega_w\left(1+\pi_t\right)^{\nu(1-\theta_w)}\left(1+\pi_{t+1}\right)^{-\theta_w(1+\eta)}\left(\frac{w_t^*}{w_{t+1}^*}\right)^{-\theta_w} G_{2,t+1} \tag{13}$$

Capital Producers

Capital producers are a group of agents who produce new units of capital from the final consumption basket and sell them to Constrained and Unconstrained firms at a nominal price Q_t^K. Then, in order to produce I_t of new capital they face adjustment costs in the form of $\frac{\psi_I}{2}\left(\frac{I_t}{I_{j,t-1}} - 1\right)^2 I_{j,t}$. First, their demand for final consumption goods comes from minimizing the basket they buy from unconstrained and constrained firms

$$\min_{I_t^{kj}} \int_0^1 P_t^j I_t^{kj} dj \text{ subject to } I_t^k = \left[\int_0^1 \left(I_t^{kj}\right)^{\frac{\theta_p - 1}{\theta_p}} dj\right]^{\frac{\theta_p}{\theta_p - 1}}.$$

the first order conditions lead to the following optimality condition:

$$I_t^{kj} = \left(\frac{P_t^j}{P_t}\right)^{-\theta_p} I_t^k \tag{14}$$

Their objective in real terms is to choose I_t in order to maximize

$$\mathbb{E}_t\sum_{i=0}^{\infty}\Lambda_t\left\{q_{t+i}^K I_{t+i} - \left[1 + \frac{\psi_I}{2}\left(\frac{I_{t+i}}{I_{t+i-1}} - 1\right)^2\right] I_{t+i}\right\}$$

Discounting is done according to patient households' preferences, who are the owners of the firms. From the first order condition a new relation can be obtained that relates the price of capital to the level of investment. The maximization problem yields the following equilibrium condition

$$1 = q_t\left(1 - \frac{\psi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \psi\frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) + \Lambda_{t+1}q_{t+1}\frac{I_{t+1}}{I_t}\left(\frac{I_{t+1}}{I_t} - 1\right)^2$$

Final Goods

A representative firm demands goods from all individual firms. As was stated before, firms are separated between constrained and unconstrained, then the demand from then is X_t^c and X_t^u, respectively. Final goods producer combines them using the following technology,

$$Y_t^D = \left[\omega_u^{\frac{1}{\theta_p}} \left(X_t^u\right)^{\frac{\theta_p-1}{\theta_p}} + \left(1-\omega_u\right)^{\frac{1}{\theta_p}} \left(X_t^c\right)^{\frac{\theta_p-1}{\theta_p}}\right]^{\frac{\theta_p}{\theta_p-1}} \tag{15}$$

where Y_t^D is the total production of the final good, ω_u of firms are considered unconstrained denominated by u, while the $1-\omega_{uc}$ percent remaining face financial constraints, denominated by c and θ_p is the elasticity of substitution between different firms' goods in consumption. As θ_p goes to infinity all goods become perfect substitutes, and as θ_p goes to zero there is no substitution possible. Final goods producer sell their output for consumption and investment at a price P_t while paying P_t^u for goods from unconstrained firms and P_t^c from constrained firms. Then, final good producers choose their inputs by maximizing profits, taking prices as given

$$\max_{X_t^u, X_t^c} P_t \left[\omega_u^{\frac{1}{\theta_p}} \left(X_t^u\right)^{\frac{\theta_p-1}{\theta_p}} + \left(1-\omega_u\right)^{\frac{1}{\theta_p}} \left(X_t^c\right)^{\frac{\theta_p-1}{\theta_p}}\right]^{\frac{\theta_p}{\theta_p-1}} - P_t^u X_t^u - P_t^c X_t^c$$

The first order conditions lead to the following optimality condition:

$$X_t^u = \omega_u \left(\frac{P_t^u}{P_t}\right)^{-\theta_p} Y_t^D,\ X_t^c = \left(1-\omega_{cu}\right) \left(\frac{P_t^c}{P_t}\right)^{-\theta_p} Y_t^D \tag{16}$$

where $P_t = \left[\int_0^1 \left(P_{jt}\right)^{1-\theta_p} dj\right]^{\frac{1}{1-\theta_p}}$, which states that the aggregate price index is an average of the individual prices weighted by the elasticity of substitution among goods. Condition (16) states that the aggregate of firms depend on its price relative to the aggregate price index, P_t, which is given by

$$P_t^{1-\theta_p} = \left(1-\omega_{cu}\right) \left(P_t^u\right)^{1-\theta_p} + \omega_{cu} \left(P_t^c\right)^{1-\theta_p} \tag{17}$$

Once decided how much of each type of good is demanded, Final goods producers decide how much will demand from each firm by maximizing profits. Assuming that firms also use a Dixit-Stiglitz aggregator

$$Y_t^{fu} = \left[\int_0^1 \left(X_{jt}^u\right)^{\frac{1}{\theta_{uc}}} dj\right]^{\theta_{uc}}, Y_t^{fc} = \left[\int_0^1 \left(X_{jt}^c\right)^{\frac{1}{\theta_{uc}}} dj\right]^{\theta_{uc}}$$

which take as inputs the goods from unconstrained and constrained firms, respectively, where each $j \in [0,1]$. Profits from period t are given by

$$\max_{X_t^u} P_t^u \left[\int_0^1 \left(X_{jt}^u \right)^{\frac{1}{\theta_{uc}}} dj \right]^{\theta_{uc}} - P_{j,t}^u X_{jt}^u$$
$$\max_{X_t^u} P_t^c \left[\int_0^1 \left(X_{jt}^c \right)^{\frac{1}{\theta_{uc}}} dj \right]^{\theta_{uc}} - P_{j,t}^c X_{jt}^c$$

