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Monetary policy, firm heterogeneity, and product variety ☆

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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. We provide empirical evidence on U.S. data that corroborates the relevance of monetary policy for product variety resulting from firm entry and exit.

> *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 remained remarkably stable and monetary policy has maintained historically low nominal interest rates. Economic theory asserts that persistently low nominal interest rates and stable inflation allow low-productive firms to remain profitable and operate, thus generating a slowdown in productivity.[1] Under these premises, monetary policy exerts an important allocative effect on the economy. In this paper, we revisit the allocative role of monetary policy across firms, by 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

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[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, 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.

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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 heterogeneous 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 the analysis, households have standard CES preferences that weigh the contribution of imperfectly substitutable goods. The variety of goods is determined by the endogenous entry and exit of firms with different productivity. Firms enter the market when expected profits exceed sunk entry costs paid in labor units. On entry, firms draw an idiosyncratic productivity level 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, inducing an empirically plausible dynamics for firm entry.

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 that prevents the survival of low-productivity firms and encompasses a decrease in prices also generates a reduction in the number of product varieties. The model shows that firm heterogeneity breaks the "neutrality of monetary policy", extending the finding in Bilbiie (2021) in a model that abstracts from firm heterogeneity.

We provide empirical evidence on the reallocative effect of monetary policy for the U.S. economy. We identify monetary policy shocks using a structural vector autoregression (SVAR) model with a standard Cholesky decomposition, similar to Christiano et al. (1999) that relies 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.

To confront our framework to the data, we extend the simple model with a gradual depreciation of firms, entrant dependent adjustment costs of entry, a standard Calvo wage setting, and monetary policy implemented with a wage-inflation targeting rule. We find that the degree of firm heterogeneity is important for the change in average productivity. In our benchmark calibration, the contractionary monetary policy generates a counterfactual increase in average productivity from the reallocation of resources to more productive firms, which is proportional to the degree of heterogeneity. We find that entry adjustment costs play an important role in replicating the observed fall in aggregate productivity. Aggregate productivity falls in response to the contractionary monetary policy shock when entry adjustment costs are low, driven by the presence of low-productivity firms that decrease the level of aggregate productivity. A lower entry rate of new firms insulates incumbent firms from competition, thus decreasing average productivity along the transition dynamics, which is consistent with the evidence in the VAR model.[2]

Several studies investigate the relationship between monetary policy and firm entry without focusing on endogenous firm exit and the resulting reallocation effect of monetary policy, 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), Bilbiie et al. (2014), Cacciatore et al. (2016), Bilbiie (2021), Bilbiie and Melitz (2020), and Chugh et al. (2020) develop models with firm entry and price rigidities, in which product variety is endogenous to monetary policy or fiscal policy.[3] Colciago et al. (2020) show that endogenous firm dynamics are critical for an empirically-congruous effect of monetary policy on unemployment.

Totzek (2009) and Colciago and Silvestrini (2020) develop models with heterogeneous firms that extend the seminar framework in Hopenhayn (1992) and Melitz (2003) to study the transmission mechanism of monetary policy shocks. Oikawa and Ueda (2018) study the reallocation effect of money growth. Cacciatore and Ghironi (2021) 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 the turnover of large firms 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, and Section 4 provides empirical evidence. Section 5 extends the simple model, focusing on the role of firm heterogeneity and the costs of entry for the propagation of monetary policy shocks. Section 6 concludes.

[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.

[3] In the open economy context, Bergin and Corsetti (2020) 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.

[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.

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, $z \in [z_{\min}, \infty]$, where $z_{\min}$ is the minimum level of productivity, 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 the next period without producing.

Households set wages one period in advance. The economy is cashless, and money is the unit of account. Monetary policy is powerful in changing the allocation of the economy 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:

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

where 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 Eq. (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 Eq. (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:

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

[5] We interpret our model as populated by different producers, each of which manufactures 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).

Each firm faces a residual demand curve with constant elasticity σ, as in Eq. (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 a productivity level below the cut-off level $z_{S,t}$ (i.e., $z < z_{S,t}$) cannot cover fixed operational costs and remain idle. The profit (dividends) 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: $S_t = \left[1 - G(z_{S,t})\right] N_t$. As in Melitz (2003), the average level of productivity $\widetilde{z}_{S,t}$ for producing firms is:

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

The average productivity level $\widetilde{z}_{S,t}$ summarizes information about the distribution of productivity across producers. Using the definition of average productivity in Eq. (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:

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

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:

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

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:

$$\widetilde{V}_t = f_E W_t, \tag{5}$$

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 5, 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 $\kappa > \sigma - 1$ determines the shape of the distribution.[6] The degree of heterogeneity in productivity is inversely related to the parameter κ, and firms become homogeneous at the lower end of the distribution for $\kappa \to \infty$. Using the properties of the Pareto

[6] In case of the unbounded Pareto distribution, as we assume, the condition is necessary to have a finite mean level of productivity. In other words, the condition ensures the variance of firm size is finite, as argued in Ghironi and Melitz (2005). The productivity dispersion is changing because of the change in the productivity cutoff. However, the shape of the distribution remains unchanged since the parameter κ is assumed to be constant.

