Monetary Policy, Firm Heterogeneity, and Product Variety*

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January 2021

Abstract

This study provides new insights on the allocative effect of monetary policy. It shows that contractionary monetary policy exerts an important reallocation effect by cleansing unproductive firms and enhancing aggregate productivity. At the same time, however, reallocation involves a reduction in the number of product variety that is central to consumer preferences and hurts welfare. A contractionary policy prevents the entry of new firms and insulates incumbent firms from competition, reducing aggregate productivity. Under demand uncertainty, the gain of the optimal monetary policy diminishes in firm heterogeneity and increases in the preference for product variety. We provide empirical evidence on US data that corroborates the relevance of monetary policy for product variety resulting from firm entry and exit.

Keywords: Monetary policy; firm heterogeneity; product variety; reallocation..
JEL classification: E32; E52; L51; O47.

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*We are grateful to Florin Bilbiie, Ippei Fujiwara, Ben Moll, Michiru Sakane, Philip Schnattinger, and Petr Sedlaceck for insightful discussions and seminar participants at the First Keio-Waseda Macro Workshop in 2018, the Annual Congress of the European Economic Association in 2020 and the University of Oxford for helpful comments. We are grateful to the Murata Science Foundation and JSPS KAKENHI Grant Number 18K01521, British Academy and Leverhulme Trust for financial support.

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Monetary policies have probably had unintended side effects on the recent productivity growth experience, but the magnitude and sign of these are unclear—in fact, these unintended consequences may well add up to a positive overall effect. Remarks by Maurice Obstfeld, chief economist at the IMF, at the joint BIS-IMF-OECD Conference, January 10, 2018. Obstfeld (2018).

1 Introduction

Over the past 40 years, inflation has been remarkably stable and monetary policy reached historically low nominal interest rates, leading to an unprecedented decline in real interest rates. Economic theory asserts that persistently low real interest rates allow low-productive firms to remain profitable and operate, thus generating a slowdown in productivity.[1] Under these premises, monetary policy exercises an important allocative effect on the economy. In this paper, we revisit the allocative role of monetary policy across firms using a novel framework that links monetary policy to the endogenous determination of product variety from entry and exit of heterogeneous firms. The analysis sheds light on important effects of monetary policy that arise from the interplay between firm heterogeneity and product variety, and it provides an empirical assessment on the channels that link monetary policy to product variety and aggregate productivity.

Our key contribution is to develop a parsimonious model with heterogenous firms and endogenous product variety with an analytical solution that transparently isolates the critical forces that determine the allocative effect of monetary policy. Central to our analysis, households have standard CES preferences that weight the contribution of imperfectly substitutable goods, whose variety is determined by the endogenous entry and exit of firms with different productivity. Firms enter the market when expected profits exceed exogenous entry costs. On entry, firms draw an idiosyncratic productivity level

[1] The idea that exceedingly low real interest rates prevent a natural "cleansing effect" to operate in the economy dates back to Schumpeter. See seminal studies by Caballero and Hammour (1994), Caballero and Hammour (1996) and Caballero et al. (2008) for a discussion of the issues. Several recent studies discussed below support this view for the protracted slowdown in productivity in developed economies in recent years.

and use one period to build capacity and produce. Only firms whose productivity is sufficiently high to cover fixed operational costs engage in production, manufacturing a single variety of goods in monopolistically competitive goods and labor markets, where nominal wages are set one period in advance. Firms that are insufficiently productive and unable to generate profits to cover fixed operational costs shut down. Nominal wage rigidities make monetary policy non-neutral and powerful in reallocating resources across heterogenous firms.

In accordance to the findings in several studies discussed below, a contractionary monetary policy reallocates resources to high-productive firms, causing the "cleansing" of firms with low productivity (Caballero and Hammour, 1994), which results in increased aggregate productivity. Since the goods market is imperfectly competitive and prices are a fixed markup over marginal costs, the rise in aggregate productivity leads to a decrease in the aggregate price that raises consumption and increases a household's utility. Unlike existing studies, however, our framework sheds light on an important, countervailing effect of monetary policy. A contractionary monetary policy which prevents the survival of low-productivity firms and encompasses a decrease in prices also generates a reduction in product variety that decreases households utility.

To investigate the effect of monetary policy on welfare, we study the Ramsey-optimal policy. To the best of our knowledge, ours is the first study to appraise optimal monetary policy in a model with endogenous entry *and* exit of heterogeneous firms and product variety. Our analysis complements related studies by Bergin and Corsetti (2008), Bilbiie et al. (2014), Cacciatore et al. (2016) and Chugh et al. (2020) that examine optimal policy with endogenous firm entry. We show that welfare depends on the interaction between average productivity *and* product variety and that changes in monetary policy induce adjustments in each of these variables that exert counteracting effects on welfare. The optimal monetary policy that replicates the allocations of an efficient economy with flexible wages involves the stabilization of nominal wages in response to demand shocks. Under flexible wages, the positive demand shock increases the marginal utility of consumption, and households extract larger utility from consuming. Therefore they optimally increase the supply of labor and reduce the aggregate wage, such that firms expand production to fulfil the exogenous increase in demand. The optimal policy that offsets distortions from nominal rigidities requires an increase in entry and a fall in exit of firms, which leads to lower aggregate productivity and an increase in product variety. To assess the gain of the optimal policy, we compare it against an inactive policy that maintains an unchanged monetary policy stance. The benefit of the optimal policy decreases in the degree of firm heterogeneity and rises in the household's preference for variety. In an economy with large firm heterogeneity, the effect of monetary policy on average productivity becomes the predominant driver of welfare that outweighs the effect of preference for variety. Therefore a reallocation of resources towards low-productive firms worsens welfare.

We extend the simple model to assess whether results continue to hold in a broader framework that accounts for a gradual depreciation of firms, includes entry costs, assumes a standard Calvo wage setting, and implements monetary policy with a Taylor rule. The degree of firm heterogeneity remains important for the change in average productivity. The contractionary monetary policy generates an increase in average productivity from the reallocation of resources to more productive firms that is proportional to the degree of heterogeneity. However, the overall increase in productivity is quantitatively small and generates similar responses in aggregate output and product variety across different degrees of firm heterogeneity. The extended model shows that the entry costs play an important role in shielding incumbent firms from the competition of newly created firms. Low entry costs increase the sensitivity of firm entry to shocks and therefore a contractionary monetary policy shock is more powerful in reducing firm entry. A lower entry of new firms insulates incumbent firms from competition, thus decreasing average productivity and raising inflation along the transition dynamics.[2]

We provide empirical evidence on the reallocative effect of monetary policy for the US economy. We identify monetary policy shocks using a structural vector autoregression (SVAR) model with a standard Cholesky decomposition as Christiano et al. (1999), relying

[2]Caballero and Hammour (2005) name recovery phases characterized by low firm exit rather than high firm entry as "reversed-liquidationist view," which works against traditional Schumpeterian creative destruction. Hamano and Zanetti (2017) show that firm exit diminishes in response to a fall in aggregate productivity.

on the assumption that monetary policy in the current period responds to changes in output and inflation, and remains irresponsive to movements in measures of firm entry, exit, and aggregate productivity. We find that a contractionary monetary policy shock significantly decreases the entry of new firms on impact, while increasing the number of business failures with some delay from the shock. Aggregate productivity falls in the aftermath of the contractionary monetary policy shock and remains below the initial level for four quarters. These results corroborate the findings in the extended model and show relevance of monetary policy for product variety resulting from firm entry and exit, suggesting at the same time that a contractionary monetary policy insulates incumbent firms from the competition of new entrants, which decreases average productivity.

Several studies investigate the relationship between monetary policy and firm entry, but without focusing on endogenous firm exit and the resulting reallocation effect of monetary policy, which is the main focus of our analysis. Bilbiie et al. (2007) show that monetary policy should stabilize producer-price inflation instead of consumer-price inflation. Bilbiie et al. (2014) investigate the optimal Ramsey policy with endogenous firm entry and product variety, establishing that positive long-run inflation is optimal when the household's preferences account for product variety. Lewis and Poilly (2012) consider the interaction between nominal wage and price rigidities under different specifications for preferences, showing that the framework generates empirically plausible fluctuations in price markup. Bergin and Corsetti (2008) and Bilbiie (2020) develop a model with firm entry and price rigidities, in which product variety is endogenous to monetary policy and critical for welfare.[3] Colciago et al. (2020) show that endogenous firm dynamics is critical for an empirically-congruous effect of monetary policy on unemployment.

Totzek (2009) develops a model with heterogeneous firms and endogenous exit to

[3] Specifically, we break the neutrality of monetary policy discussed in Bilbiie (2020) by incorporating the reallocation effect of monetary policy based on heterogeneous firms. In the open economy context, Bergin and Corsetti (2015) analyze specialization across industries and the dynamics of comparative advantage across countries due to the terms of trade fluctuations triggered by monetary policy. Hamano and Picard (2017) investigate the optimal exchange rate system with firm entry and show a higher welfare gain from fixed exchange rate system under lower preference for variety. Cacciatore et al. (2016) analyze the interaction between product and labor market (de)regulation and the optimal Ramsey policy in a monetary union.

study the transmission mechanism of monetary policy shocks, finding similar quantitative results without focusing on optimal policy. Oikawa and Ueda (2018) study the reallocation effect of money growth. Cacciatore and Ghironi (2014) investigate the Ramsey optimal monetary policy, allowing for international reallocation of heterogeneous firms in exporting markets. Hamano and Pappadà (2020) show that a fixed exchange rate regime generates large firms turnover in export markets, which is detrimental to welfare.[4]

The remainder of the paper is organized as follows. Section 2 lays out the model. Section 3 studies the allocative effect of monetary policy to assess the gain of optimal policy. Section 4 extends the simple model, focusing on the role of firm heterogeneity and the costs of entry for the propagation of monetary policy shocks. Section 5 provides empirical evidence. Section 6 concludes.

2 The Model

The economy is populated by a continuum of households of unit mass, each of which provides a differentiated labor service indexed by $j \in [0, 1]$ and a continuum of maximizing producers, each of which has a distinct idiosyncratic productivity, $z \in [z_{min}, \infty]$, and manufactures a single variety of imperfectly substitutable goods.[5] Firms enter the market by incurring a fixed entry cost expressed in wage units. On entry, they draw a permanent idiosyncratic productivity. Firms use one period to build capacity, production takes place one period after entry, and firms completely depreciate after producing. Production requires payment of a fixed operational cost. Thus, only a subset of firms, whose productivity is sufficiently large to cover the fixed cost of production, produces while other firms remain idle and depreciate in next period without producing.

Households set wages one period in advance. The economy is cashless, and money

[4]A growing number of studies considers the effect of monetary policy in the allocation of resources, focusing on the misallocation of resources in frictional financial markets in an open economy (Gopinath et al., 2017) and under-development in financial markets (Aoki et al., 2010 and Reis, 2013). Unlike our analysis, these studies abstract from endogenous firm exit and the critical interplay with product variety.

[5]We interpret our model as populated by different producers, each of which manufacture a distinct product variety. However, an alternative interpretation is one large firm with multiple production lines, as in Chugh et al. (2020) and Hamano and Zanetti (2017).

is the unit of account. Monetary policy is non-neutral for the presence of nominal wage rigidities. The next section describes the optimizing behavior of households and firms.