Then the period t Both X_t^c and X_t^u are in turn an aggregate of perfectly competitive firms consumption basket of goods where the demand of each individual firm is given by

$$X_{j,t}^u = \left(\frac{P_{jt}^u}{P_t^u} \right)^{-\theta_{uc}} Y_t^{fu}, \tag{18}$$

$$X_{j,t}^c = \left(\frac{P_{jt}^c}{P_t^c} \right)^{-\theta_{uc}} Y_t^{fc} \tag{19}$$

Unconstrained Firms

It is assumed that unconstrained firms disclose all the information required by the public, so information asymmetries do not present a relevant problem. This assumption allows unconstrained firms to borrow directly from households on the debt market without going to financial intermediaries. At this point, firms decide how much to produce and how much to spend on new capital. The following production function appropriately describes the technology used by unconstrained firms to produce

$$f\left(H_{j,t}^u, K_{j,t-1}^u, z_t\right) = Y_{j,t}^u = z_t \left(H_{j,t}^u\right)^{1-\alpha} \left(K_{j,t-1}^u\right)^{\alpha}, \tag{20}$$

where $H_{j,t}^u$ is the amount of labor hired by the firm j, $K_{j,t-1}^u$ is the amount of capital used in production by the firm and z_t is a productivity shock. Investment spending takes the form

$$I_{j,t}^u = K_{j,t}^u - (1-\delta) K_{j,t-1}^u \tag{21}$$

where $I_{j,t}^b$ refers to the purchases of capital by firm j.

Unconstrained firms also face menu costs of changing prices, i.e. a cost incurred by the firms due to the price-adjustment process itself. It is assumed that the real costs of changing the nominal prices the firm charge is [2]

$$\frac{\psi_p}{2}\left(\frac{P_t^u}{P_{t-1}^u}-1\right)^2.$$

Firms need to finance all the costs that they face in order to produce and sell their goods, these include: capital investments, $P_t I_{j,t}^u$, wage payments for an amount $W_t H_{j,t}^u$, where W_t are the wages paid on labor, and menu costs. In order to finance these expenditures, unconstrained firms must borrow from households in the form of bonds, equivalent to

$$B_t^u = W_t H_{j,t}^u + Q_t^K I_{j,t}^u \tag{22}$$

households charge an interest rate, r_t^b, for these bonds which, along with the principal, have to be paid at the end of the period. Then the total amount that firms must pay back to households is equivalent to $\left(1+r_t^b\right) B_t$. Then the unconstrained firm problem becomes

$$\max_{K_{j,t}^u H_{j,t}^u, I_{j,t}^u} \sum_{t=0}^{\infty} \Lambda_{t+1}\left(P_{j,t}^u Y_{j,t}^u - \left(1+r_t^b\right) W_t H_{j,t}^u - \left(1+r_t^b\right) Q_t^K I_{j,t}^u - \frac{\psi_p}{2}\left(\frac{P_{j,t}^u}{P_{j,t-1}^u}-1\right)^2 P_t\right)$$

subject to (20), (21) and (18) .

From the first order conditions, assuming that γ_t^b is the Lagrangian multiplier for the output condition, and omitting the firm indicator, then the following optimality conditions are obtained[3]:

$$w_t\left(1+r_t^b\right) = (1-\alpha) z_t \left(\frac{K_{t-1}^u}{H_t^u}\right)^{\alpha} \gamma_t^u \tag{23}$$

$$\left(1+r_t^b\right) q_t^K = \mathbb{E}_t\left(1+\pi_{t+1}\right) \Lambda_{t+1} \begin{pmatrix} (1-\delta) q_{t+1}^K \left(1+r_{t+1}^b\right) \\ +\alpha z_{t+1}\left(\frac{H_{t+1}^u}{K_t^u}\right)^{1-\alpha} \gamma_{t+1}^u \end{pmatrix} \tag{24}$$

$$\begin{pmatrix} (1-\theta_p)\left(\frac{P_t^u}{P_t}\right)^{1-\theta_p} Y^{fu} \\ +\theta_p\left(\frac{P_t^u}{P_t}\right)^{-\theta_p} \gamma_t^u Y_t^{fu} \end{pmatrix} = \begin{pmatrix} \psi_p\left(1+\pi_t^u\right)\pi_t^u \\ -\mathbb{E}_t \psi_p\left(1+\pi_{t+1}\right)\left(1+\pi_{t+1}^u\right)\left(\pi_{t+1}^u\right)\Lambda_{t+1} \end{pmatrix} \tag{25}$$

The optimality conditions (23) and (24) are the same as the ones obtained in the standard model except for the fact that now the interest rate, r_t^b, and the Lagrangian multiplier, γ_t^u, appear modifying both the marginal productivity of labor and of capital.From these, it can be seen that the marginal

[2] Due to the existence of firm specific the usual Calvo-pricing assumption is replaced by quadratic cost of adjusting prices.

[3] Note that $\Lambda_{t+1} = \beta\frac{\lambda_{t+1}}{\lambda_t}$

productivity of labor and capital will be higher than the standard case because now firms must also pay for the financial cost of using production inputs.