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

$$\frac{S_t}{N_t} = z_{\min}^{\kappa}(\widetilde{z}_{S,t})^{-\kappa}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{\kappa}{\sigma-1}}. \tag{6}$$

As discussed, there exists a cut-off of idiosyncratic productivity level, $z_{S,t}$, for which the firm earns zero profits, such that: $D_t(z_{S,t}) = 0$.[7] This *zero cutoff profits* condition can be rewritten by using the Pareto distribution as:

$$\widetilde{D}_{S,t} = \frac{\sigma-1}{\sigma\kappa}\frac{P_t\int_0^1 C_t(j)dj}{S_t}. \tag{7}$$

2.6. Households optimizing decisions

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

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

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,[8] 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:

$$W_t(j) = \frac{\theta}{(\theta-1)(1+\nu)}\frac{\eta \mathrm{E}_{t-1}\left[L_t(j)^{1+\varphi}\right]}{\mathrm{E}_{t-1}\left[\frac{L_t(j)}{P_tC_t(j)}\right]}. \tag{8}$$

Eq. (8) 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, $(\theta-1)(1+\nu)\mathrm{E}_{t-1}\left[\frac{L_t(j)}{P_tC_t(j)}\right]$. 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:

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

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

$$1 = (1+i_t)E_t\left[Q_{t,t+1}(j)\right]. \tag{9}$$

2.7. Equilibrium

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

$$\mu_t \equiv P_tC_t. \tag{10}$$

[7] With the dividends of average producing firm $\widetilde{D}_{S,t}$, the zero cutoff profit condition is rewritten as $\widetilde{D}_{S,t} = \frac{\sigma-1}{\kappa-(\sigma-1)}fW_t$. And note that from the optimal pricing and the Pareto distribution, we have $\left(\frac{p_t(\widetilde{z}_{S,t})}{P_t}\right)^{1-\sigma} = \frac{1}{S_t}$ and $\left(\frac{p_t(\widetilde{z}_{S,t})}{p_t(z_{S,t})}\right)^{1-\sigma} = \frac{\kappa}{\kappa-(\sigma-1)}$. Plugging these relationships in the zero cutoff profit condition, we get $fW_t = \frac{1}{\sigma}\frac{\kappa-(\sigma-1)}{\kappa}\frac{P_t\int_0^1 C_t(j)dj}{S_t}$. Combining these two equations, we get (7).

[8] 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 fulfill the preference for variety of the households, as shown in Bilbiie et al. (2008), Lewis (2013), and Chugh et al. (2020).

By combining Eq. (10) with the Euler equation (9), the following transversality condition holds:

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

which shows that the monetary stance μ_t is tightly linked to the future expected path of the nominal interest rate.[9]

Using the average price for producers $\widetilde{p}_{S,t}$, 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 (5), the definition of average dividends ($\widetilde{D}_{S,t}$), and the zero cut-off profit condition (7), which yields:

$$N_{t+1} = \frac{\beta(\sigma-1)}{\sigma\kappa} \frac{\mu_t}{W_t f_E}. \tag{11}$$

Using the zero cutoff profits condition and the average dividends, the number of producing firms in each period t is:

$$S_t = \frac{\kappa - (\sigma-1)}{\sigma\kappa} \frac{\mu_t}{W_t f}. \tag{12}$$

Using (6), the average productivity of producers is given by:

$$\widetilde{z}_{S,t} = z_{\min} \left[\frac{\kappa}{\kappa - (\sigma-1)}\right]^{\frac{1}{\sigma-1}} \left(\frac{S_t}{N_t}\right)^{-\frac{1}{\kappa}}. \tag{13}$$

Noting that $p_t(\widetilde{z}_{S,t})\widetilde{y}_{S,t} = p_t(\widetilde{z}_{S,t})^{1-\sigma} P_t C_t$, the average scale of production $\widetilde{y}_{S,t}$ is:

$$\widetilde{y}_{S,t} = \frac{\sigma-1}{\sigma} \frac{\mu_t \widetilde{z}_{S,t}}{S_t W_t}, \tag{14}$$

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:[10]

$$L_t = S_t \left(\frac{\widetilde{y}_{S,t}}{\widetilde{z}_{S,t}} + f\right) + N_{t+1} f_E. \tag{15}$$

Substituting for N_{t+1}, S_t, and $\widetilde{y}_{S,t}$ from Eqs. (11), (12), and (14), respectively, in the labor market clearing condition (15) and using the outcome in the equilibrium wage in Eq. (8), yields the following closed-form solution for the wage:

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

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.

3. Monetary policy, firm entry, and the reallocation effect

In this section, we study the role of monetary policy under distortionary nominal wage rigidities. In our set up, monetary policy is non-neutral. Bilbiie (2021) shows that output remains unchanged in response to monetary policy shocks despite price rigidities under specific conditions. Instantaneous firm entry, combined with Dixit and Stiglitz (1977) preferences, fully absorbs the change in monetary policy and substitutes for price flexibility in the welfare-based relative price when individual prices are sticky. Thus, output remains unchanged in response to the monetary policy shock. We break the neutrality of monetary policy by departing from instantaneous entry, by assuming that new firms need time to build. In our framework, we show that firm heterogeneity on its own breaks the neutrality via the reallocation effect of monetary policy. Under our assumption of one period wage stickiness, the current wage is insensitive to monetary policy shocks, and the monetary policy stance μ_t is powerful to change the allocations in the economy, as summarized by the next proposition.

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

[10] The labor market clearing condition (15) can be rewritten as: $W_t L_t = (\sigma-1)S_t\widetilde{D}_{S,t} + \sigma S_t f W_t + N_{t+1}\widetilde{V}_t$.

Table 1
Model with nominal wage rigidities.