2.1 Households

The representative household maximizes expected utility, $E_t \sum_{s=t}^{\infty} \beta^{s-t} U_t(j)$, where $0 < \beta < 1$ is the exogenous discount factor. Utility of each individual household j at time t depends on consumption $C_t(j)$ and the supply of labor $L_t(j)$, as follows:

$$U_t(j) = \alpha_t \ln C_t(j) - \eta \frac{[L_t(j)]^{1+\varphi}}{1+\varphi},$$

where α_t is an exogenous demand shifter at time t. The parameter $\eta > 0$ represents the disutility of supplying labor, and $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply. The household's consumption basket is defined by the CES aggregator:

$$C_t(j) = \left(\int_{\varsigma \in \Omega} c_t(j,\varsigma)^{1-\frac{1}{\sigma}} d\varsigma \right)^{\frac{1}{1-\frac{1}{\sigma}}}, \tag{1}$$

where the subset Ω of produced goods is available from the universe of goods. $c_t(j,\varsigma)$ is the demand of household j for the product variety ς, and $\sigma > 1$ is the elasticity of substitution among differentiated product variety. Note that from the CES aggregation of the consumption basket in equation (1), the marginal utility of one additional variety is equal to $1/(\sigma - 1)$, which encapsulates the household's preference for variety, as in Dixit and Stiglitz (1977). Optimal consumption for each variety is:

$$c_t(j,\varsigma) = \left(\frac{p_t(\varsigma)}{P_t} \right)^{-\sigma} C_t(j), \tag{2}$$

and the associated price index that minimizes the nominal expenditure is:

$$P_t = \left(\int_{\varsigma \in \Omega} p_t(\varsigma)^{1-\sigma} d\varsigma \right)^{\frac{1}{1-\sigma}}.$$

2.2 Production Decision and Pricing

Firms have distinct idiosyncratic productivity z. Each firm manufactures one variety in a monopolistically competitive market. The firm with productivity z adjusts labor input to manufacture output $y_t(z)$ and cover the fixed operational costs f. Labor demand $l_t(z)$ is equal to:

$$l_t(z) = \frac{y_t(z)}{z} + f. \tag{3}$$

In equation (3), the labor required for production, $l_t(z)$, is composed of imperfectly substitutable labor input from each household j, aggregated according to the CES aggregator:

$$l_t(z) = \left(\int_0^1 l_t(z,j)^{1-\frac{1}{\theta}} dj \right)^{\frac{1}{1-\frac{1}{\theta}}},$$

where the demand for labor of type j to the firm with productivity z is given by:

$$l_t(z,j) = \left(\frac{W_t(j)}{W_t} \right)^{-\theta} l_t(z),$$

where W_t is the wage index:

$$W_t = \left(\int_0^1 W_t(j)^{1-\theta} dj \right)^{\frac{1}{1-\theta}}.$$

Each firm faces a residual demand curve with constant elasticity σ, as in equation (2), and maximizes dividends, $D_t(z) = p_t(z)y_t(z) - l_t(z)W_t$. Demand determines the scale of production, and profit maximization for the firm with productivity level z yields the optimal pricing rule:

$$p_t(z) = \frac{\sigma}{\sigma - 1} \frac{W_t}{z}.$$

Due to the fixed operational costs, f, the firm with productivity z may be insufficiently profitable to start production. Firms with productivity that is below the cut-off level $z_{S,t}$ (i.e., $z < z_{S,t}$) cannot cover fixed operational costs and remain idle. The profit for the firm with idiosyncratic productivity z is:

$$D_t(z) = \begin{cases} \frac{1}{\sigma}\left(\frac{p_t(z)}{P_t}\right)^{1-\sigma} P_t \int_0^1 C_t(j)dj - fW_t, & \text{if } z > z_{S,t} \\ = 0 & \text{otherwise.} \end{cases}$$

2.3 Firm Averages

In each period t, the subset S_t of the N_t existing firms that entered the market in period $t-1$ have an idiosyncratic productivity above the cut-off level $z_{S,t}$ and start producing. Thus, the number of producing firms in each period t is: $S_t = [1 - G(z_{S,t})]\, N_t$. As in Melitz (2003), the average level of productivity $\widetilde{z}_{S,t}$ for producing firms is:

$$\widetilde{z}_{S,t} \equiv \left[\frac{1}{1 - G(z_{S,t})} \int\limits_{z_{S,t}}^{\infty} z^{\sigma-1} dG(z)\right]^{\frac{1}{\sigma-1}}. \tag{4}$$

The average productivity level $\widetilde{z}_{S,t}$ summarizes information about the distribution of productivity across producers. Using the definition of average productivity in equation (4), we can express the average price and profits as: $\widetilde{p}_{S,t} \equiv p_t(\widetilde{z}_{S,t})$ and $\widetilde{D}_{S,t} \equiv D_t(\widetilde{z}_{S,t})$, respectively.

2.4 Firm Entry and Exit

During each period t, there is a mass of N_{t+1} new-entrant firms that have sufficiently large expectations on profits to cover the exogenous entry costs f_E. On entry, new entrants draw an idiosyncratic productivity z from a time-invariant distribution $G(z)$, where $z \in [z_{\min}, \infty)$. To cover entry costs, new entrants hire labor services $l_{E,t}$, such that $f_E = l_{E,t}$. Labor services are composed of imperfectly differentiated labor input offered by households (indexed by j), such that:

$$l_{E,t} = \left(\int_0^1 l_{E,t}(j)^{1-\frac{1}{\theta}} dj\right)^{\frac{1}{1-\frac{1}{\theta}}}, \tag{5}$$

where $\theta > 1$ is the elasticity of substitution among labor services. The total cost related to entry is thus equal to: $\int_0^1 l_{E,t}(j)W(j)dj$. Cost minimization of entry cost yields the following labor demand for each j-type labor:

$$l_{E,t}(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\theta} l_{E,t}. \tag{6}$$

After entry at time t, the new firm requires one period to build capacity before starting production in period $t+1$. Entry of new firms takes place until the expected value of entry is equal to the entry cost, $f_E W_t$, which yields the following free entry condition:

$$\widetilde{V}_t = f_E W_t, \tag{7}$$

where $\widetilde{V}_t$ is the expected value of entry (defined below). As in Bergin and Corsetti, 2008, we assume that producing firms entirely depreciate after production at the end of each period t. In Section 4, we relax this simplifying assumption with a more realistic law of motion for the firms' dynamics.

2.5 Distribution of Idiosyncratic Productivity

The idiosyncratic productivity has a Pareto distribution $G(z)$, defined by:

$$G(z) = 1 - \left(\frac{z_{\min}}{z}\right)^{\kappa},$$

where $z_{\min}$ is the minimum level of productivity, and $\kappa > \sigma - 1$ determines the shape of the distribution. The degree of heterogeneity in productivity is inversely related to the parameter κ, and firms become homogeneous with same productivity z at the lower end of distribution for $\kappa \to \infty$. Using the properties of the Pareto distribution, we can write the average productivity for firms as:

$$\widetilde{z}_{S,t} = z_{S,t}\left[\frac{\kappa}{\kappa - (\sigma - 1)}\right]^{\frac{1}{\sigma-1}}.$$

Similarly, using $S_t = [1 - G(z_{S,t})] N_t$, the share of producing firms, S_t, over the total number of firms, N_t, is:

$$\frac{S_t}{N_t} = z_{\min}^{\kappa} (\widetilde{z}_{S,t})^{-\kappa} \left[\frac{\kappa}{\kappa - (\sigma - 1)} \right]^{\frac{\kappa}{\sigma - 1}}. \tag{8}$$

As discussed, there exists a cut-off of idiosyncratic productivity level, $z_{S,t}$, for which the firm earns zero profits, such that: $D_t(z_{S,t}) = 0$. Using the zero profit condition with the Pareto distribution, we obtain the following zero cutoff profits (ZCP) condition:

$$\widetilde{D}_{S,t} = \frac{\sigma - 1}{\sigma \kappa} \frac{P_t \int_0^1 C_t(j) dj}{S_t}. \tag{9}$$

2.6 Households Optimizing Decisions

In each period t, the household j faces the budget constraint:

$$P_t C_t(j) + B_t(j) + x_t(j) N_{t+1} \widetilde{V}_t = (1 + \nu) W_t(j) L_t(j) + (1 + i_{t-1}) B_{t-1}(j) + x_{t-1}(j) S_t \widetilde{D}_{S,t} + T_t^f, \tag{10}$$

where $B_t(j)$ and $x_t(j)$ are bond holdings and share holdings of mutual funds, respectively. $1 + \nu$ is a labor subsidy issued by the government. i_t is the net nominal interest rate between $t - 1$ and t, and T_t^f is a lump-sum transfer from the government. The household j sets the wage one period in advance, facing the following labor demand:

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\theta} L_t.$$

By maximizing expected utility in each period t, the optimal wage, $W_t(j)$, is given by:

$$W_t(j) = \frac{\theta}{(\theta - 1)(1 + \nu)} \frac{\eta \mathrm{E}_{t-1} \left[L_t(j)^{1+\varphi} \right]}{\mathrm{E}_{t-1} \left[\frac{\alpha_t L_t(j)}{P_t C_t(j)} \right]}. \tag{11}$$

Equation (11) shows that the household sets the wage to equate the expected marginal cost of supplying additional labor services, $\eta \theta W_t(j)^{-1} \mathrm{E}_{t-1} \left[L_t(j)^{1+\varphi} \right]$, to the expected marginal revenue, $(\theta - 1)(1+\nu)\,\mathrm{E_{t-1}}\left[\frac{\alpha_t L_t(j)}{P_t C_t(j)}\right]$. Since the wage is set one period in advance, the wage at time t depends on the expectations formed in the previous period $t-1$.

The first order condition for share holdings yields:

$$\widetilde{V}_t = E_t\left[Q_{t,t+1}(j)\frac{S_{t+1}}{N_{t+1}}\widetilde{D}_{S,t+1}\right], \tag{12}$$

where $Q_{t,t+1}(j)$ is the nominal stochastic discount factor defined as $Q_{t,t+1}(j) = E_t\left[\frac{\beta\alpha_{t+1}P_t C_t(j)}{\alpha_t P_{t+1} C_{t+1}(j)}\right]$. Finally, the first order condition for bond holdings yields the standard Euler equation:

$$1 = (1+i_t)E_t\left[Q_{t,t+1}(j)\right]. \tag{13}$$

2.7 Equilibrium

In equilibrium, households are symmetric and $C_t(j) = C_t$, $L_t(j) = L_t$, $M_t(j) = M_t$, and $W_t(j) = W_t$. As in Corsetti and Pesenti (2009) and Bergin and Corsetti (2008), we define a monetary stance μ_t, proportional to total expenditures:

$$\mu_t \equiv P_t C_t. \tag{14}$$

By combining equation (14) with the Euler equation (13), the following transversality condition holds:

$$\frac{\alpha_t}{\mu_t} = \mathrm{E}_t \lim_{s\to\infty} \beta^s \frac{1}{\mu_{t+s}} \prod_{\tau=0}^{s-1}(1+i_{t+\tau}),$$

which shows that the monetary stance μ_t, is tightly linked to the future expected path of the nominal interest rate.[6]

[6]Similarly, the monetary stance can be represented by real money holdings, which is related to the nominal interest rate from the households' demand for money. By adding utility from money holdings (i.e., including the term $\chi \ln(M_t(j)/P_t)$ in the utility function) and savings in terms of money, the first order condition with respect to money holdings is: $\frac{\mu_t}{\alpha_t} = \frac{M_t}{\chi}\left(\frac{i_t}{1+i_t}\right)$.

In this instance, the monetary stance is set by the quantity of money M_t for a given interest rate and demand.

Using the average price for producers $\widetilde{p}_{S,t}$, the average dividends can be expressed as: $\widetilde{D}_{S,t} = \frac{1}{\sigma}\frac{\mu_t}{S_t} - fW_t$. The number of new entrants in each period t is obtained by combining the free entry condition (7), the definition of average dividends ($\widetilde{D}_{S,t}$) and the zero cut-off profit condition (9) together, which yield:

$$N_{t+1} = \frac{\beta(\sigma-1)}{\sigma\kappa}\frac{\mu_t}{W_t f_E}\frac{E_t[\alpha_{t+1}]}{\alpha_t}. \tag{15}$$

Using the ZCP and the average dividends, the number of producing firms in each period t is:

$$S_t = \frac{\kappa-(\sigma-1)}{\sigma\kappa}\frac{\mu_t}{W_t f}. \tag{16}$$

Using (8) the average productivity of producers is given by:

$$\widetilde{z}_{S,t} = z_{\min}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\sigma-1}}\left(\frac{S_t}{N_t}\right)^{-\frac{1}{\kappa}}. \tag{17}$$

Substituting the number of producing firms, S_t, from equation (16) into equation (18), the average scale of production, $\widetilde{y}_{S,t}$, is:

$$\widetilde{y}_{S,t} = \frac{\sigma-1}{\sigma}\frac{\mu_t\widetilde{z}_{S,t}}{S_t W_t}, \tag{18}$$

showing that the scale of output is proportional to the level of average productivity $\widetilde{z}_{S,t}$.