Condition (25) can be restated as

$$\frac{P_t^u}{P_t} = \left(\frac{\theta_p}{\theta_p - 1}\right)\gamma_t^u \tag{26}$$
$$+\mathbb{E}_t \frac{\psi_p}{\left(\theta_p - 1\right)Y_t}\left\{\left(1+\pi_{t+1}\right)\left(1+\pi_{t+1}^u\right)\left(\pi_{t+1}^u\right)\Lambda_{t+1} - \left(1+\pi_t^u\right)\pi_t^u\right\}\left(\frac{P_t^u}{P_t}\right)^{\theta_p}$$

which can be restated as

$$P_t^u = \left(\frac{\theta_p}{\theta_p - 1}\right)\left(\gamma_t^u + \Omega_t^u\right)P_t \tag{27}$$

where $\Omega_t^u = \mathbb{E}_t \frac{\psi_p}{(\theta_p-1)\theta_p Y_t^D}\left\{\left(1+\pi_{t+1}\right)\left(1+\pi_{t+1}^u\right)\left(\pi_{t+1}^u\right)Q_{t+1} - \left(1+\pi_t^u\right)\pi_t^u\right\}\left(\frac{P_t^u}{P_t}\right)^{\theta_p}$ and acts as a second source of cost for the firm coming from the fact that for a firm is costly to change prices. This condition states that an unconstrained firm will choose to charge higher prices if it expects growing inflation or expects interest rates in the future. In other words, unconstrained firms will charge a higher price if $\left(1+r_{t+1}^u\right)\left(1+\pi_{t+1}\right)\left(1+\pi_{t+1}^u\right)\left(\pi_{t+1}^u\right)\Lambda_{t+1} > \left(1+r_t^u\right)\left(1+\pi_t^u\right)\pi_t^u$. If prices are totally flexible then $\psi = 0$, condition (27) reduces to the usual condition on New Keynesian models. Condition (27) also shows that there is a wedge between marginal costs and firm prices due to the markup, $\theta_p/(\theta_p - 1)$, introduced by the monopolistic competition.

Constrained Firms

Constrained firms cannot get resources directly from households because they find it too costly to provide information to the market. This assumption has two consequences on the finances of constrained firms. First, they can only borrow funds from banks since these have unique advantages in monitoring firms and producing information. In addition, banks provide only secured lending, so these firms must provide collateral for the loans they obtain from banks. The basic structure of the constrained firms block is similar to that of unconstrained firms. Technology is given by the production function

$$f\left(H_{j,t}^c, K_{j,t-1}^c, z_t\right) = z_t\left(H_{j,t}^c\right)^{1-\alpha}\left(K_{j,t-1}^c\right)^{\alpha}, \tag{28}$$

where H_t^u is the amount of labor hired by the constrained j firm, $K_{j,t-1}^c$ is the amount of capital used in production by the constrained firm j in period t and z_t is a productivity shock. Investment spending in new capital by the firm j is given by

$$I^c_{j,t} = K^c_{j,t} - (1-\delta)K^c_{j,t-1} \tag{29}$$

which follows the structure of unconstrained firms. Constrained firms also face menu costs of changing prices, i.e. a cost incurred by the firm due to the price-adjustment process itself. It is assumed that the real costs of changing the nominal prices it charges is

$$\frac{\psi_p}{2}\left(\frac{P^c_t}{P^c_{t-1}} - 1\right)^2.$$

Taking into account wage payments and investment spending, then the total amount borrowed by constrained firms is then

$$L^c_{j,t} = W_t H^c_{j,t} + P_t I^c_{j,t} \tag{30}$$

and at the end of the period these firms must pay back $\left(1+r^l_t\right)L_t$, where r^l_t is the nominal interest rate charged by banks for these loans.

The collateral constraint is modeled following Kiyotaki and Moore [1995]. This constraint requires that the amount borrowed by a firm plus interest cannot be greater than a proportion κ of the expected future value of the firm's total capital.

$$\left(1+r^l_t\right)L_{j,t} \leq \kappa Q^K_{t+1}K^c_t. \tag{31}$$

A constraint like (31) has several interpretations in the literature. The parameter κ can be thought of as a measure for risk. In this interpretation, in a high risk economy κ should be positive and smaller than in a low risk economy where the parameter should be bigger. Also, it can be interpreted as the maximum fraction of capital that the producer can credibly pledge in cases where it cannot pay in full. This feature is introduced into the model to capture the idea that a proportion of firms require collateral to secure their lending.

Taking all into account the constrained firm problem becomes

$$\max_{Y^c_{j,t}H^c_{j,t},I^c_{j,t}} \sum_{t=0}^{\infty}\left(P^c_{j,t}Y^c_{j,t} - \left(1+r^l_t\right)W_t H^c_{j,t} - \left(1+r^l_t\right)Q^K_t I^c_{j,t} - \frac{\psi}{2}\left(\frac{P^c_{j,t}}{P^c_{j,t-1}} - 1\right)^2 P_t\right)$$

subject to (28), (29), (31) and (19).

From the first order conditions, and assuming that γ_t^c is the Lagrangian multiplier for the output condition and ϕ_t^u is the Lagrangian multiplier of the collateral constraint, the following optimality conditions are obtained:

$$w_t\left(1+r_t^l\right)\left(1+\phi_t^u\right) = \left(1-\alpha\right)z_t\left(\frac{K_{t-1}^c}{H_t^c}\right)^{\alpha}\gamma_t^c \tag{32}$$

$$\left(1+r_t^l\right)q_t^K\left(1+\phi_t^u\right) = \mathbb{E}_t\mathit{\Lambda}_{t+1}\left(\begin{array}{c}\left(1-\delta\right)q_{t+1}^K\left(1+r_{t+1}^l\right)\left(1+\phi_{t+1}^u\right)+\kappa q_{t+1}^K\phi_{t+1}\\ +\alpha z_{t+1}\left(\frac{H_{t+1}^c}{K_t^c}\right)^{1-\alpha}\gamma_{t+1}^c\end{array}\right) \tag{33}$$

$$\left(\begin{array}{c}\left(1-\theta_p\right)\left(\frac{P_t^c}{P_t}\right)^{1-\theta}Y_t^{fc}\\ +\theta_p\left(\frac{P_t^c}{P_t}\right)^{-\theta_p}\gamma_t^cY_t^{fc}\end{array}\right) = \left(\begin{array}{c}\psi_p\left(1+\pi_t^c\right)\pi_t^c\\ -\mathbb{E}_t\psi_p\left(1+\pi_{t+1}\right)\left(1+\pi_{t+1}^c\right)\pi_{t+1}^c\Lambda_{t+1}\end{array}\right) \tag{34}$$