Monetary stance	$\mu_t = P_t C_t$
Wages	$W_t = \Gamma E_{t-1}\left[\mu_t^{1+\varphi}\right]^{\frac{1}{1+\varphi}}$
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	$\widetilde{z}_{S,t} = z_{\min}\left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\sigma-1}}\left(\frac{S_t}{N_t}\right)^{-\frac{1}{\kappa}}$
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	$\widetilde{D}_{S,t} = \frac{1}{\sigma}\frac{\mu_t}{S_t} - fW_t$
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	$L_t = (\sigma-1)\frac{S_t\widetilde{D}_{S,t}}{W_t} + \sigma S_t f + N_{t+1} f_E$

Proposition 1. *In each period t, an expansionary monetary stance that increases (μ_t) generates the survival of producing firms (S_t) with lower average productivity ($z_{S,t}$), stimulating the entry of new firms (N_{t+1}). A contractionary monetary stance generates opposite dynamics.*

Proof. Straightforward from Eqs. (12) and (13). □

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 Eq. (12). On the other hand, average productivity levels among producing firms, $\widetilde{z}_{S,t}$, decline, as shown in Eq. (13). An expansionary monetary policy stance that increases aggregate expenditure also allows low-productive firms to remain 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 number of new firms in the next period, N_{t+1}, which determines the 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, $Q_{t,t+1}$, thus increasing share prices, $\widetilde{V}_t$, which raise the number of new firms through the free entry condition in Eq. (5). In our set up, monetary policy is non-neutral, and the following corollary holds.

Corollary. *Firm heterogeneity makes monetary policy non-neutral even with instantaneous entry of producers and Dixit and Stiglitz (1977) preferences.*

Proof. As Proposition 1 shows, changes in monetary stance μ_t generate instantaneous adjustments in the number of producing firms S_t *and* their average efficiency $\widetilde{z}_{S,t}$ through the reallocation effect. Also, the average production $\widetilde{y}_{S,t}$ in Eq. (14) changes with the monetary stance μ_t. As a result, aggregate consumption is expressed as $C_t = Y_t\left(W_t, N_t\right)\mu_t^{\left(\frac{1}{\sigma-1}-\frac{1}{\kappa}+1\right)}$. Thus, the monetary policy stance μ_t is non-neutral in influencing aggregate consumption even with instantaneous adjustments of producing firms and Dixit and Stiglitz (1977) preferences.[11] □

Bergin and Corsetti (2008), Bilbiie et al. (2007), Bilbiie (2021) establish the non-neutrality of monetary policy by assuming new entrants need time to build under sticky prices. However, by abstracting from firm heterogeneity, their framework is unable to account for the effect of monetary policy on aggregate productivity, which in our analysis is a central channel for the reallocative effect of monetary policy.

4. VAR evidence

In this section, we provide empirical evidence on the effect of monetary policy on firm entry and exit as well as aggregate productivity. To facilitate comparisons with related studies, we use the same sample period (1965Q3-1995Q3) and an identification scheme similar to Christiano et al. (1999).[12] Our VAR model includes the original variables in Christiano et al. (1999), namely the log

[11] By plugging the previously found solutions, we have $Y_t\left(W_t, N_t\right) \equiv \left[\frac{\kappa}{\kappa-(\sigma-1)}\right]^{\frac{1}{\kappa}} \frac{(\sigma-1)z_{\min}N_t^{\kappa}}{\sigma(\sigma f)^{\left(\frac{1}{\sigma-1}-\frac{1}{\kappa}\right)}W_t^{\left(\frac{1}{\sigma-1}-\frac{1}{\kappa}+1\right)}}$.

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

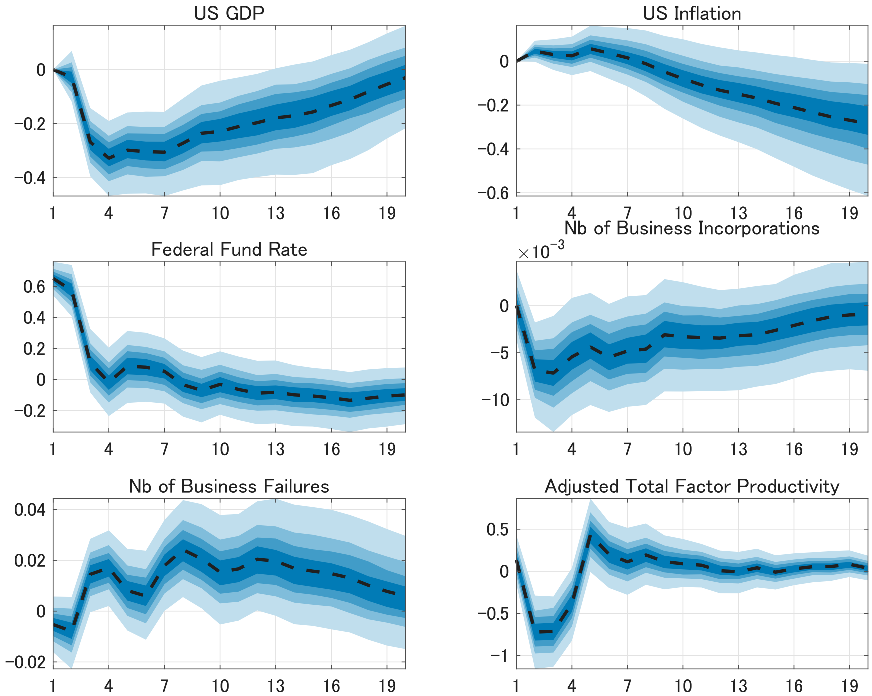

Fig. 1. VAR evidence on monetary policy shock, firm turnover, and productivity.
Effects of a positive contractionary shock to the Federal Fund Rate. Multivariate VAR, 1965:Q3-1995:Q3. Gray bands are 30%, 50%, 68% and 90% bootstrap confidence bands.