Once we derive a solution for the wage W_t, we obtain the closed-form solution for the system. Since the labor market is monopolistically competitive, the demand for labor determines the supply of labor, which yields: $L_t = S_t l_t(\widetilde{z}_{S,t}) + N_{t+1}l_{E,t}$ and provides the following labor market clearing condition:[7]

$$L_t = S_t\left(\frac{\widetilde{y}_{S,t}}{\widetilde{z}_{S,t}} + f\right) + N_{t+1}f_E. \tag{19}$$

Substituting for N_{t+1}, S_t, and $\widetilde{y}_{S,t}$ from equations (15), (16), and (18), respectively,

[7]The labor market clearing condition (19) can be rewritten as: $W_t L_t = (\sigma-1)S_t\widetilde{D}_{S,t} + \sigma S_t f W_t + N_{t+1}\widetilde{V}_t$.

into the labor market clearing condition (19), and using the outcome in the equilibrium wage in equation (11), yields the following closed-form solution for the wage:

$$W_t = \left\{ \frac{\eta\theta}{(\theta-1)(1+\nu)} \frac{E_{t-1}\left[\left(\frac{\sigma-1}{\sigma} + \frac{\kappa-(\sigma-1)}{\sigma\kappa} + \frac{\beta(\sigma-1)}{\sigma\kappa}\frac{E_t[\alpha_{t+1}]}{\alpha_t}\right)\mu_t\right]^{1+\varphi}}{E_{t-1}\left[\left(\frac{\sigma-1}{\sigma} + \frac{\kappa-(\sigma-1)}{\sigma\kappa} + \frac{\beta(\sigma-1)}{\sigma\kappa}\frac{E_t[\alpha_{t+1}]}{\alpha_t}\right)\alpha_t\right]} \right\}^{\frac{1}{1+\varphi}}. \tag{20}$$

To simplify the analysis, we assume that exogenous changes in demand are permanent, such that $E_t[\alpha_{t+1}] = \alpha_t$, where $\alpha_{t+1} = \alpha_t \epsilon_{t+1}$ and $E_t[\epsilon_{t+1}] = 1$. This simplifying assumption allows us to focus on the fundamental mechanism for the effect of monetary policy in a transparent way, and we will relax this assumption in the extended model in Section 4. Using this specification for the demand shock, the current shock at time t becomes irrelevant for the number of new entrants, N_{t+1}, since changes in future expected demand in period $t+1$ perfectly offset changes in current demand in period t, and the wage equation (20) becomes:

$$W_t = \Gamma \left\{ \frac{E_{t-1}\left[\mu_t^{1+\varphi}\right]}{E_{t-1}[\alpha_t]} \right\}^{\frac{1}{1+\varphi}}, \tag{21}$$

where $\Gamma^{1+\varphi} \equiv \eta\theta/[(\theta-1)(1+\nu)]$ encapsulates the degree of monopolistic distortions in the labor market.

To close the model, we assume the government balances the budget with lump-sum transfers in each period t, such that:

$$T_t^f = \nu W_t L_t.$$

Using closed-form solutions for W_t, N_{t+1}, S_t and $\widetilde{z}_{S,t}$, it is straightforward to obtain analytical solutions to the system of equations for an arbitrary monetary stance μ_t. Table 1 summarizes the model.

Table 1: Model with nominal wage rigidities

Monetary Stance	$\mu_t = P_t C_t$
Wages	$W_t = \Gamma \left\{ \frac{E_{t-1}\left[\mu_t^{1+\varphi}\right]}{E_{t-1}[\alpha_t]} \right\}^{\frac{1}{1+\varphi}}$
Number of Entrants	$N_{t+1} = \frac{\beta(\sigma-1)}{\sigma\kappa} \frac{\mu_t}{W_t f_E}$
Number of Producers	$S_t = \frac{\kappa-(\sigma-1)}{\sigma\kappa} \frac{\mu_t}{W_t f}$
Average Productivity	$\widetilde{z}_{S,t} = \left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\sigma-1}} \left(\frac{S_t}{N_t}\right)^{-\frac{1}{\kappa}}$
Production Scale	$\widetilde{y}_{S,t} = \frac{\sigma-1}{\sigma} \frac{\mu_t \widetilde{z}_{S,t}}{S_t W_t}$
Average Price	$\widetilde{p}_{S,t} = \frac{\sigma}{\sigma-1} \frac{W_t}{\widetilde{z}_{S,t}}$
Price Index	$P_t = S_t^{-\frac{1}{\sigma-1}} \widetilde{p}_{S,t}$
Consumption	$C_t = S_t^{\frac{\sigma}{\sigma-1}} \widetilde{y}_{S,t}$
Dividends of Producers	$\widetilde{D}_{S,t} = \frac{1}{\sigma} \frac{\mu_t}{S_t} - f W_t$
Dividends of Firms	$\widetilde{D}_t = \frac{S_t}{N_t} \widetilde{D}_{S,t}$
Share Price	$\widetilde{V}_t = f_E W_t$
Labor Supply	$L_t = (\sigma - 1) \frac{S_t \widetilde{D}_{S,t}}{W_t} + \sigma S_t f + N_{t+1} f_E$

3 Monetary Policy, Firm Entry and the Reallocation Effect

In this section, we study the role of monetary policy under distortionary nominal wage rigidities. First we characterize the efficient allocation under flexible wages that serve as a benchmark to monetary policy in the attainment of the efficient policy. We show that monetary policy is powerful in balancing out the number of firms (and thus product variety) and aggregate productivity to achieve the efficient allocations when nominal wages are staggered. The benefit of the optimal policy that offsets nominal distortions decreases in the degree of firm heterogeneity and increases in the household preference for variety.

3.1 Allocations under Flexible Wages

To establish the efficient allocations, we characterize the equilibrium under flexible wages and assume that monetary stance remains inactive, such that $\mu_t = \mu_0$. Under flexible wages, the wage adjusts freely in response to shocks, and the wage equation (21) becomes:

$$W_t = \Gamma \mu_0 \left(\frac{1}{\alpha_t} \right)^{\frac{1}{1+\varphi}}. \tag{22}$$

Equation (22) shows that in response to the positive demand shock, the nominal wage decreases – the extent of which is determined by the elasticity of labor supply ($\frac{1}{1+\varphi}$). The positive demand shock increases the marginal utility of consumption, and households extract larger utility from consuming, which requires higher production. The firms increase production and increase labor demand, and households satisfy the higher demand by accepting lower wages. When the elasticity of labor supply is large (i.e. low value of φ), wages decrease more extensively for a given demand shift. The reduction in the wage decreases the entry cost for new firms and production costs for the incumbent firms, therefore increasing the number of new entrants, N_{t+1}, and producing firms, S_t, as shown in equations (15) and (16). At the same time, the low wage allows low-productive firms to continue to operate, resulting in decreases in average productivity across producers, $\widetilde{z}_{S,t}$, as shown in equation (17). Also the average scale of production, $\widetilde{y}_{S,t}$, decreases. Thus, the efficient equilibrium under flexible wages entails an inverse relationship between the product variety that results from the entry and exit of firms and average productivity. As we will show, the optimal monetary policy replicates the allocation under flexible wages, including the above trade-off.[8]

3.2 The allocative Effect of Monetary Policy

We now compare the optimal allocations under flexible wages against those in the model with staggered wages that was developed in Section 3. Under our assumption of one period wage stickiness, the wage sets in period $t-1$ is unresponsive to the shocks in the

[8] Note that it is possible to achieve the Pareto efficient allocations under flexible wages by introducing an appropriately designed subsidy that offsets the distortions related to monopolistic competition in the labor market. It is straightforward to show that the optimal subsidy is equal to:

$$1 + \nu = \frac{\theta}{\theta - 1}.$$

Despite the welfare detrimental monopolistic distortions in the labor market, the monopolistic distortions in the goods market are efficient with the Dixit-Stiglitz preferences since rents encourage firms to enter to fulfil the preference for variety of the households, as shown in Bilbiie et al. (2008), Lewis (2013) and Chugh et al. (2020).

current period t. Since the wage fails to change in response to the current demand shock, the number of new entrants and producing firms (N_{t+1} and S_t) as well as the average level of productivity and output ($\widetilde{z}_{S,t}$ and $\widetilde{y}_{S,t}$) are also insensitive to the current demand shock. Thus, the economy operates suboptimally compared to the model under flexible wages, in which the wage falls in response to the shock. Since monetary policy is non-neutral for the presence of nominal wage rigidities, the monetary policy stance, μ_t, is powerful to change the allocations in the economy to achieve efficiency, as outlined in the following proposition.

Proposition 1. *In each period t, an expansionary (contractionary) monetary stance generates the survival of less (more) efficient producing firms, and it induces a higher (lower) number of new entrants.*

Proof. Straightforward from equations (16) and (17). □

Proposition 1 sheds light on two important opposing forces that operate with changes in the monetary policy stance. On one hand, the number of producing firms, S_t, increases following an expansionary monetary stance, as shown in equation (16). On the other hand, the average productivity level among producing firms, $\widetilde{z}_{S,t}$, declines, as shown in equation (17). An expansionary monetary policy stance that increases aggregate expenditure also allows low-productive firms to stay in the market. Conversely, a contractionary monetary policy stance that reduces aggregate expenditure *cleanses* the market from low-productive firms, increasing aggregate productivity. In other words, monetary policy entails a reallocation effect among heterogeneous firms. Importantly, monetary policy is powerful to determine the balance between the number of firms and hence product varieties as well as overall efficiency.

Monetary policy changes the current number of producers, S_t, their average efficiency, $\widetilde{z}_{S,t}$, and the future number of new firms, N_{t+1}, which determines the future number of varieties in period $t+1$. An expansionary monetary policy stance increases the value of future expected wealth by raising the stochastic discount factor, $Q_{t,t+1}$, and thus increasing share prices, $\widetilde{V}_t$, which increases the number of new firms through the free entry condition in equation (7). Bergin and Corsetti (2008) establish a similar mechanism for the effect of monetary policy on the entry of firms and product variety. However, by assuming homogeneous firms, their framework is unable to account for the effect of monetary policy on aggregate productivity, which instead is a central channel for the effect of monetary policy in our analysis.[9]

3.3 Monetary Policy Rules

In this section, we define the Ramsey optimal monetary policy rule that is consistent with the attainment of the efficient allocations under flexible wages. We then explore the welfare gain of the optimal policy, comparing it to an inactive rule with a passive stabilization policy.

3.3.1 The Optimal Monetary Policy Rule

The planner maximizes the expected utility of households, $E_{t-1}\left[U_t\right]$, by setting the monetary policy stance, μ_t. In our model, the ex-ante (dis)utility of supplying labor is constant, and expected utility is thus given by:[10]

$$\mathrm{E}_{t-1}\left[U_t\right] = E_{t-1}\left[\alpha_t lnC_t\right] = \mathrm{E}_{t-1}\left[\frac{\sigma}{\sigma-1}\alpha_t \ln S_t + \alpha_t \ln \widetilde{y}_{S,t}\right]. \tag{23}$$

[9] Different from our mechanism, Oikawa and Ueda (2018) establish that an expansionary monetary policy may *increase* aggregate productivity when a large growth rate of money imposes large costs on low-productive firms that can change price infrequently.

[10] Note that combining the labor market clearing condition with the solution for the wage, it yields:

$$E_{t-1}\left[L_t^{1+\varphi}\right] = E_{t-1}\left[\frac{\left(\frac{\sigma-1}{\sigma}+\frac{\kappa-(\sigma-1)}{\sigma\kappa}+\frac{\beta(\sigma-1)}{\sigma\kappa}\frac{E_t[\alpha_{t+1}]}{\alpha_t}\right)\mu_t}{W_t}\right]^{1+\varphi}$$

$$= E_{t-1}\left[\frac{\left(\frac{\sigma-1}{\sigma}+\frac{\kappa-(\sigma-1)}{\sigma\kappa}+\frac{\beta(\sigma-1)}{\sigma\kappa}\frac{E_t[\alpha_{t+1}]}{\alpha_t}\right)\mu_t}{\Gamma\left\{\frac{E_{t-1}\left[\left(\frac{\sigma-1}{\sigma}+\frac{\kappa-(\sigma-1)}{\sigma\kappa}+\frac{\beta(\sigma-1)}{\sigma\kappa}\frac{E_t[\alpha_{t+1}]}{\alpha_t}\right)\mu_t\right]^{1+\varphi}}{E_{t-1}\left[\left(\frac{\sigma-1}{\sigma}+\frac{\kappa-(\sigma-1)}{\sigma\kappa}+\frac{\beta(\sigma-1)}{\sigma\kappa}\frac{E_t[\alpha_{t+1}]}{\alpha_t}\right)\alpha_t\right]}\right\}^{\frac{1}{1+\varphi}}}\right]^{1+\varphi} = \left[\frac{\left(1-\frac{(\sigma-1)}{\sigma\kappa}(1-\beta)\right)}{\Gamma}\right]^{1+\varphi} E_{t-1}\left[\alpha_t\right],$$

which is constant.