The optimality conditions (32) and (33) are the same as the ones obtained for the unconstrained firms except that now it appears the interest rate on bank loans and the Lagrangian multiplier of the collateral constraint, ϕ_t^u, appears modifying them. Assuming that the constraint is always binding, then ϕ_t is always positive. Equation (32) implies that the marginal productivity of labor of constrained firms must always be higher than that of unconstrained firms. A similar effect can be found on the optimality condition of capital, a positive ϕ_t increases the required marginal productivity of capital due to the fact that capital must be financed with loans, which leads to a reduction in the optimal level of capital. However, a capital increase reduces the effect of the collateral constraint, so forward-looking firms trying to achieve their optimal production level will want to increase investment.

As with the unconstrained firms, condition (34) can be restated as

$$P_t^c = \left(\frac{\theta_p}{\theta_p-1}\right)\left(\gamma_t^c+\Omega_t^c\right)P_t \tag{35}$$

where $\Omega_t^c = \frac{\psi_p}{(\theta_p-1)\theta_pY_t^c}\left\{\left(1+\pi_{t+1}\right)\left(1+\pi_{t+1}^c\right)\pi_{t+1}^c\Lambda_{t+1}-\left(1+\pi_t^c\right)\pi_t^c\right\}\left(\frac{P_t^c}{P_t}\right)^{\theta_p}$. Similarly to what is seen for unconstrained firms, Ω_t^c acts as a second source of cost for the firm coming since for a firm is costly to change prices. This condition states that a constrained firm will choose to charge higher prices if it expects growing inflation or if it expects higher interest rates in the future. In other words, constrained firms will charge a higher price if $\left(1+\pi_{t+1}\right)\left(1+\pi_{t+1}^c\right)\left(\pi_{t+1}^c\right)\Lambda_{t+1} > \left(1+\pi_t^c\right)\pi_t^c$. If prices are totally flexible then $\psi = 0$, condition (35) reduces to the usual condition on New Keynesian models. Condition (35) also shows that there is a wedge between marginal costs and firm prices due to the markup, $\theta_p/(\theta_p-1)$, introduced by the monopolistic competition. From this condition can be seen that the price of constrained goods is not only increased by the marginal cost, γ_t^c, but also by the variable Ω_t^c.

Banks

Financial intermediaries only lend to constrained firms using funds that are obtained from households' deposits, D_t. On the asset side of the balance sheet banks only have loans made to constrained firms, L_t. Then the balance sheet at the beginning of period t is given by

$$L_t = D_t \tag{36}$$

Banks' income is determined by the interest rate they charge on loans, r_t^l, and by the amount of loans provided to firms, L_t, so every period the banks receive $\left(1 + r_t^l\right) L_{t-1}$, while its cost comes from the interest that they pay from deposits $\left(1 + r_t^d\right) D_{t-1}$. Then their profits are given by

$$\Pi_t^{Bank} = \left(1 + r_t^l\right) L_{t-1} - \left(1 + r_t^d\right) D_{t-1}$$

Profit maximization and perfect competition in the banking sector leads to the following condition

$$r_t^d = r_t^l$$

Central Bank

It is assumed that the central bank follows a simple Taylor rule in the form of

$$1 + r_t^d = \left(1 + r_t^d\right)^{\tau_r} \left[\frac{1}{\beta}\left(1 + \pi_t\right)^{\tau_\pi} \left(1 + \frac{Y_t}{Y_{t-1}}\right)^{\tau_g}\right]^{1-\tau_r} \left(1 + u_t\right) \tag{37}$$

where u_t are exogenous monetary policy shocks τ_π is a parameter that measures the response of the central bank to an increase in inflation, which is assumed to be greater than one, and τ_g is a parameter that measures the response of the central bank to changes in growth.

Aggregation and Market Clearing

Aggregate variables add up the by-firm amounts from constrained and unconstrained firms according to their mass. Per-capita amounts from unrestricted and restricted patient households, according to their respective mass ω_{cu} and $1-\omega_{cu}$.

$$Y_t = C_t + I_t + \frac{\psi}{2}\left(\left(1-\omega_{cu}\right)\pi_t^u + \omega_{cu}\pi_t^c\right) + \frac{\psi}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2 I_t \tag{38}$$

$$\int_0^1 I_t^k dk = I_t = \omega_{cu}I_t^c + \left(1-\omega_{cu}\right)I_t^u = \int_0^{\omega_{cu}} I_t^j dj + \int_{\omega_{cu}}^1 I_t^j dj \tag{39}$$

$$\int_0^1 b_t^i di = b_t = \left(1-\omega_{cu}\right)b_t^u = \int_{\omega_{cu}}^1 b_t^j dj \tag{40}$$

$$\int_0^1 h_t^i di = H_t = \omega_{cu}H_t^c + \left(1-\omega_{cu}\right)H_t^u = \int_0^{\omega_{cu}} H_t^j dj + \int_{\omega_{cu}}^1 H_t^j dj \tag{41}$$