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.[13] In addition to these variables, we include the log of the number of new business incorporations and the log of the number of business failures from the Dun and Bradstreet. dataset.[14] Because our main focus is on the interplay between 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). Table 5 in Appendix A summarizes 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.[15] We set the number of lags in the VAR equal to 4.[16]

Fig. 1 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. Fig. 4 in Appendix B reports 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 but 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, and GDP falls with a hump-shaped response. The IRF of the number of business failures increases gradually, peaking after eight quarters and returning slowly to the original level. These dynamics for

[13] Christiano et al. (1999) perform 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".

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

[15] 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.

[16] 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 variables. As a robustness check, Appendix B shows results from the VAR model estimated with net business formation instead of new business incorporations and with business bankruptcy filings taken from U.S. bankruptcy courts instead of the number of business failures. The exercise provides qualitatively similar results to the benchmark model.

the measures of firm entry and exit are similar to those in Uusküla (2016). The novel finding from our analysis is the sharp fall in adjusted total factor of productivity in the two quarters in the aftermath of the shock and 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. Thus, our evidence demonstrates that the contractionary monetary policy is important for firm entry and exit, and it generates a fall in aggregate productivity.[17] However, as Proposition 1 shows, a contractionary monetary policy shock results in a rise in aggregate productivity of producing firms due to the reallocation in the benchmark model presented in Section 2. To reconcile the VAR evidence on the response of aggregate productivity to monetary policy shock with the dynamics in the simple theoretical model, we extend the simple model in a broader framework to study the response of aggregate productivity to monetary policy shock.[18]

5. 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 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.

5.1. 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: $N_{t+1} = (1-\delta)\left(N_t + H_t\right)$, 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:

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

where the real net interest rate r_t is defined as:

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

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:

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

and

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

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 C for derivation):

$$\left(\frac{W_t'(j)}{W_t}\right)^{1+\varphi\theta} = \frac{\frac{\eta\theta}{(\theta-1)(1+\nu)} \sum_{k=0}^{\infty} (\beta\vartheta)^k E_t\left[\left(\frac{W_{t+k}}{W_t}\right)^{\theta(1+\varphi)} L_{t+k}^{1+\varphi}\right]}{\sum_{k=0}^{\infty} (\beta\vartheta)^k E_t\left[\frac{1}{C_{t+k}} \frac{W_{t+k}}{P_{t+k}} \left(\frac{W_{t+k}}{W_t}\right)^{\theta-1} L_{t+k}\right]}, \tag{16}$$

[17] The increase in aggregate productivity in response to an expansionary monetary policy shock is discussed in a recent studies by Aghion et al. (2019) and Moran and Queralto (2018). In these papers, the rise in aggregate productivity is associated with higher investments that foster economic growth followed by monetary expansion.

[18] We performed robustness analyses 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) (U.S. data), and Gortz et al. (2021) (U.K. data). A similar issue arises with 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.

where $W_t'(j)$ stands for the optimal preset wage. In equilibrium, all households are symmetric. Thus we have $C_t(j) = C_t$ and $W_t'(j) = W_t'$. Using the equilibrium condition, the above optimal wage setting condition (16) can be represented as the wage Phillips curve:

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

where $\hat{\mu}_t^w$ is the deviation of the wage markup μ_t^w from its steady state value. Nominal 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:

$$w_t = \mu_t^w \frac{\eta L_t^{\varphi} C_t}{1}.$$

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:

$$\widetilde{v}_t = w_t f_E \left(\frac{H_t}{H_{t-1}}\right)^{\omega}$$

When the value of $\omega > 0$ is high, the entry process is sluggish.

Taylor rule. We define the following monetary policy rule as:

$$1 + i_t = (1+i)\, E_t \left[\pi_{t+1}^w\right]^{\phi_{\pi^w}} \upsilon_t,$$

where υ_t is an exogenous monetary policy shock. In our setup, nominal rigidity is at wage level and neither at the average price level nor the level of the welfare-consistent price index. We assume that the monetary policy rule primarily stabilizes nominal wage by targeting wage inflation.[19] Finally, we define the number of non-producing firms that remain idle and real GDP as: $\mathcal{D}_t \equiv N_t - S_t$ and $Y_t \equiv w_t L_t + N_{D,t}\widetilde{d}_t$. We assume that the monetary policy shock is equal to: $\ln \upsilon_t = \epsilon_{\upsilon,t}$, where the shock components $\epsilon_{\upsilon,t}$ are i.i.d. with zero mean. To solve the model we approximate the system around the non-stochastic, zero inflation steady state, assuming that $\upsilon_0 = 1$. Table 2 summarizes the extended model.