Applying the values for S_t and $\widetilde{y}_{S,t}$ in equations (16) and (15), respectively, to equation (23), the expected utility can be rewritten as:[11]

$$E_{t-1}\left[U_t\right] = \left(\frac{1}{\sigma-1} + 1 - \frac{1}{\kappa}\right)\left[E_{t-1}\left[\alpha_t \ln \mu_t\right] - \frac{E_{t-1}\left[\alpha_t\right]}{1+\varphi} \ln E_{t-1}\left[\mu_t^{1+\varphi}\right]\right] + \text{cst}, \qquad (24)$$

where the term *cst* regroups constant terms that are unrelated to the effect of monetary policy. To derive the optimal monetary policy stance, we differentiate equation (24) with respect to μ_t, which leads to the rule outlined in the next Proposition.

Proposition 2. *The optimal policy rule that produces the efficient allocations in the economy with flexible wages is:* $\mu_t = \mu_0 \alpha_t^{\frac{1}{1+\varphi}}$.

Proof. By applying the optimal policy rule in Proposition 2 to equations (16), (17), (18) and (15), the number of producers S_t, the entry of firms N_{t+1}, the productivity level $\widetilde{z}_{S,t}$ and the scale of production of average producers $\widetilde{y}_{S,t}$ are the same as those in the economy with flexible wages described in Section 3.1. Appendix A shows the derivation of the optimal policy rule. □

Proposition 2 establishes that optimal policy accommodates the demand shock and allows total expenditures to expand in response to an increase in demand. By substituting the optimal policy rule in Proposition 2 in the wage equation (21), the optimal wage is:

$$W_t = \Gamma \mu_0. \qquad (25)$$

Equation (25) shows that optimal policy completely stabilizes the wage by removing uncertainty related to future labor demand, and μ_0 represents the nominal anchor of the economy that determines the nominal wage level. In the presence of the appropriate labor subsidy in footnote 8, optimal policy achieves Pareto efficiency.

[11] Appendix A shows the derivation of expected utility.

3.4 Welfare Gain of the Optimal Rule

In this section, we discuss the welfare gain of optimal policy. To study the contribution of optimal policy, we compare the optimal monetary policy rule against an alternative policy rule of an inactive central bank that maintains a constant monetary stance $\mu_t = \mu_0$.[12] It is straightforward to show that the welfare difference between the optimal stabilizing policy, which we now refer to as $E_{t-1}\left[U_t^S\right]$, and the non-stabilizing policy, which we refer to as $E_{t-1}\left[U_t^{NS}\right]$, is given by:[13]

$$
\begin{aligned}
& E_{t-1}\left[U_t^S\right] - E_{t-1}\left[U_t^{NS}\right] \\
&\qquad = \left(\frac{1}{\sigma-1} + 1 - \frac{1}{\kappa}\right)\frac{1}{1+\varphi}\left(E_{t-1}\left[\alpha_t \ln \alpha_t\right] - E_{t-1}\left[\alpha_t\right]\ln E_{t-1}\left[\alpha_t\right]\right) \\
&\qquad\qquad = \left(\frac{1}{\sigma-1} + 1 - \frac{1}{\kappa}\right)\frac{1}{1+\varphi}\left(E_{t-1}\left[\epsilon_t \ln \epsilon_t\right]\right) > 0 \qquad (26)
\end{aligned}
$$

Equation (26) shows that the welfare loss of the non-stabilizing policy is proportional to the households' love for variety, $1/(\sigma-1)$, the degree of heterogeneity in the productivity across firms, κ, and the inverse of the elasticity of labor supply, $1/(1+\varphi)$. The next proposition identifies gains and losses of the optimal stabilizing policy rule.

Proposition 3. *Under demand uncertainty, the policy gain (loss) of optimal monetary policy increases in the love for variety, and it decreases in the degree of heterogeneity across firms. A higher labor supply elasticity ($1/\varphi$) amplifies the gain (loss) of optimal policy.*

Proof. Since $\kappa > \sigma - 1$, the term $\left(\frac{1}{\sigma-1} + 1 - \frac{1}{\kappa}\right)\frac{1}{1+\varphi}$ is a strictly positive and increasing function of $1/\sigma$, κ and $1/\varphi$. □

To interpret Proposition 3, consider the case of a monetary expansion that generates an increase in the number of producers and new entrants and reduces the threshold of

[12] We use the same alternative policy rule in Bergin and Corsetti (2008) that encapsulates the case of monetary policy inaction and facilitates the comparison of results with related studies.

[13] Note that $f(\epsilon_t) = \epsilon_t \ln \epsilon_t$ is a convex function with respect to ϵ_t for $\epsilon_t > 0$. By applying Jensen's inequality, it yields: $E_{t-1}\left[\epsilon_t \ln \epsilon_t\right] > E_{t-1}\left[\epsilon_t\right]\ln E_{t-1}\left[\epsilon_t\right]$, with $E_{t-1}\left[\epsilon_t\right] = 1$, $E_{t-1}\left[\epsilon_t \ln \epsilon_t\right] > 0$.

idiosyncratic productivity of producing firms. Such a policy allocates resources to low-productive firms and thereby decreases average productivity in the economy. For a given degree of love for variety, $1/(\sigma - 1)$, the reallocation effect of monetary policy increases in the degree of firm heterogeneity associated with low values of κ. The lower the dispersion of idiosyncratic productivity, the lower the contraction in aggregate productivity and therefore the reallocation effect of monetary policy. At the limiting case of $\kappa = \infty$, when firms are homogeneous at the lower end of distribution and there is no reallocation effect, monetary policy involves no efficiency loss. Similarly, for a given degree of firm heterogeneity determined by the parameter κ, the gains from optimal policy are proportional to the degree of love for variety. A contractionary monetary policy stance in the presence of firm heterogeneity reallocates resources to more productive firms that remain profitable and continue to operate in the market in result to their high productivity. At the same time, the contractionary monetary policy stance decreases the number of variety in the economy, which decreases welfare, given the households love for variety. In the limiting case of $\kappa = \sigma - 1$ – the smallest love for variety under our parametric restriction – the gain of the optimal policy is also the smallest.

The policy gain increases with the elasticity of the labor supply $(1/\varphi)$, *ceteris paribus.* When the labor supply is perfectly inelastic $(\varphi = \infty)$, production is fixed, and monetary policy becomes ineffective. Thus there is no gain in the optimal policy.

Finally, it is instructive to consider an alternative interpretation on the gain from optimal stabilization, by rewriting the expected utility in equation (23) as:

$$\mathrm{E}_{t-1}\left[U_t\right] = \frac{\sigma}{\sigma - 1}\left[\mathrm{E}_{t-1}\alpha_t \mathrm{E}_{t-1}\ln S_t + Cov(\alpha_t, \ln S_t)\right] + \mathrm{E}_{t-1}\alpha_t \mathrm{E}_{t-1}\ln\widetilde{y}_{S,t} + Cov(\alpha_t, \ln\widetilde{y}_{S,t}). \tag{27}$$

We use the alternative representation for expected utility in equation (27) to express the welfare gain of optimal policy over the non-stabilizing policy. Since the non-stabilizing policy involves the same wage under optimal policy, the expected number of producers, S_t, and the average production, $\widetilde{y}_{S,t}$, coincide under the two policies, and the welfare gain associated to the optimal policy can be expressed as:[14]

$$E_{t-1}\left[U_t^S\right] - E_{t-1}\left[U_t^{NS}\right] \quad = \quad \frac{\sigma}{\sigma-1}Cov(\alpha_t, \ln S_t) + Cov(\alpha_t, \ln\widetilde{y}_{S,t}). \tag{28}$$

Equation (28) shows that the welfare gain from optimal policy depends on the co-movement of the the demand shock with the number of producers, $Cov(\alpha_t, \ln S_t)$, and average output, $Cov(\alpha_t, \ln\widetilde{y}_{S,t})$. The response of average output to the demand shock is isomorphic to the response of average productivity, as seen in equation (17). Thus $Cov(\alpha_t, \ln\widetilde{y}_{S,t}) = Cov(\alpha_t, \ln\widetilde{z}_{S,t})$. Equation (18) implies that $Cov(\alpha_t, \ln\widetilde{y}_{S,t}) < 0$, and equation (16) implies that $Cov(\alpha_t, \ln S_t) > 0$. The gain of the optimal policy depends on the balance between the two covariances. By construction, equation (26) is isomorphic to equation (28) as:

$$\frac{\sigma}{\sigma-1}Cov(\alpha_t, \ln S_t) + Cov(\alpha_t, \ln\widetilde{z}_{S,t}) \quad = \quad \left(\frac{1}{\sigma-1} + 1 - \frac{1}{\kappa}\right)\frac{1}{1+\varphi}E_{t-1}\left[\epsilon_t \ln\epsilon_t\right] > 0 \tag{29}$$

Equation (29) shows that the gain of optimal policy is independent from the expected *level* of output and the number of producers. Instead it is determined by the comovements of the shocks with the number of producing firms, which determine product variety, and aggregate productivity, which countermoves in response to the demand shock. In other words, the optimal monetary policy strikes the efficient balance by generating optimal comovements between the number of product varieties and efficiency as under the flexible wages.

[14]By assuming $\alpha_{t-1} = 1$ and $E_{t-1}\left[\alpha_t\right] = \alpha_{t-1}$, the wage under the non-stabilizing policy characterized by constant monetary stance as $\mu_t = \mu_0$ coincides to the wage under the optimal policy:

$$W_t^{NS} = \Gamma\mu_0\left\{\frac{1}{E_{t-1}\left[\alpha_t\right]}\right\}^{\frac{1}{1+\varphi}} = \Gamma\mu_0.$$

As a result, the expected allocations for the number of producers, S_t, and the average production, $\widetilde{y}_{S,t}$, are the same as those for the optimal stabilizing policy. This result is different from Corsetti and Pesenti (2009) and Bergin and Corsetti (2008), in which the non-stabilizing policy results in higher marginal cost due to uncertainty in future periods. Note, however, that a more general process of demand shock introduces uncertainty in the future number of firms and thus uncertainty in future labor demand, which exacerbates the distortion of nominal rigidities, as shown in equation (20).

4 Extensions to the Model

To study our mechanisms in a broader framework, we extend the simple model across the following dimensions: *(i)* abstract from the full depreciation of firms and assume a law of motion for the number of producers, *(ii)* use standard Calvo wage setting to include nominal wage rigidities, *(iii)* embed adjustment costs in firm entry, and, finally, *(iv)* use a Taylor rule to implement monetary policy. In what follows, we outline these extensions to the baseline model and then simulate the system to study the effect of monetary policy, focusing on the role of heterogeneity and entry adjustment costs for the impact of monetary policy. We use the welfare-based consumer price index, P_t, as the numéraire, define the real average price as: $\widetilde{\rho}_{S,t} \equiv \frac{\widetilde{p}_{S,t}}{P_t}$, and express real variables in lowercase letters.[15]

4.1 The Extended Model

Law of motion for firms. At the end of each period t, a fraction δ of firms exits the economy. The law of motion for the number of existing firms is: $N_{t+1} = (1-\delta)(N_t + H_t)$, where H_t denotes the number of new entrants in period t.