The endogenous variables in this model are: Y_t, Y_t^c, Y_t^u, C_t, H_t, H_t^c, H_t^u, K_t^c, K_t^u, I_t^c, I_t^u, γ_t^c, γ_t^u, π_t, r_t^b, r_t^l, r_t^d, b_t, d_t, l_t, π_t, π_t^c, π_t^u, R_t, w_t, P_t, P_t^c, P_t^u and ϕ_t. The exogenous variables are u_t,z_t, which are assumed to follow AR(1) processes:

$$u_t = \rho_u u_{t-1} + \varepsilon_{u,t} \tag{42}$$

$$\ln(z_t) = \rho_z \ln(z_{t-1}) + \varepsilon_{z,t} \tag{43}$$

4 Calibration

In this section, I discuss the calibrated parameters used in the model. For the most part, the values of these parameters, which are now standard in the literature, were taken primarily taken from complemented Garcia et al. [2019] with from Christiano et al. [2005] and Christiano et al. [2010b]. The discount rate of households in both countries, β, is set equal to 0.99, with this value, while the habit formation parameter, τ, is 0.77. Capital share in the production function is 0.36, depreciation is set to 1.9% and the investment adjustment cost, ψ_I is set to 2, which is in the range of values estimated by Christiano et al. [2010b].

In terms of the parameters related to the goods market, the parameter that measures the elasticity of substitution among goods, θ_p, is set to 4. The parameter that measures the cost of adjusting prices, ψ_P, is set to 3. The papers that were used as a model for both the basic model and the parameter values do not use a quadratic cost of adjustment as a way to model price stickiness and instead use Calvo prices, so they do not have a parameter value to use as a base. Instead, other papers in the literature were used to find a sensible value for ψ_P, which include Gavin et al. [2013], Niemann et al.

[2013] and Leith and Liu [2016], the range of values used was wide as it went from 2 to 116. Several parameter values were tried in the model, and the results did not seem much affected by the changes, so a low value was used.

With regards to the parameters related to the labor market and wage setting, the relative disutility of labor, χ, is chosen to ensure that in the steady state households allocation time to work is close to 0.32; this yields $\chi = 40$. The inverse of Frisch elasticity parameter, η, is assumed to be equal to 1, which implies that the utility is quadratic in leisure and a labor supply elasticity of 1. The price elasticity of substitution among different types of labor, θ_w, is 6, which implies a markup value in the labor market of 1.2. This markup value lies in between of the 1.05 used in Christiano et al. [2005] and the 1.5 used in Smets and Wouters [2007]. The fraction of households that are given the opportunity to re-optimize their wages is 0.2, which implies a value of ϕ_w of 0.3. The rate of wage indexation, ν, is 0.2, which is lower than the values used normally in the literature which go from 0.7 to 1.

The value of the sensitivity of the monetary policy to changes in inflation, τ_π is set to 1.2, and its sensitivity to changes in growth, τ_g, is set to 0.125 while the indexation of the interest rate is set to 0.7.

Table 1: Parameter Values

Parameter	Value	Description
β	0.99	Household discount factor
χ	40	Labor relative disutility factor
δ	0.019	Depreciation rate
η	1	Inverse Frisch elasticity
α	0.36	Capital share
τ	0.77	Habit formation parameter
θ_p	4	Price elasticity of demand for individual good
θ_w	6	Price elasticity of demand for individual labor
ν	0.2	Wage indexation to π_{t-1}
ψ_p	3	Price adjustment cost parameter
ψ_I	5	Investment adjustment cost parameter
τ_π	1.5	Interest rate sensitivity to inflation
τ_g	0.125	Interest rate sensitivity to growth
ω_{cu}	0.8	Percentage of unconstrained firms
ω_w	0.3	Wage stickiness
κ	0.05	Collateral constraint parameter
ρ_z	0.95	Autoregressive coefficient of productivity shock
ρ_u	0.2	Autoregressive coefficient of monetary shock