5.1.1. Calibration

The calibration is summarized in Table 3.[20] The discount factor, β, is set equal to 0.99. The inverse of the Frisch elasticity of labor supply, φ, is set equal to 2. The elasticity of substitution among varieties is set equal to 3.8. The coefficient of relative risk aversion, γ, is set equal to 2. The elasticity of substitution among varieties, σ, the exogenous exit shock, δ, and Pareto distribution parameter, κ, are set equal to 3.8, 0.025 and 3.4, respectively, as in Ghironi and Melitz (2005). The parameters that determine nominal wage stickiness, ϑ, and the elasticity of substitution among differentiated labor services, θ, are set equal to 0.64 and 3.5, respectively, as in Christiano et al. (2005), Kim and Ruge-Murcia (2009), and Amano and Gnocchi (2017). The parameter that determines the entry adjustment costs, ω, is set equal to 2.42, as in Bergin et al. (2018) to match the entry dynamics in the U.S. economy. The coefficient in the Taylor rule ($\phi_{\pi^w} = 1.5$) is consistent with the simple monetary rule in Bilbiie et al. (2007). We set $f = 0.003673$ so that the share of producing firms, S/N, is equal to 0.94 at the steady state, as described in Hamano and Zanetti (2017). Further, the dis-utility in labor supply is set equal to $\eta = 0.9309$ to have $L = 1$ and $1 + \nu = \theta/(\theta - 1)$, thereby removing the steady-state distortions for the wage markup.

5.1.2. Monetary policy shock

Fig. 2 shows the IRFs of the model to a 1% increase in the monetary policy shock, $\epsilon_{\upsilon,t}$. The entries show the responses of output, Y_t, wage inflation, π_t^w, nominal 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, $\widetilde{z}_{S,t}$. The exercise compares the baseline calibration with $\kappa = 3.8$ (solid lines) against alternative calibration with lower degrees of heterogeneity with $\kappa = 30$ (dashed lines).

A contractionary monetary policy shock generates a reduction in output on impact. Output, Y, wage inflation, π^w, and the number of new firms, H, decrease while the number of idle firms, $\mathcal{D}$ increases. The higher exit of low productivity firms increases average productivity of the producing firms, $\widetilde{z}_S$. These responses are short-lived except for the reaction of firm entry, H, which is persistent for the presence of entry adjustment costs (i.e., $\omega > 0$).

[19] We also could have some persistence from the past inflation as $1 + i_t = \left(1 + i_{t-1}\right)^{\rho}\left[(1+i)\, E_t \left[\pi_{t+1}^w\right]^{\phi_{\pi^w}}\right]^{1-\rho} \upsilon_t$ with $0 < \rho < 1$. Further, in our setup with firm heterogeneity, the average nominal price inflation is different from nominal wage inflation because of endogenous changes in the cutoff level of productivities. We also could assume that monetary authority conducts policy based on the average nominal price $\tilde{P}_t \equiv S_t^{\frac{1}{\sigma-1}} P_t$, which is not indexed with changes in the number of product varieties. Specifically, we could assume the following standard Taylor rule such that $1 + i_t = \left(1 + i_{t-1}\right)^{\rho}\left[\left(1+\tilde{\pi}_t\right)^{\phi_\pi}\left(\frac{Y_t}{Y_t^f}\right)^{\phi_Y}\right]^{1-\rho} \upsilon_t$ where ϕ_π and ϕ_Y stand for the reaction of the monetary authority with respect to the average price inflation and output gap, respectively. However, the extended model's quantitative ability is similar with those obtained under these more general policy rules.

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

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	$\widetilde{v}_t = w_t f_E \left(\frac{H_t}{H_{t-1}} \right)^{\omega}$
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	$N_{t+1} = (1 - \delta) \left(N_t + H_t \right)$
Euler shares	$\widetilde{v}_t = \beta (1 - \delta) E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-1} \left(\widetilde{v}_{t+1} + \widetilde{d}_{t+1} \right) \right]$
Euler bonds	$1 = \beta E_t \left[\left(\frac{C_{t+1}}{C_t} \right)^{-1} (1 + r_{t+1}) \right]$
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	$w_t = \mu_t^w \frac{\eta L_t^{\varphi} C_t}{1}$
Wage inflation	$\left(\frac{W_t'}{W_t} \right)^{1+\varphi\theta} = \frac{\frac{\eta\theta}{(\theta-1)(1+\nu)} \sum_{k=0}^{\infty} (\beta\vartheta)^k E_t \left[\left(\frac{W_{t+k}}{W_t} \right)^{\theta(1+\varphi)} L_{t+k}^{1+\varphi} \right]}{\sum_{k=0}^{\infty} (\beta\vartheta)^k E_t \left[\frac{1}{C_{t+k}} \frac{W_{t+k}}{P_{t+k}} \left(\frac{W_{t+k}}{W_t} \right)^{\theta-1} L_{t+k} \right]}$
CPI inflation	$\frac{w_t}{w_{t-1}} = \frac{1+\pi_t^w}{1+\pi_t}$
Monetary policy	$1 + i_t = (1 + i) E_t \left[\pi_{t+1}^w \right]^{\phi_{\pi^w}} \upsilon_t$

Table 3
Calibration.