Calvo wage setting. Households finance firms by purchasing shares in mutual funds. The budget constraint for household j expressed in real terms is:

$$C_t(j)+b_t(j)+x_t(j)(N_t+H_t)\widetilde{v}_t = (1+\nu)\,w_t(j)L_t(j)+(1+r_t)b_{t-1}(j)+x_{t-1}(j)N_t(\widetilde{v}_t+\widetilde{d}_t)+t^f{}_t, \tag{30}$$

where the real net interest rate r_t is defined as:

$$1+r_t \equiv \frac{1+i_{t-1}}{1+\pi_t}, \tag{31}$$

[15] Hamano and Zanetti (2018) establish the relevance of quality and variety bias for aggregate prices in a model with firm entry and exit.

and π_t is the net inflation rate of the welfare-consistent consumption basket between period t and $t-1$. The optimal conditions for share and bond holdings, $x_t(j)$ and $b_t(j)$, are:

$$\widetilde{v}_t = \beta\left(1-\delta\right)E_t\left[\frac{\alpha_{t+1}C_t}{\alpha_t C_{t+1}}\left(\widetilde{v}_{t+1}+\widetilde{d}_{t+1}\right)\right],$$

and

$$1 = \beta E_t\left[\frac{\alpha_{t+1}C_t}{\alpha_t C_{t+1}}\frac{1+i_{t-1}}{1+\pi_t^c}\right],$$

respectively. Unlike the baseline model with one-period wage stickiness, we assume that wages are set *à* la Calvo (1983), and only a fraction of $1-\vartheta$ households re-optimize their wages during each period t. The optimal wage-setting condition is (see Appendix B for derivation):

$$\left(\frac{W_t'}{W_t}\right)^{1+\varphi\theta} = \frac{\frac{\eta\theta}{(\theta-1)(1+\nu)}\sum_{k=0}^{\infty}\left(\beta\vartheta\right)^k E_t\left[\left(\frac{W_{t+k}}{W_t}\right)^{\theta(1+\varphi)}L_{t+k}^{1+\varphi}\right]}{\sum_{k=0}^{\infty}\left(\beta\vartheta\right)^k E_t\left[\frac{\alpha_{t+k}}{C_{t+k}}\frac{W_{t+k}}{P_{t+k}}\left(\frac{W_{t+k}}{W_t}\right)^{\theta-1}L_{t+k}\right]}, \tag{32}$$

which can be represented as the wage Phillips curve:

$$\pi_t^w = \beta E_t\left[\pi_{t+1}^w\right] - \frac{\left(1-\beta\vartheta\right)\left(1-\vartheta\right)}{\left(1+\theta\varphi\right)\vartheta}\widehat{\mu}_t^w,$$

where $\widehat{\mu}_t^w$ is the deviation of the wage markup μ_t^w from its steady state value. Wage inflation π_t^w and welfare-consistent inflation π_t are related by: $w_t/w_{t-1} = (1+\pi_t^w)/(1+\pi_t)$, and the wage markup μ_t^w is determined by the following equation:

$$w_t = \mu_t^w\frac{\eta L_t^{\varphi}C_t}{\alpha_t}.$$

Entry adjustment costs. As in Lewis (2009), Lewis and Poilly (2012) and Bergin et al. (2018), we assume entry adjustment costs, and the free entry condition becomes:

$$w_t f_E = \widetilde{v}_t \varpi_t + \widetilde{v}_t \varpi_{1,t} H_t + \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} (\widetilde{v}_{t+1} \varpi_{2,t+1} H_{t+1}) \right],$$

where

$$\varpi_t(H_t, H_{t-1}) = 1 - F_{N,t}(\frac{H_t}{H_{t-1}}),$$

ϖ_t is the probability of a successful entry, and ϖ_{it} is the first derivative of the success rate with respect to its ith argument. $F_{N,t}$ is the failure rate with $F_{N,t}(1) = F'_{N,t}(1) = 0$ and $F''_{N,t}(1) = \omega$. When the value of ω is high, the entry process is sluggish. When $\varpi_t = 1$, the free entry condition becomes the same as in the baseline model: $w_t f_E = \widetilde{v}_t$.

Taylor rule. Real GDP is defined from the income side as $Y_t \equiv w_t L_t + N_{D,t} \widetilde{d}_t$. Noting Y_t^f as GDP under flexible wages, we define the following Taylor rule as:

$$i_t + 1 = (i_{t-1} + 1)^{\rho} \left[\left(\frac{P_t^e}{P_{t-1}^e} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^f} \right)^{\phi_Y} \right]^{1-\rho} \upsilon_t,$$

where υ_t is an exogenous monetary policy shock. We assume that monetary authority conducts policy based on an imperfectly measured price P_t^e, which is not indexed with changes in the number of product varieties. The corresponding empirically consistent inflation π_t^e is thus defined as:

$$1 + \pi_t^e = (1 + \pi_t) \left(\frac{S_t}{S_{t-1}} \right)^{\frac{1}{\sigma - 1}}.$$

Idle firms and shocks. Finally, the number of non-producing firms that remain idle is:

$$\mathcal{D}_t \equiv N_t - S_t.$$

Table 2: The Extended Model

Price Index	$1 = S_t^{-\frac{1}{\sigma-1}} \widetilde{\rho}_{S,t}$
Pricing	$\widetilde{\rho}_{S,t} = \frac{\sigma}{\sigma-1} \frac{w_t}{\widetilde{z}_{S,t}}$
Dividends of Firms	$\widetilde{d}_t = \frac{S_t}{N_t} \widetilde{d}_{S,t}$
Dividends of Producers	$\widetilde{d}_{S,t} = \frac{1}{\sigma} \frac{C_t}{S_t} - f w_t$
Free Entry	$w_t f_E = \widetilde{v}_t \varpi_t + \widetilde{v}_t \varpi_{1,t} H_t + \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\gamma} (\widetilde{v}_{t+1} \varpi_{2,t+1} H_{t+1}) \right]$
Labor Market Clearing	$w_t L_t = (\sigma - 1) S_t \widetilde{d}_{S,t} + \sigma S_t f w_t + H_t \widetilde{v}_t$
Average Productivity	$\widetilde{z}_{S,t} = z_{\min} \left[\frac{\kappa}{\kappa-(\sigma-1)} \right]^{\frac{1}{\sigma-1}} \left(\frac{S_t}{N_t} \right)^{-\frac{1}{\kappa}}$
Zero Cutoff Profits	$\frac{1}{\sigma} \frac{C_t}{S_t} \left[\frac{\kappa-(\sigma-1)}{\kappa} \right] = f w_t$
Motion of firms	$N_{t+1} = (1 - \delta) (N_t + H_t)$
Euler Shares	$\widetilde{v}_t = \beta (1 - \delta) E_t \left[\left(\frac{\alpha_t C_{t+1}}{C_t \alpha_{t+1}} \right)^{-1} \left(\widetilde{v}_{t+1} + \widetilde{d}_{t+1} \right) \right]$
Euler Bonds	$1 = \beta E_t \left[\left(\frac{\alpha_t C_{t+1}}{C_t \alpha_{t+1}} \right)^{-1} (1 + r_{t+1}) \right]$
Number of idle firms	$\mathcal{D}_t = N_t - S_t$
GDP Definition	$Y_t = w_t L_t + N_{D,t} \widetilde{d}_t$
Real Return	$1 + r_t \equiv \frac{1+i_{t-1}}{1+\pi_t}$
Wage Markup	$w_t = \mu_t^w \frac{\eta L_t^{\varphi} C_t}{\alpha_t}$
Wage Inflation	$\left(\frac{W_t'}{W_t} \right)^{1+\varphi\theta} = \frac{\frac{\eta\theta}{(\theta-1)(1+\nu)} \sum_{k=0}^{\infty} (\beta\vartheta)^k E_t \left[\left(\frac{W_{t+k}}{W_t} \right)^{\theta(1+\varphi)} L_{t+k}^{1+\varphi} \right]}{\sum_{k=0}^{\infty} (\beta\vartheta)^k E_t \left[\frac{\alpha_{t+k}}{C_{t+k}} \frac{W_{t+k}}{P_{t+k}} \left(\frac{W_{t+k}}{W_t} \right)^{\theta-1} L_{t+k} \right]}$
CPI Inflation	$\frac{w_t}{w_{t-1}} = \frac{1+\pi_t^w}{1+\pi_t}$
Empirical Inflation	$1 + \pi_t^e = (1 + \pi_t) \left(\frac{S_t}{S_{t-1}} \right)^{\frac{1}{\sigma-1}}$
Monetary Policy	$i_t + 1 = (i_{t-1} + 1)^{\rho} \left[\left(\frac{P_t^e}{P_{t-1}^e} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^f} \right)^{\phi_Y} \right]^{1-\rho} \upsilon_t$

Exgenous shocks. We assume the exogenous processes for the demand shifter is equal to: $\ln \alpha_t = 0.8 \ln \alpha_{t-1} + \epsilon_t$ and that the monetary policy shock is equal to: $\ln \upsilon_t = \epsilon_{\upsilon,t}$, where the shock components ϵ_t and $\epsilon_{\upsilon,t}$ are i.i.d. with zero mean, respectively.

To solve the model we approximate the system around the non-stochastic, zero inflation steady state, assuming that $\alpha_0 = \upsilon_0 = 1$. Table 2 summarizes the extended model.

Table 3: Calibration

β	Discount factor	0.99
φ	Frisch elasticity of labor supply	2
σ	Elasticity of substitution among varieties	11.5
γ	Risk aversion	2
δ	Exogenous death shock	0.059
κ	Pareto shape	11.5070
λ	Calvo wage parameter	0.64
θ	Elasticity of substitution among workers	0.9524
ω	Entry adjustment cost	8.311
ρ	Interest smoothing on previous rate	0.8
ϕ_π	Inflation target	1.5
ϕ_Y	Output gap stabilization	0.1

4.1.1 Calibration

The calibration is standard and based on Hamano and Zanetti (2017), summarized in Table 3.[16] The discount factor, β, is set equal to 0.99. The Frisch elasticity of labor supply, φ, is set equal to 2. The elasticity of substitution among varieties, σ, is set equal to 11.5. The coefficient of risk aversion, γ, is set equal to 2. The exogenous exit shock, δ, and Pareto distribution parameter, κ, are set equal to 0.059 and 11.5070, respectively, to match business cycle moments of plant/product turnover, as described in Broda and Weinstein (2010). The parameters that determine nominal wage stickiness, λ, and the elasticity of substitution among differentiated labor services, θ, are set equal to 0.64 and 0.9524, respectively, as in Christiano et al. (2005). The parameter that determines the entry adjustment costs , ω, is set equal to 8.311, as in Lewis and Poilly (2012), and we will perform robustness analysis on this parameter. The coefficients in the Taylor rule ($\rho = 0.8$, $\phi_\pi = 1.5$ and $\phi_Y = 0.1$) are consistent with Gertler et al. (1999).

4.1.2 Monetary Policy Shock

Figure 1 shows the IRFs of the model to a 1% increase in the monetary policy shock, $\epsilon_{v,t}$. The entries show the responses of output, Y_t, measured CPI inflation, π_t^e, nominal

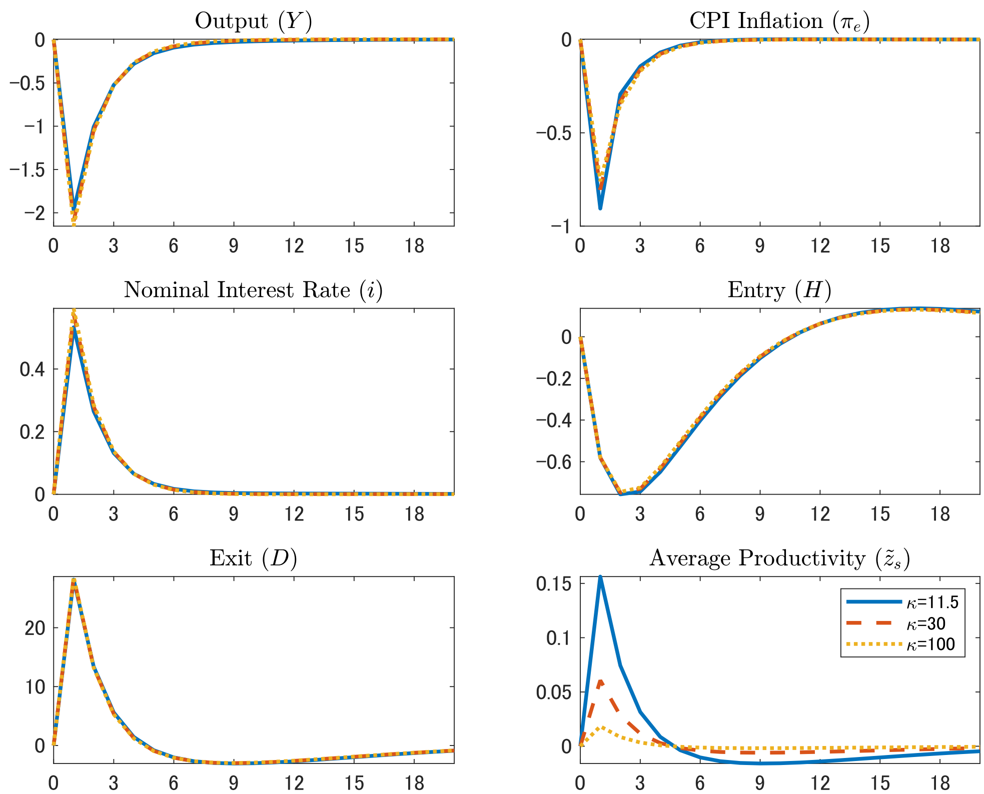
[16]The steady state and the cyclical properties of the model under flexible wages are isomorphic to Hamano and Zanetti (2017).

interest rate, i_t , the number of new entrants, H_t, the number of shutdown firms, $\mathcal{D}_t$, and the average labor productivity for producing firms , $\widetilde{z}_{S,t}$, for three alternative calibrations of the degree of firm heterogeneity controlled by the parameter κ. The exercise compares the baseline calibration with $\kappa = 11.50$ (solid lines) against alternative calibrations with lower degrees of heterogeneity with $\kappa = 50$ (dashed lines) and $\kappa = 100$ (dotted lines), respectively. The IRFs show that the response of aggregate productivity and the consequent reallocation effect of monetary policy depends on the degree of firm heterogeneity. However, the effect is quantitatively small and the responses of aggregate output and product variety are similar across economies with different degrees of firm heterogeneity.