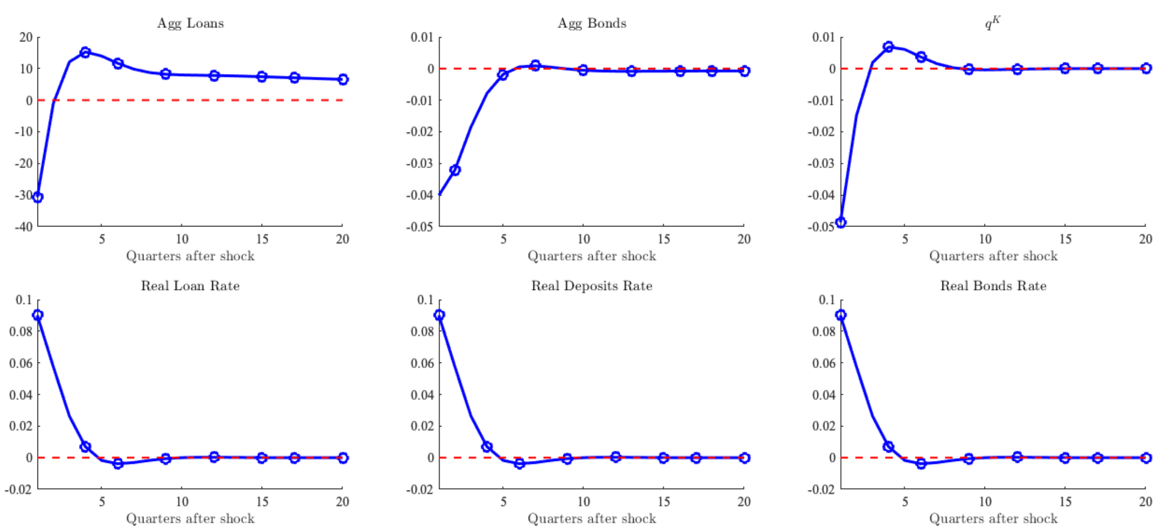
5 Results

In this section, I study monetary policy transmission by analyzing the model impulse responses to an unanticipated increase in the policy rate. The transmission mechanism of monetary policy shocks in this model takes place through its effect on real and nominal interest rates, on investment, the distribution of resources between constrained and unconstrained, and labor market equilibrium. The results show two significant effects of the presence of heterogeneous firms for monetary policy. First, constrained and unconstrained firms have different responses to monetary policy shocks, not only in the size of the reaction but also in their direction. Second, the results show that a contractionary monetary policy shock shifts total lending away from small firms, in line with the assessment from Oliner and Rudebusch [1996].

Response to Monetary Shocks in the Heterogenous Firm Model

On impact, a contractionary monetary policy shock increases the real interest rate on deposits which is transmitted to the interest rate on corporate bonds and deposits, Figure 1. Regarding financial assets, households substitute their savings from deposits to bonds, which is reflected in the substantial fall in loans compared to a mild decrease in bonds. In this case, the main driver of this effect is the decrease in the collateral price, which limits the amount that constrained firms can borrow.

Figure 1: Effects of a Monetary Policy Shock on Financial Variables



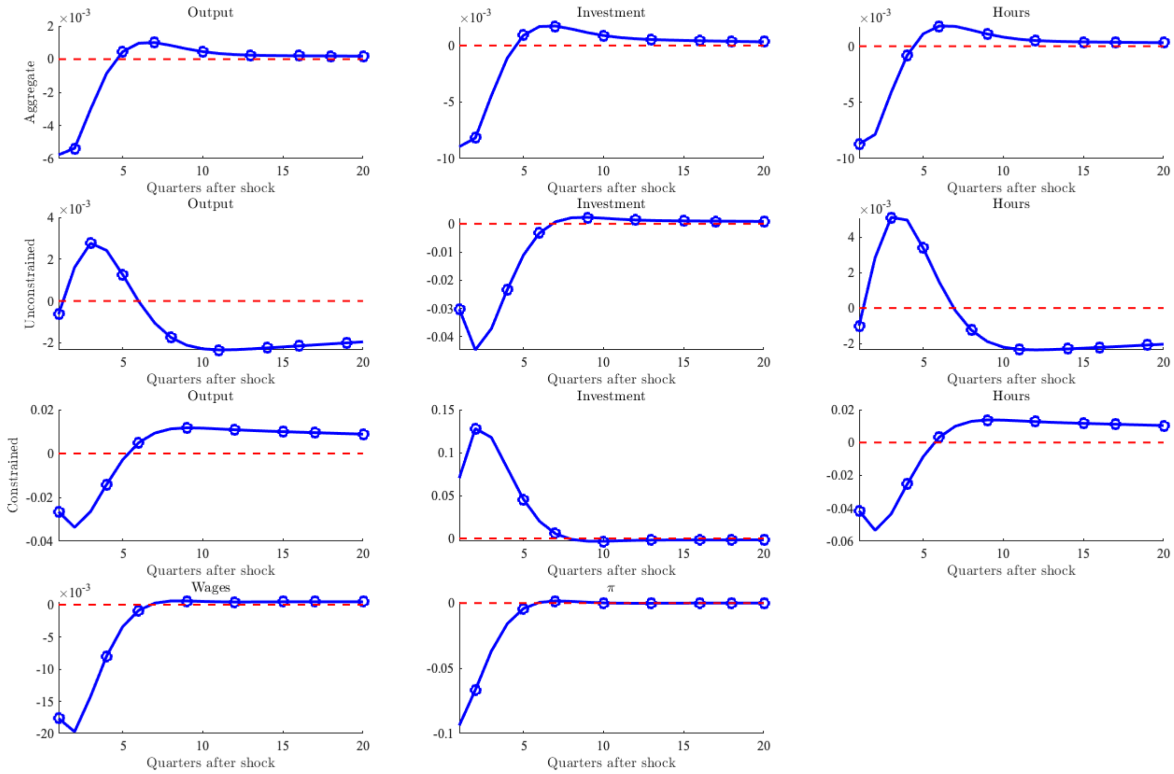
Source: Author's Calculations

In terms of real variables, Figure 2 shows the effect on output, hours, wages, investment, and inflation. The impact over the aggregate economy is consistent with what has been found in the literature that studies monetary policy shocks, such as Christiano et al. [2010b]. However, the effect of a monetary policy shock varies on firms with different levels of financial constraints; as such, the effects on constrained and unconstrained firms compensate and cancel each other. On impact, both unconstrained and constrained firms show a decrease in output. Unconstrained firms have a temporary recovery, but they have a diminished production that takes a long period to recover after this initial recovery.

On the other hand, Constrained firms have a more substantial decrease on output on impact, and they take a long time to recover. However, after their recovery, their output stays above their initial level for an extended period. Although the dynamics of the firms are entirely different and do not resemble the usual dynamics of output after a monetary policy shock, their aggregation does show the expected dynamics. This indicates that the dynamics cancel each other, so aggregate dynamics hide essential dynamics that are important to disentangle.