β	Discount factor	0.99
φ	Inverse of elasticity of labor supply	2
γ	Relative risk aversion	2
σ	Elasticity of substitution among varieties	3.8
δ	Exogenous death shock	0.025
κ	Pareto shape	3.4
ϑ	Calvo wage parameter	0.64
θ	Elasticity of substitution among workers	3.5
ω	Entry adjustment cost	2.42
ϕ_{π^w}	Wage inflation target	1.5
f	Fixed cost for production	0.003673
η	Dis-utility in labor supply	0.9309

The difference in the response of average productivity (bottom-right panel) across the different degrees of heterogeneity shows that firm heterogeneity plays an important role for efficiency gains in terms of higher productivity that result from the cleansing of low-productive firms. 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. In this case, the efficiency gain stemming from the cleansing effect attenuates the reduction in output in response to the tightening of monetary policy, and it reduces the fall in entry of new producers compared to those with a high value of κ (i.e., low firm heterogeneity).[21]

Our extended model with the benchmark calibration fails to reproduce the sharp and persistent decline in aggregate productivity in response to the contractionary monetary policy shock in the VAR model. We now show that the adjustment costs to firm entry play a critical role to generate a response of aggregate productivity consistent with the VAR model. Sufficiently low adjustment costs to firm entry *insulate* incumbent firms from the competition of new entrants and thus play a central role for the reduction in aggregate productivity in response to the contractionary monetary policy shock.

[21] A contractionary monetary policy shock cannot generate a substantial difference in wage inflation and firm exit for different degrees in firm heterogeneity ($\kappa = 3.4$ or $\kappa = 30$) with the parametrization we consider. This is because firm heterogeneity is unable to influence the wage or wage dynamics. This finding is consistent with the solution of the simple model in the previous section (Table 1).

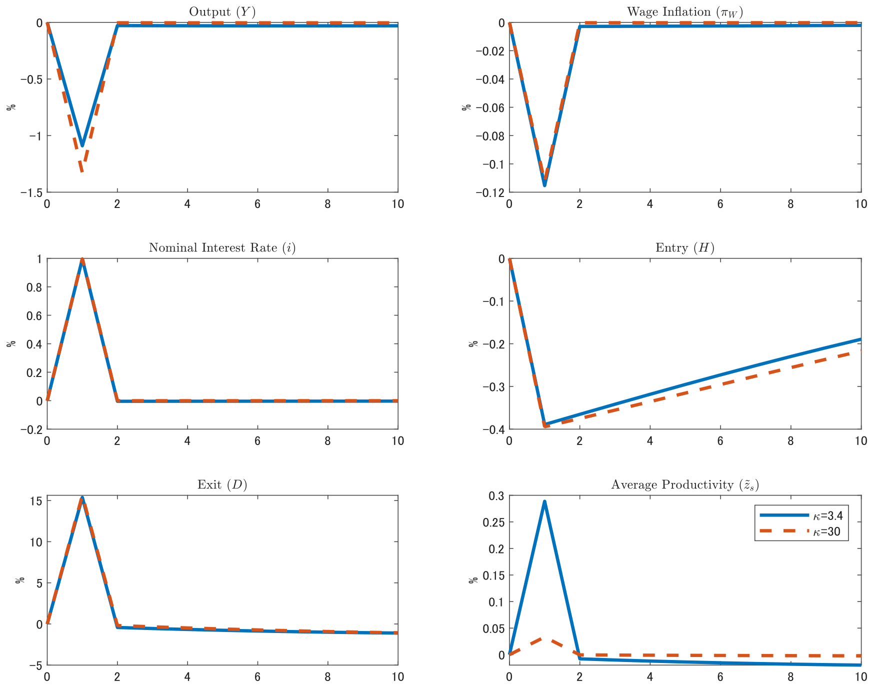

Fig. 2. Monetary shock and firm heterogeneity (κ.)
Each entry shows the percentage-point response of one of the model's variables to a one-percentage deviation of the contractionary monetary shock for the benchmark economy (solid line, $\kappa = 3.4$) and the economy with a low level of firm heterogeneity (dotted line, $\kappa = 30$).

Fig. 3 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 $\omega = 2.42$ (solid lines) against the alternative calibrations with minimal entry adjustment costs, which are equal to $\omega = 0.01$ (dashed lines). With low entry adjustment costs, the number of firms entering the economy, H, declines substantially on impact by around 70 percentage points, showing a persistent recovery phase (dashed line). The large reduction in firm entry generates a sharp fall in the total number of firms, which results in output below the equilibrium for several quarters. In the presence of low adjustment costs, the sharp and persistent wage deflation leads to a less contractionary and persistent response of the nominal interest rate. Fig. 7 in Appendix D provides IRFs for the complete set of variables.

The large and protracted decline in firm entry reduces competition for incumbent firms via lower wage costs, slowing down the number of exiting firms, D. Further, less competition results in a lower productivity for incumbent firms. Although the productivity of average incumbent plants, $\tilde{z}_S$ rises on impact, it falls in subsequent periods (as in the dashed line). Since the fall in entry insulates producing firms from competition, the larger the fall in entry, the stronger the reduction in firm exit and the fall in the productivity of producing firms. Our findings thus bear support to the insulation effect of entry on exit in the aftermath of a monetary policy shock, as outlined in Caballero and Hammour (1994) and Hamano and Zanetti (2017) in the context of technology shocks. To the best of our knowledge, our study is the first to link the insulation effect to the reallocative power of monetary policy.[22]

To summarize, with sufficiently low entry adjustment costs, a contractionary monetary policy increases the average productivity on impact, while decreasing it in subsequent periods, consistent with the VAR evidence. We establish that the theoretical model requires low entry adjustment costs that magnify the fall in the entry of new firms and insulate the incumbent firms from competition in response to the contractionary monetary policy shock. The lower degree of competition allows low-productivity firms to remain in the market, therefore reducing aggregate productivity. While low adjustment costs generate a fall in productivity consistent with the VAR model, they produce a counterfactual large fall in entry. Table 4 summarizes the findings on the impact and transitory responses of entry, exit, and aggregate productivity to a contractionary monetary policy shock in the simple model (row 1), the extended models with high- and low-adjustment costs (row 2 and 3, respectively), and the VAR model (row 4).