In accordance with the results in Section 3, a contractionary monetary policy shock decreases the entry of new firms, H, and increases the number of idle firms, $\mathcal{D}$, that have low productivity and therefore remain unprofitable and terminate production. The higher exit of low productivity firms increases average productivity of the producing firms, $\widetilde{z}_S$, and therefore decreases measured CPI inflation, π^e, as single varieties are produced with a more productive technology.[17] Despite the increase in productivity, aggregate output, Y, falls in result to the decrease in the number of producing firms and new entrants. Thus, the contractionary monetary policy shock generates a strong cleansing effect that wipes out firms with low productivity. The response of average productivity (bottom-right panel) shows that the efficiency gains in terms of higher productivity that result from the cleansing of low-productive firms depends on the degree of firm heterogeneity. The average productivity of producing firms increases sharply when firm heterogeneity is high. Thus, a lower value of κ (i.e., high firm heterogeneity) is associated with a stronger reallocation and cleansing effect of monetary policy. However, for a given contractionary monetary policy shock, the change in productivity level is quantitatively small, amounting to 0.2% for the case with a large degree of heterogeneity ($\kappa = 11.5$), and therefore generates a limited change in firms entry and exit and aggregate output. Given the relatively high adjustment costs to entry in the benchmark calibration ($\omega = 8.311$), a contractionary monetary policy shock fails to generate a substantial fall in entry and hence a large

[17]See Hamano and Zanetti (2018) for a study of inflation dynamics with endogenous variety and product quality.

Figure 1: Monetary Shock and Firm Heterogeneity (κ)



Each entry shows the percentage-point response of one of the model's variables to a one-percentage deviation of the monetary shock for the benchmark economy (solid line, $\kappa = 11.5$), the economy with a medium level of firm heterogeneity (dashed line, $\kappa = 30$), and the economy with a low level of firm heterogeneity (dotted line, $\kappa = 100$).

response in other aggregate variables. Consequently, the reallocation effect is limited. Appendix C reports the IRFs for the complete set of variables.

Figure 2 shows the IRFs to a 1% contractionary monetary policy shock for different values of the entry adjustment costs parameter, ω. It compares the baseline calibration for $\omega = 8.311$ (solid lines) against the alternative calibrations of lower entry costs for $\omega = 0.05$ (dashed lines) and $\omega = 0.001$ (dotted lines). The case with $\omega = 0.001$ is isomorphic to the model without entry adjustment costs while the case with $\omega = 0.05$ is an intermediate entry adjustment costs between the benchmark value and zero entry adjustment costs. The figure shows that entry adjustment costs are critical for the response of the variables to the contractionary monetary policy shock and, in particular, to the response of firm exit. With low entry costs, the number of firms entering the economy, H, declines sharply on impact (dashed and dotted lines versus solid line) while the number of exiting firms, $\mathcal{D}$, increases on impact. The decline in entry reduces competition for incumbent firms, slowing down the number of shut down firms in subsequent periods (as in the dashed and dotted lines versus the solid line). Since the fall in entry insulates producing firms from competition, the larger the fall in entry, the stronger the reduction in firm exit in the following periods. Our findings thus bear support to the *insulation effect* of entry on exit, as originally outlined in Caballero and Hammour (1994).[18]

When the entry adjustment costs are low (dotted line), the productivity of average incumbent plants, $\widetilde{z}_S$, increases on impact for the cleaning effect of monetary policy while it decreases along the transitory dynamics for to the insulation effect (dashed and solid lines for $\widetilde{z}_S$). Accordingly, inflation decreases on impact in response to an increase in aggregate productivity while it increases due to the survival of inefficient (low-productivity) firms in subsequent periods (insulation effect). Appendix C provides IRFs for the complete set of variables. To the best of our knowledge, ours is the first study to link the insulation effect to the reallocative power of monetary policy. The next section provides empirical evidence on the theoretical mechanisms.[19]

5 VAR Evidence

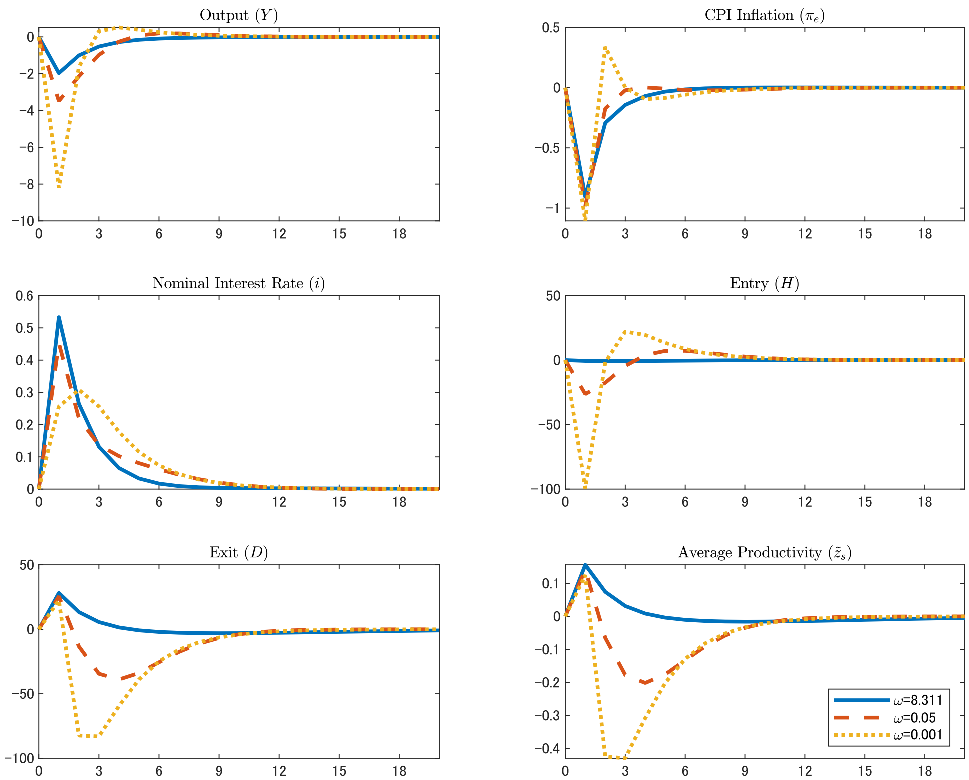
In this section, we provide empirical evidence on the effect of monetary policy for product variety from firm entry and exit, and aggregate productivity. To facilitate comparisons with other studies, we use the same sample period (1965Q3-1995Q3) and a similar identification scheme in Christiano et al. (1999).[20] Our VAR model includes the original

[18] Hamano and Zanetti (2017) show that the insulation effect is also critical in the propagation of technology shocks.

[19] Our analysis shows that entry costs interplay with monetary policy in the allocation of resources across firms with different productivity. Future studies could investigate whether the interaction between cost of entry and monetary policy could explain the permanent changes in the cross-sectional distribution of firms discussed in Autor et al. (2020) and Bergin and Corsetti (2020). Fernandez-Villaverde et al. (2020) and Hamano and Oikawa (2021) provide a recent attempt to study market concentration in a model with heterogeneous firms, but abstracting from monetary policy.

[20] Extending the analysis to more recent data is problematic since measures of entry and exit were discontinued in the late 1990s. Uusküla (2016) provides a detailed discussion on data limitations.

Figure 2: Monetary Policy Shock and Entry Adjustment Cost(ω)



Each entry shows the percentage-point response of one of the model's variables to a one-percentage deviation of the monetary shock for the benchmark economy (solid line with $\omega = 8.311$), the economy with a medium level of entry adjustment cost (dashed line with $\omega = 0.05$), and the economy with low a level of entry adjustment cost (dotted line with $\omega = 0.001$).

variables in Christiano et al. (1999), namely the log of real GDP, the log of the implicit GDP deflator, the smoothed change in an index of sensitive commodity prices (a component in the Bureau of Economic Analysis' index of leading indicators), the federal funds rate, the log of total reserves, the log of non-borrowed reserves plus extended credit, and the log of M1, respectively.[21] In addition to these variables, we include the log of the number of new business incorporations and the log of number of business failures from the Dun and Bradstreet Inc. dataset.[22] Since our main focus is on the interplay between

[21] Christiano et al. (1999) performs a number of robustness analyses with the inclusion of different variables in their VAR models. Our analysis is based on their benchmark "Fed Fund Model with M1."

[22] The original data is given on monthly basis for both the number of new business incorporations, and the number of business failures. We transform them to quarterly series by summing three consecutive months. We thank Lenno Uusk*ü*la for kindly sharing the data set.

entry and exit with aggregate productivity in response to a monetary policy shock, we also include the growth rate of utilization-adjusted total factor productivity from Fernald (2012). Appendix D provides a summary of the data sources.We identify monetary policy shocks using a standard Cholesky decomposition, relying on the assumption that monetary policy reacts to contemporaneous changes in output growth and inflation, and remains irresponsive to the measures of entry, exit, and aggregate productivity.[23] We set the number of lags in the VAR equal to 4.[24]

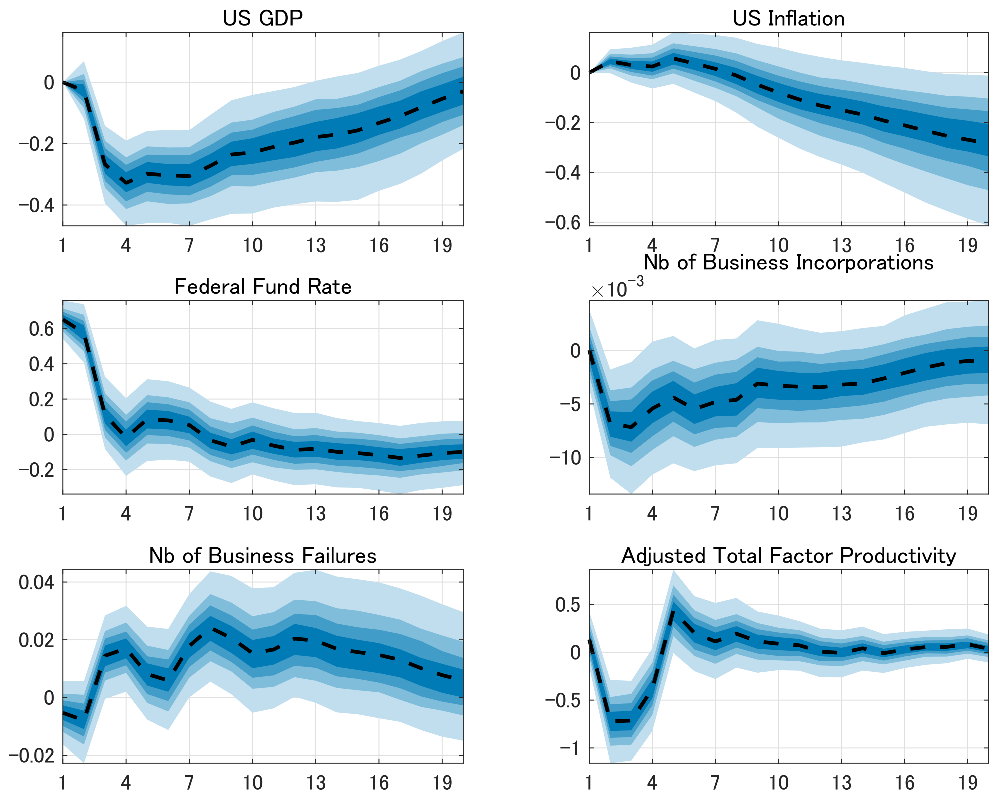
Figure 3 provides the impulse response functions (IRFs) to a positive federal funds rate shock for the log of real GDP, the log of the implicit GDP deflator, the federal funds rate, the number of new business incorporations, the number of business failures, and the growth of adjusted total factor productivity, together with 30%, 50%, 68%, and 90% bootstrap confidence bands. Appendix E reports the responses for all variables in the VAR. A positive shock to the federal funds rate generates a persistently negative response in GDP, which falls substantially in the short-run and subsequently recovers, following an inverted, hump-shaped trajectory. The contractionary monetary policy shock generates a protracted fall in inflation. The IRFs of the log of real GDP, the log of the implicit GDP deflator, and the federal funds rate are similar to those obtained in Christiano et al. (1999).