The effect of investment and hours have the same story, aggregate dynamics show the expected dynamics, but the individual dynamics are different. It is essential to note the dynamics from investment, where a contractionary shock leads to an increase in investment contrary to what is expected. This is because after a contractionary shock, the collateral price decreases, so they increase capital to compensate for their decline in collateral. As such, the reaction of constrained firms in the presence of a reduction in the collateral value is a combination of a decreased activity that leads to a decrease in demand for loans and an increase in investment, compensating for the loss of value in collateral.

Figure 2: Effects of a Monetary Policy Shock on Real Variables and Inflation



Source: Author's Calculations

6 Conclusions

In this paper, I present a medium-sized DSGE model to analyze the effects of monetary policy shocks on the economy. The general equilibrium model I developed is populated by firms, constrained and unconstrained, households, capital producers, financial intermediaries, and a central bank. The novel feature of the model is to abandon the representative firm assumption by identifying firms as either financially constrained or unconstrained while keeping the model tractable. The financial constraints come from the fact that some firms do not release enough information to the public, so they need to guarantee the loans they take using collateral.

Unconstrained firms are assumed to release enough information to the public, so households understand the company well, and they are willing to lend resources directly to these firms. On the other hand, constrained firms need to rely on financial institutions for loans by not releasing information to the public. These loans are required to be secured by collateral. The model also includes several rigidities that are now standard in monetary literature: external habit formation, staggered wages, cost of investment, and cost of adjusting prices.

The model is then used to study monetary policy transmission by analyzing the model's impulse responses to an unanticipated increase in the policy rate. First, the results show that financially constrained firms respond more strongly to monetary policy shocks than unconstrained firms. They also show that aggregate dynamics hide the individual dynamics that compensate and can cancel each other. Finally, the results are in line with what was found by Oliner and Rudebusch [1996], after a contractionary monetary policy shock, total lending shifts away from small firms.

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A Equilibrium Conditions

B Equilibrium Conditions 2

The endogenous variables

1	2	3	4	5	6	7	8	9
C_t	λ_t	b_t	$G_{1,t}$	Y_t^u	Y_t^c	Y_t	ϕ_t	l_t^c
Y_t^u	r_t^d	w_t	$G_{2,t}$	H_t^u	H_t^c	H_t	π_t^u	K_t
Y_t^c	r_t^b	Λ_t	q_t	K_t^u	K_t^c	u_t	π_t^c	Y_t^D
p_t^u	π_t	b_t^u	r_t^l	γ_t^u	γ_t^c	z_t	res_t	
p_t^c	d_t	w_t^*	l_t	I_t^u	I_t^c	I_t	$prof_t^b$	

Monetary Policy

$$1 + r_t^d = \frac{1}{\beta}\left(1 + \pi_t\right)^{\tau_\pi}\left(1 + \frac{Y_t}{Y_{t-1}}\right)^{\tau_g}\left(1 + u_t\right) \tag{1}$$

$$x_t = \left(1 + \pi_{t+1}\right) m_{t+1} - m_t \tag{2}$$

Households:

$$\mathit{\Lambda}_{t,t+1} = \beta\frac{\lambda_{t+1}\left(1+r^b_{t+1}\right)}{\lambda_t\left(1+r^b_t\right)} \tag{3}$$

$$Y^u_t = \left(p^u_t\right)^{-\theta_p} Y_t \tag{4}$$

$$Y^c_t = \left(p^c_t\right)^{-\theta_p} Y_t \tag{5}$$

$$1 = \left(1-\omega_{cu}\right)\left(p^u_t\right)^{1-\theta_p} + \omega_{cu}\left(p^c_t\right)^{1-\theta_p} \tag{6}$$

$$1+\pi^u_t = \left(1+\pi_t\right)\frac{p^u_t}{p^u_{t-1}} \tag{7}$$

$$1+\pi^c_t = \left(1+\pi_t\right)\frac{p^c_t}{p^c_{t-1}} \tag{8}$$

$$\lambda_t\left(1+r^d_t\right) = \frac{1}{C_t-\tau C_{t-1}} \tag{9}$$

$$\lambda_t = \beta\mathbb{E}_t\left(\frac{1+r^b_t}{1+\pi_{t+1}}\right)\lambda_{t+1} \tag{10}$$

$$\lambda_t = \beta\mathbb{E}_t\left(\frac{1+r^d_t}{1+\pi_{t+1}}\right)\lambda_{t+1} \tag{11}$$

$$C_t+d_t+b_t = m_t+w_tH_t \tag{12}$$

$$w^*_t = \frac{\theta_w}{\theta_w-1}\chi\frac{G_{1t}}{G_{2t}} \tag{13}$$

$$w_t = \tag{14}$$

$$G_{1,t} = \left(\frac{w^*_t}{w_t}\right)^{-\theta_w(1+\eta)} H^{1+\eta}_t + \mathbb{E}_t\beta\omega_w\left(1+\pi_t\right)^{-\nu(1+\eta)\theta_w}\left(1+\pi_{t+1}\right)^{\theta_w(1+\eta)}\left(\frac{w^*_{t+1}}{w^*_t}\right)^{-\theta_w(1+\eta)} G_{1,t+1} \tag{15}$$

$$G_{2,t} = \left(\frac{w^*_t}{w_t}\right)^{-\theta_w} H_t\lambda_t\left(1+r^d_t\right) + \mathbb{E}_t\beta\omega_w\left(1+\pi_t\right)^{\nu(1-\theta_w)}\left(1+\pi_{t+1}\right)^{-\theta_w(1+\eta)}\left(\frac{w^*_t}{w^*_{t+1}}\right)^{-\theta_w} G_{2,t+1} \tag{16}$$