[22] Our analysis shows that entry adjustment 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. (2021) is a recent attempt to study market concentration in a model with heterogeneous firms, abstracting from monetary policy.

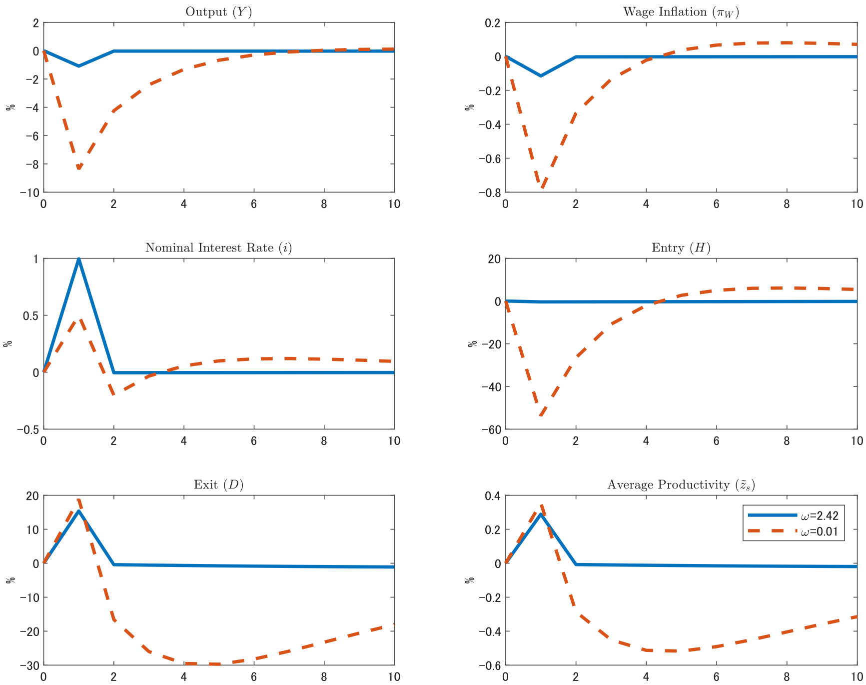

Fig. 3. Monetary policy shock and entry adjustment cost(ω).
Each entry shows the percentage-point response of one of the model's variables to a one-percentage deviation of the contractionary monetary shock for the benchmark economy (solid line with $\omega = 2.42$) and the economy with low a level of entry adjustment cost (dotted line with $\omega = 0.01$).

Table 4
Impact and transitory effects of a monetary contraction.

	Entry H impact	Transitory	Exit D impact	Transitory	Productivity $\tilde{z}_S$ impact	Transitory
(1) Simple model	↓	–	↑	–	↑	–
(2) Extended (ω high)	↓	–	↑	–	↑	–
(3) Extended (ω low)	↓↓	↓↓	↑↑	↓↓	↑	↓
(4) VAR model	–	↓	–	↑	–	↓

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 other studies, we find that an expansionary monetary policy shock prevents the cleansing of low-productive firms from the economy, generating a slowdown in productivity. 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 the competition of new entrants, therefore reducing aggregate productivity. We show that an extended version of the model requires low adjustment costs and hence a large response of firm entry to generate the observed response in 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 such as financial frictions, price distortions, and a wider range of shocks that could in principle exert an important quantitative influence on the allocative effect of monetary policy.[23] The enriched model could provide an empirical assessment of a broad range of channels that contributes to the allocative effect of monetary policy, which we plan to pursue in the future.

Data availability

Data will be made available on request.

[23] Hamano and Zanetti (2021) provide normative analysis on the effect of monetary policy in the presence of heterogeneous firms. They show that under demand uncertainty the gain of the optimal monetary policy diminishes in firm heterogeneity and increases in the preference for product variety.

Table 5
Data.

Series name	Source
U.S. 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	U.S. Bankruptcy court
Adjusted Total Factor Productivity	Fernald's web site

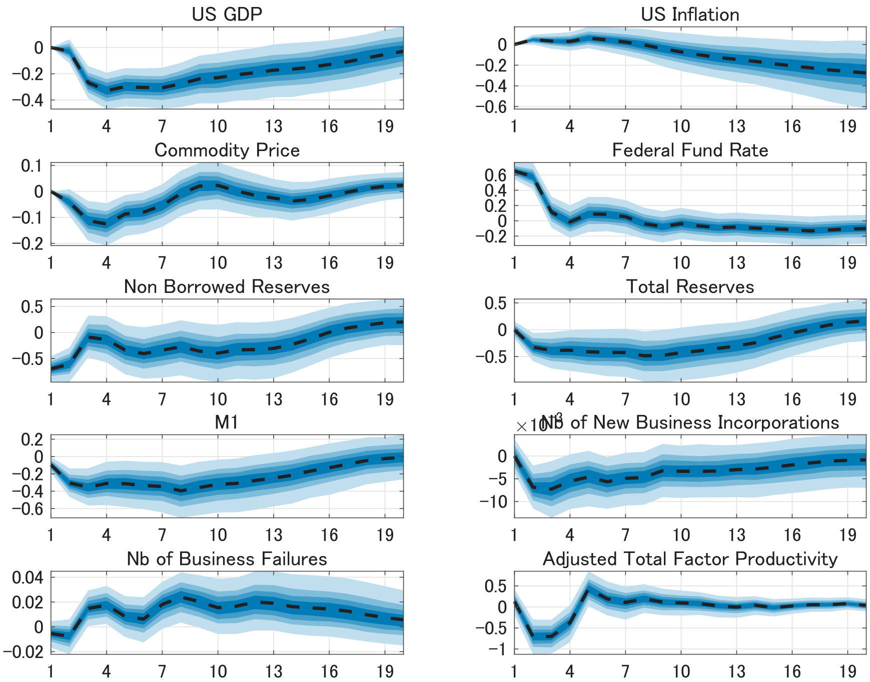

Fig. 4. The benchmark VAR.
Effects of the federal fund rate shock, multivariate VAR, time period 1965Q3-1995Q3. Gray areas are 30%, 50%, 68% and 90% bootstrap confidence bands, respectively.