The number of new business incorporations falls on impact, replicating the inverted hump-shaped response of GDP. The IRF of the number of business failures increases gradually, peaking after eight quarters, and then returning slowly to the original level. These dynamics for the measures of firm entry and exit are similar to those in Uusküla

[23]The exact ordering of the variables in the VAR model is: log of real GDP, log of the implicit GDP deflator, smoothed change in an index of sensitive commodity prices, Federal Funds Rate, log of total reserves, log of nonborrowed reserves plus extended credit, log of M1, number of new business incorporations, and the number of business failures and growth of adjusted total factor productivity.

[24]Bergin and Corsetti (2008) include "entry" (net business formation or new incorporations in their paper) at the end of Christiano et al. (1999)'s ordering of variables. Lewis and Poilly (2012) find similar VAR evidence, using the same sample period as Bergin and Corsetti (2008), while ordering net business formation before the monetary shock. Our results are robust with respect to the ordering of the variables. As a robustness check, Appendix E shows results from the VAR model estimated with net business formation instead of new business incorporations, and with Business bankruptcy filings taken from US Bankruptcy courts instead of the number of business failures. The exercise provides qualitatively similar results to the benchmark model.

Figure 3: VAR evidence on Monetary Policy Shock, Firm Turnover, and Productivity



Effects of a shock to the Federal Fund Rate. Multivariate VAR, 1965:Q3-1995:Q3. Gray bands are 30%, 50%, 68% and 90% bootstrap confidence bands.

(2016). The novel finding from our analysis is the sharp fall in the adjusted total factor of productivity in the two quarters in the aftermath of the shock and the subsequent quick recovery. Based on these findings, our VAR model shows that a contractionary monetary policy shock reduces firm entry and increases firm exit and it generates a fall in aggregate productivity on impact. Thus, our evidence shows that the contractionary monetary policy is important for firm entry and exit, and it generates a fall in aggregate productivity. The finding shows that the contractionary monetary policy insulates incumbent firms from the competition of new firms and generates a decline in aggregate productivity. Our results provide an alternative characterization of the decline of aggregate productivity in response to a contractionary monetary policy shocks as discussed in the recent studies by

Aghion et al. (2019) and Moran and Queralto (2018).[25]

6 Conclusion

This paper studies the allocative role of monetary policy when firms are heterogeneous and households gain utility from product variety. In line with several studies, we find that an expansionary monetary policy prevents the cleansing of low-productive firms from the economy, thus generating a slowdown in productivity that diminishes welfare. However, our framework shows that the larger number of operating firms raises product variety and enhances welfare, an important effect of monetary policy that is overlooked in related studies. We establish that the standard optimal policy that offsets nominal distortions in New Keynesian models needs to strike a balance between the countervailing forces of productivity and product variety on welfare. Our analysis demonstrates that under demand uncertainty, the gain from optimal monetary policy increases in the preference for variety, and it decreases in the degree of heterogeneity across firms. A VAR model shows that a monetary policy shock exerts a relevant effect on firm entry and exit and aggregate productivity. A contractionary monetary policy shock that decreases the entry of new firms shields incumbent firms from competition of new entrants, therefore reducing aggregate productivity.

The analysis opens interesting directions for future research. While our parsimonious model provides an analytical solution and transparently isolates the critical role of firm heterogeneity for the allocative effect of monetary policy, future studies could extend our simple framework to account for additional propagation channels like financial frictions,

[25]To conclude the section, we note that we performed robustness analysis and estimated a VAR model using series for establishment births and deaths (data on 'Openings' and 'Closings') from Business Employment Dynamics (BED) that allow to extend the sample period to 2017Q4. The evidence based on these series and the more recent time period becomes blurred. The contractionary monetary shock becomes slightly expansionary in short run, a counter-factual response originally documented in Gertler and Karadi (2015), Ramey (2016) (US data), and Gortz et al. (2021) (UK data). A similar issue arises with the responses of establishment births and deaths. In addition, the zero lower bound of monetary policy requires the VAR model to account for the non-negative constraint on the nominal interest rate and the effect of unconventional monetary policy in the identification of monetary policy shocks, as outlined in Ikeda et al. (2020). Using the same establishment turnover data from the BED on a different VAR specification, Uusküla (2016) finds similar counter-factual responses.

price distortions, and a wider range of shocks that could in principle exert an important quantitative influence on the allocative effect of monetary policy. The enriched model could be taken to the data to provide an empirical assessment of a broad range of channels for the allocative effect of monetary policy. We plan to pursue some of these ideas in future work.

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A Optimal Policy

Using the solutions in Section 3, expected utility $E_{t-1}[U_t]$ can be expressed as:

$$
\begin{aligned}
E_{t-1}[U_t] = E_{t-1}[\alpha_t \ln C_t] &= E_{t-1}\left[\alpha_t \ln S_t^{\frac{\sigma}{\sigma-1}} \widetilde{y}_{S,t}\right] \\
&= E_{t-1}\left[\alpha_t \ln S_t^{\frac{\sigma}{\sigma-1}} \frac{\mu_t \widetilde{z}_{S,t}}{S_t W_t}\right] + cst \\
&= E_{t-1}\left[\alpha_t \left(\frac{1}{\sigma-1}\ln S_t + \ln\mu_t - \ln W_t + \ln\widetilde{z}_{S,t}\right)\right] + cst \\
&= E_{t-1}\left[\frac{1}{\sigma-1}\alpha_t \ln\frac{\mu_t}{W_t f_t} + \alpha_t(\ln\mu_t - \ln W_t) + \alpha_t \ln\left[\frac{\mu_{t-1}W_t f_t}{\mu_t W_{t-1} f_{E,t-1}} \frac{E_{t-1}[\alpha_t]}{\alpha_{t-1}}\right]^{\frac{1}{\kappa}}\right] + cst \\
&= E_{t-1}\left[\left(\frac{1}{\sigma-1} + 1 - \frac{1}{\kappa}\right)\alpha_t(\ln\mu_t - \ln W_t)\right] + cst' \\
&= \left(\frac{1}{\sigma-1} + 1 - \frac{1}{\kappa}\right)\left[E_{t-1}[\alpha_t \ln\mu_t] - \frac{E_{t-1}[\alpha_t]}{1+\varphi}\ln E_{t-1}\left[\mu_t^{1+\varphi}\right]\right] + cst'.
\end{aligned}
$$

The last equation is equation (24).

The first order condition with respect to μ_t yields:

$$
\left(\frac{1}{\sigma-1} + 1 - \frac{1}{\kappa}\right)\left[\frac{\alpha_t}{\mu_t} - \frac{E_{t-1}[\alpha_t]}{E_{t-1}\left[\mu_t^{1+\varphi}\right]} \frac{(\mu_t)^{1+\varphi}}{\mu_t}\right] = 0
$$

Solving the above equation for μ_t, optimal policy satisfies $\mu_t = \mu_0 \alpha_t^{\frac{1}{1+\varphi}}$.

B Wage Dynamics

This appendix shows the derivation of the optimal wage setting of the household in the extended model. The expected life-time utility of the representative household is given by:

$$
E_t \sum\nolimits_{k=0}^{\infty} (\beta\vartheta)^k U_t(C_{t+k}(j),\ L_{t+k|t}(j)),
$$

where $L_{t+k|t}(j)$ are the consumption and labor supply at $t+k$ under the preset wage rate $W_t^{'}(j)$. The household maximizes the utility by setting $W_t^{'}(j) = 0$. The first order condition yields:

$$W_t^{'}(j) = \frac{\frac{\eta\theta}{(\theta-1)(1+\nu)} \sum_{k=0}^{\infty} (\beta\vartheta)^k E_t \left[L_{t+k|t}^{1+\varphi}(j) \right]}{\sum_{k=0}^{\infty} (\beta\vartheta)^k E_t \left[\frac{\alpha_{t+k}}{C_{t+k}} \frac{1}{P_{t+k}} L_{t+k|t}(j) \right]},$$

and using

$$L_{t+k|t}(j) = \left(\frac{W_t^{'}(j)}{W_{t+k}} \right)^{-\theta} L_{t+k},$$

it yields equation (32).

Using the definition of wage index and assuming the low of large number holds, nominal wage dynamics is described by:

$$\left(\frac{W_t^{'}}{W_t} \right)^{1-\theta} = \frac{1 - \vartheta \pi_t^{w\theta-1}}{\vartheta}.$$

Combining the log-linearized equation above and equation (32), we obtain the following wage equation:

$$\pi_t^w = \beta E_t \left[\pi_{t+1}^w \right] - \frac{(1-\beta\vartheta)(1-\vartheta)}{(1+\theta\varphi)\vartheta} \widehat{\mu}_t^w.$$

C IRFs

This appendix shows the IRFs of the model to a 1% increase in the monetary policy shock, $\epsilon_{v,t}$, for the complete set of variables. Figure 4 shows IRFs for values of κ equal to 11.5 (solid line), 50 (dashed line) and 100 (dotted line). Figure 5 shows IRFs for values of ω equal to 8.311 (solid line), 0.05 (dashed line) and 0.001 (dotted line).