Capital Producers:

$$1 = q_t\left(1-\frac{\psi}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2-\psi\frac{I_t}{I_{t-1}}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right)+\mathit{\Lambda}_{t+1}q_{t+1}\frac{I_{t+1}}{I_t}\left(\frac{I_{t+1}}{I_t}-1\right)^2 \tag{17}$$

$$K_t = \left(1-\delta\right)K_{t-1}+\left(1-\frac{\psi}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right)I_t \tag{18}$$

Unconstrained Firms

$$Y_t^u = z_t \left(H_t^u\right)^{1-\alpha} \left(K_{t-1}^u\right)^{\alpha} \tag{19}$$

$$I_t^u = K_t^u - (1-\delta) K_{t-1}^u \tag{20}$$

$$b_t^u = w_t H_t^u + q_t^K I_t^u \tag{21}$$

$$w_t \left(1 + r_t^b\right) = (1-\alpha) z_t \left(\frac{K_{t-1}^u}{H_t^u}\right)^{\alpha} \gamma_t^u \tag{22}$$

$$\left(1 + r_t^b\right) q_t^K = \mathbb{E}_t \left(1 + \pi_{t+1}\right) \Lambda_{t+1} \begin{pmatrix} (1-\delta) q_{t+1}^K \left(1 + r_{t+1}^b\right) \\ +\alpha z_{t+1} \left(\frac{H_{t+1}^u}{K_t^u}\right)^{1-\alpha} \gamma_{t+1}^u \end{pmatrix} \tag{23}$$

$$\begin{pmatrix} (1-\theta_p) \left(\frac{P_t^u}{P_t}\right)^{1-\theta_p} Y_t \\ +\theta_p \left(\frac{P_t^u}{P_t}\right)^{-\theta_p} \gamma_t^u Y_t \end{pmatrix} = \begin{pmatrix} \psi_p \left(1 + \pi_t^u\right) \pi_t^u \\ -\mathbb{E}_t \psi_p \left(1 + \pi_{t+1}\right) \left(1 + \pi_{t+1}^u\right) \left(\pi_{t+1}^u\right) \Lambda_{t+1} \end{pmatrix} \tag{24}$$

Constrained Firms

$$Y_t^c = z_t \left(H_t^c\right)^{1-\alpha} \left(K_{t-1}^c\right)^{\alpha} \tag{25}$$

$$\left(1 + r_t^l\right) q_t^K \left(1 + \phi_t\right) = \mathbb{E}_t \left(1 + \pi_{t+1}\right) \Lambda_{t+1} \begin{pmatrix} (1-\delta) q_{t+1}^K \left(1 + r_{t+1}^l\right) \left(1 + \phi_{t+1}\right) \\ +\kappa (1-\delta) q_{t+1}^K \phi_{t+1} + \alpha z_{t+1} \left(\frac{H_{t+1}^c}{K_t^c}\right)^{1-\alpha} \gamma_{t+1}^c \end{pmatrix} \tag{26}$$

$$w_t \left(1 + r_t^l\right) \left(1 + \phi_t\right) = (1-\alpha) z_t \left(\frac{K_{t-1}^c}{H_t^c}\right)^{\alpha} \gamma_t^c \tag{27}$$

$$\begin{pmatrix} (1-\theta_p) \left(\frac{P_t^c}{P_t}\right)^{1-\theta} Y_t \\ +\theta_p \left(\frac{P_t^c}{P_t}\right)^{-\theta_p} \gamma_t^c Y_t \end{pmatrix} = \begin{pmatrix} \psi_p \left(1 + \pi_t^c\right) \pi_t^c \\ -\mathbb{E}_t \psi_p \left(1 + r_{t+1}^l\right) \left(1 + \phi_{t+1}\right) \left(1 + \pi_{t+1}\right) \left(1 + \pi_{t+1}^c\right) \pi_{t+1}^c Q_{t+1} \end{pmatrix} \tag{28}$$

$$l_t^c = w_t H_{j,t}^c + q_t^K I_t^c \tag{29}$$

$$K_t^c = I_t^c + (1-\delta) K_{t-1}^c \tag{30}$$

$$\left(1 + r_t^l\right) l_t = \kappa q_t^K (1-\delta) K_{t-1}^c \tag{31}$$

Banks

$$\frac{\left(1+r_t^d\right)}{1-\xi^d} = 1 + r_t^l \tag{32}$$

$$l_t + res_t = d_t + x_t \tag{33}$$

$$res_t = xxd_t \tag{34}$$

$$prof_t^b = \left(1+r_t^l\right) l_t - \left(1+r_t^d\right) d_t \tag{35}$$

Markets Conditions

$$H_t = \omega_{cu} H_t^u + (1-\omega_{cu}) H_t^c \tag{36}$$

$$I_t = \omega_{cu} I_t^u + (1-\omega_{cu}) I_t^c \tag{37}$$

$$b_t = \omega_{cu} b_t^u \tag{38}$$

$$l_t = (1-\omega_{cu}) l_t^c \tag{39}$$

$$Y_t = C_t + I_t + \frac{\psi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 + \frac{\psi}{2}\left((1-\omega_{cu})\pi_t^u + \omega_{cu}\pi_t^c\right) + \frac{\psi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{40}$$

$$Y_t = \omega_{cu} Y_t^u + (1-\omega_{cu}) Y_t^c \tag{41}$$

Exogenous Process

$$z_t = \rho_t^z z_{t-1} + \epsilon_{zt} \tag{42}$$

$$u_t = \rho_t^u u_{t-1} + \epsilon_t^u \tag{43}$$