Figure 4: IRFs with different κ

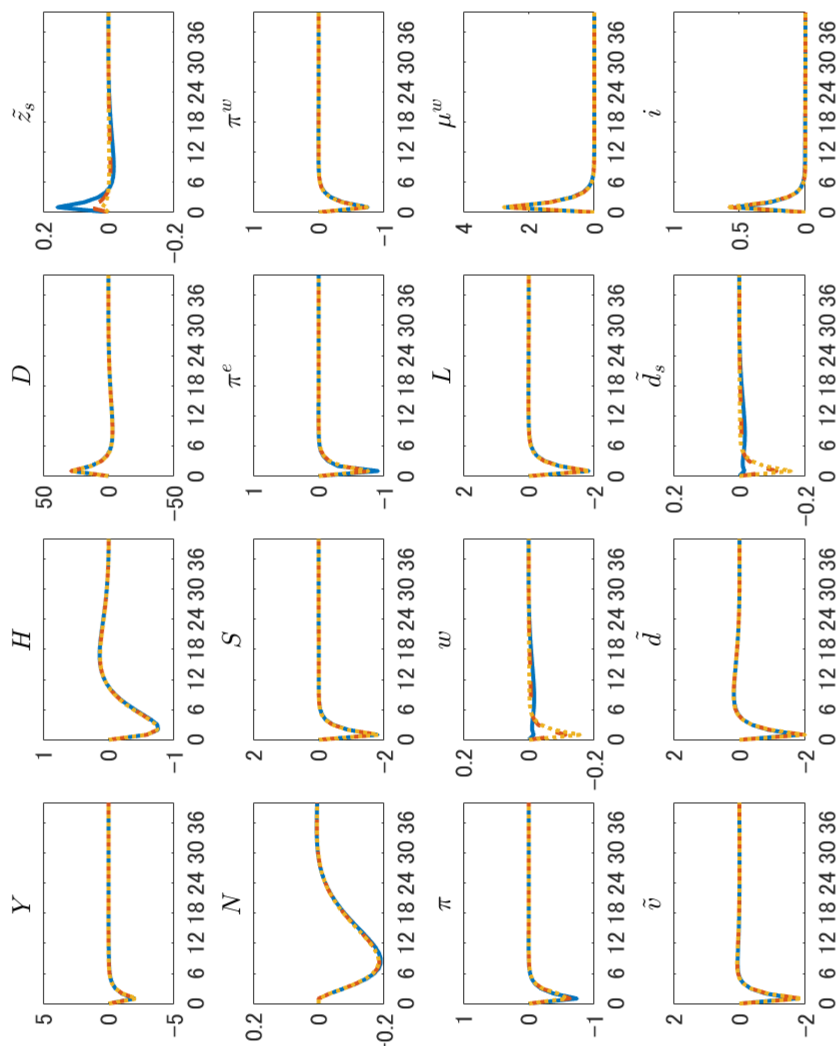
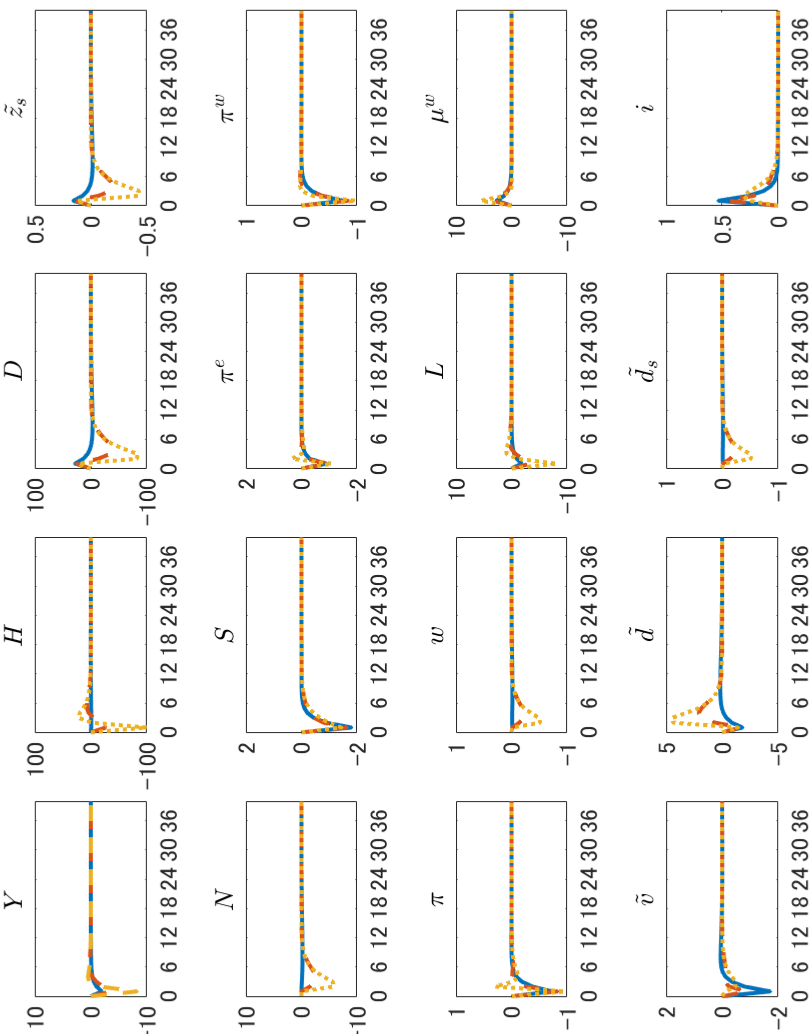


Figure 5: IRFs with different ω



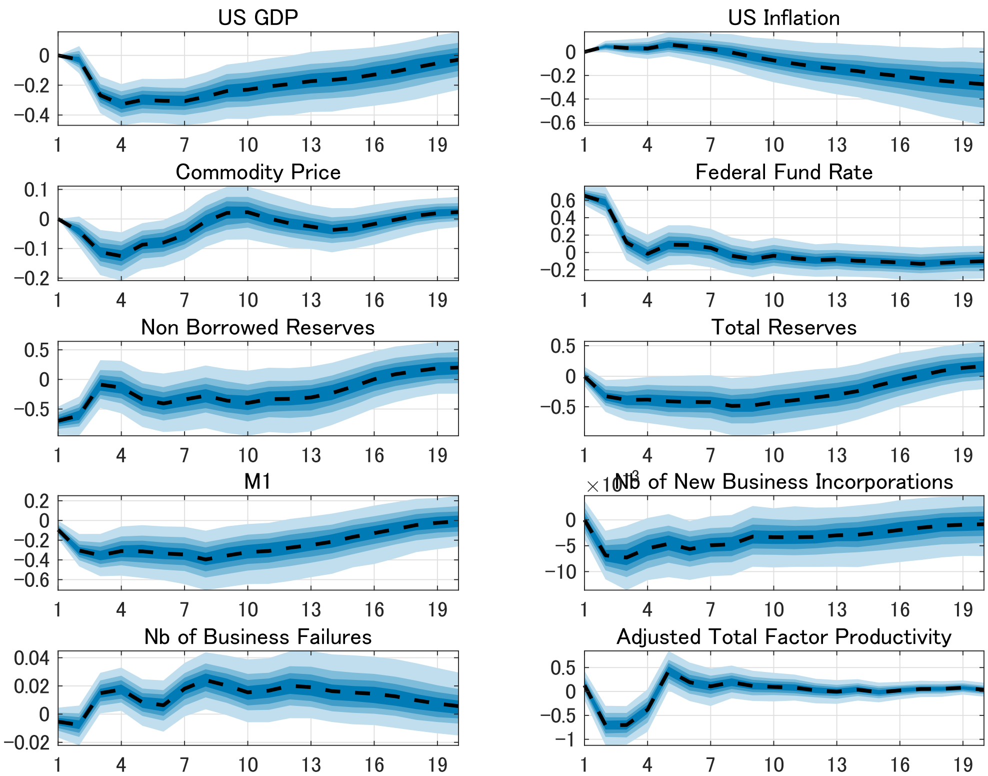
D Data

Table 4: Data

Series Name	Source
US GDP	Bureau of Economic Analysis
GDP deflator	Bureau of Economic Analysis
Federal Fund Rates	Federal Reserves
M1	Federal Reserves
Non-borrowed reserves	Federal Reserves
Total reserves	Federal Reserves
Commodity price	Bureau of Economic Analysis
Number of Business Incorporations	Dun and Bradstreet, Inc.
Net Business formation	Dun and Bradstreet, Inc.
Number of Business failures	Dun and Bradstreet, Inc.
Number of Business Bankruptcy Filings	US Bankruptcy court
Adjusted Total Factor Productivity	Fernald's web site

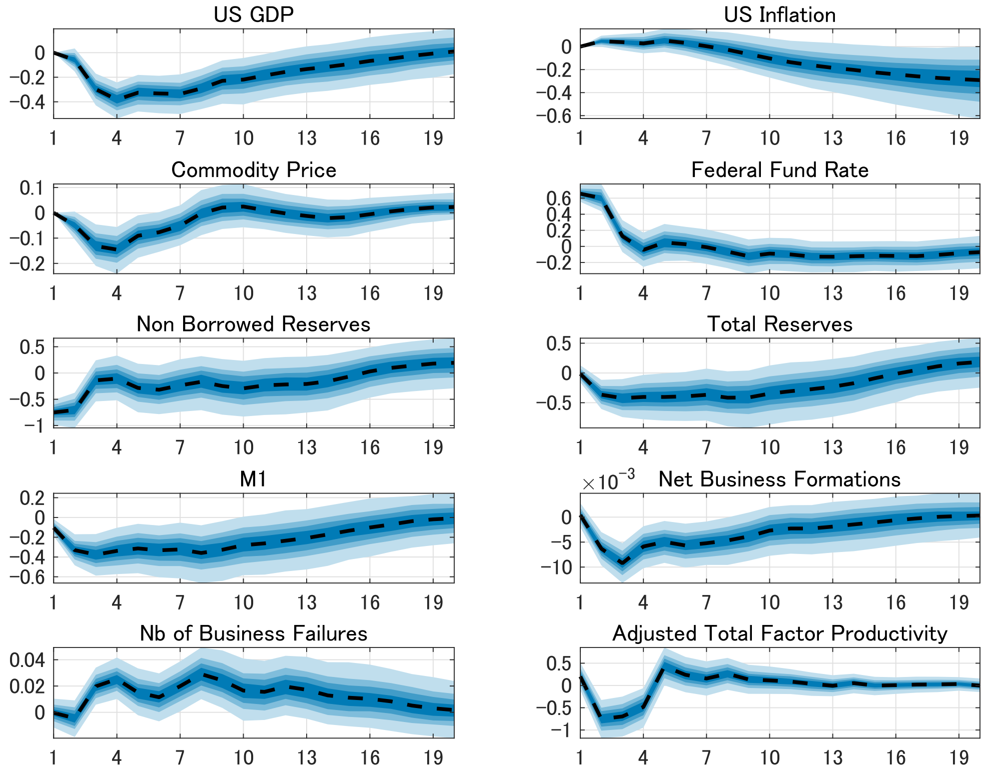
E VAR with Alternative Measures of Entry and Exit

Figure 6: The Benchmark VAR



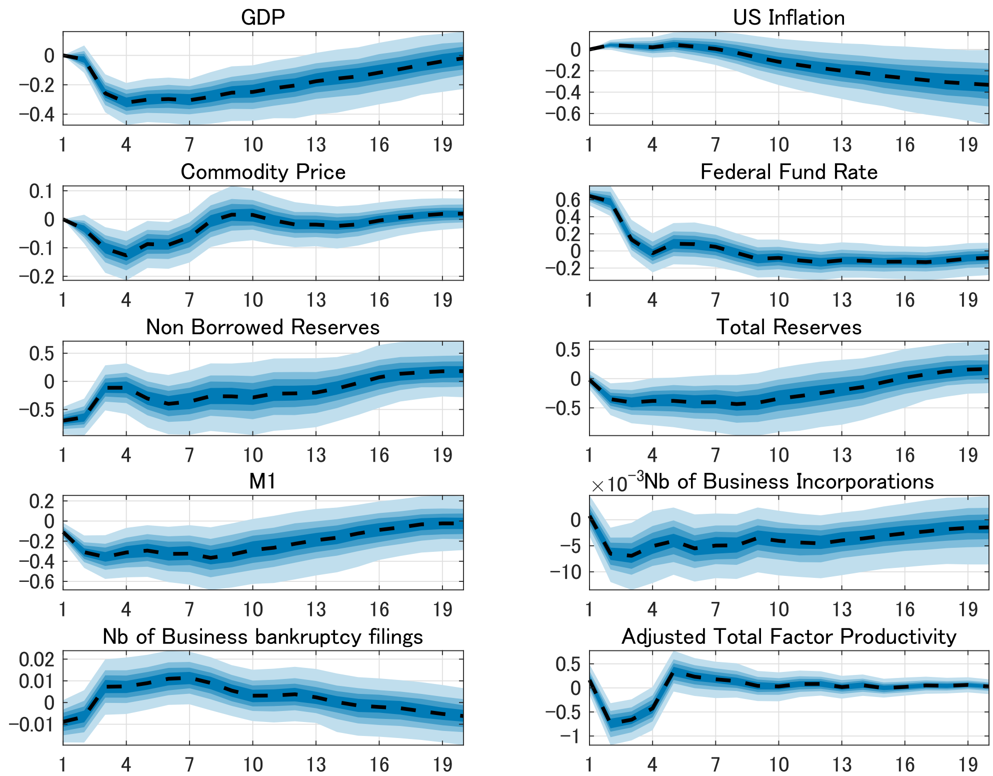
Effects of the federal fund rate shock, multivariate VAR, time period 1965Q3-1995Q3. Gray areas are 30%, 50%, 68% and 90% bootstrap confidence bands, respectively.

Figure 7: VAR with Net Business Formation Index



Effects of the federal fund rate shock, multivariate VAR, time period 1965Q3-1995Q3. Gray areas are 30%, 50%, 68% and 90% bootstrap confidence bands, respectively. The original Net Business Formation Index is monthly data, we use the value in the third month to construct the quarterly time series.

Figure 8: VAR with Number of Business Bankruptcy Filings



Effects of the federal fund rate shock, multivariate VAR, time period 1965Q3-1995Q3. Gray areas are 30%, 50%, 68% and 90% bootstrap confidence bands, respectively.