Appendix A. Data

See Table 5.

Appendix B. VAR with alternative measures of entry and exit

See Figs. 4–6.

Appendix C. 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:

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

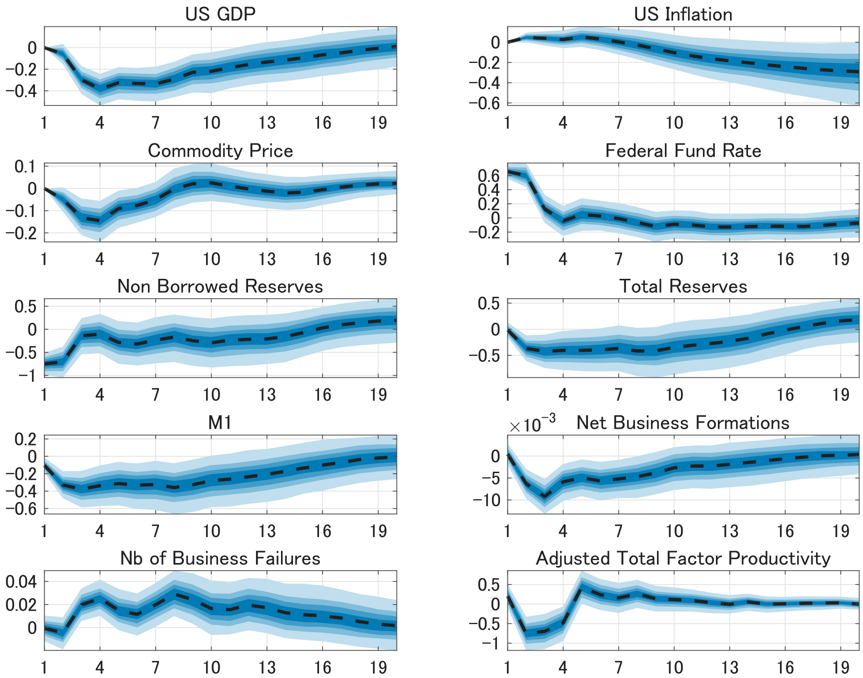

Fig. 5. VAR with Net Business Formation Index.
Effects of the federal fund rate shock, multivariate VAR, time period 1965Q3-1995Q3. Gray areas are 30%, 50%, 68% and 90% bootstrap confidence bands, respectively. The original Net Business Formation Index is monthly data, we use the value in the third month to construct the quarterly time series.

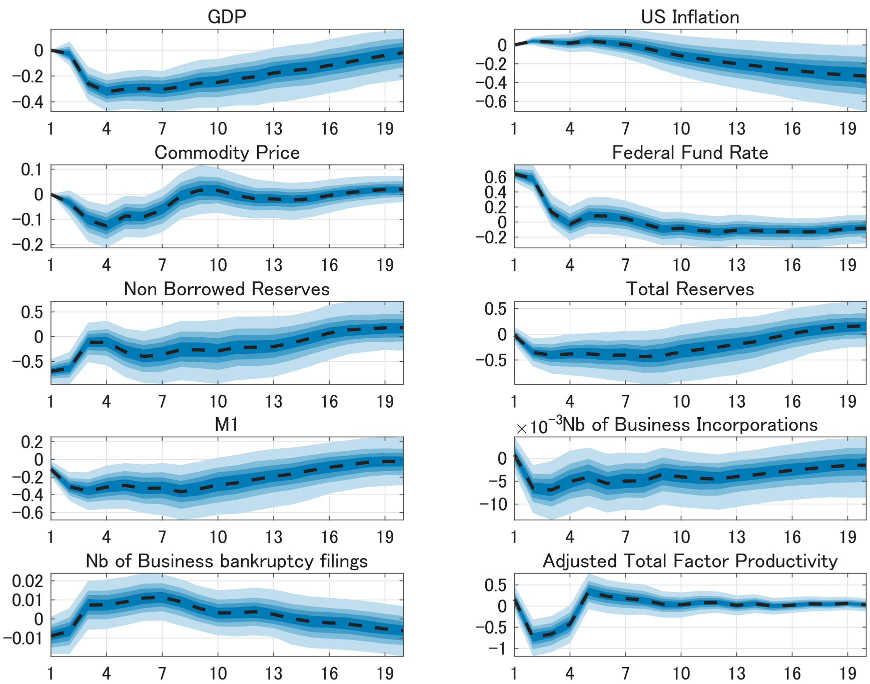

Fig. 6. VAR with number of business bankruptcy filings.
Effects of the federal fund rate shock, multivariate VAR, time period 1965Q3-1995Q3. Gray areas are 30%, 50%, 68% and 90% bootstrap confidence bands, respectively.

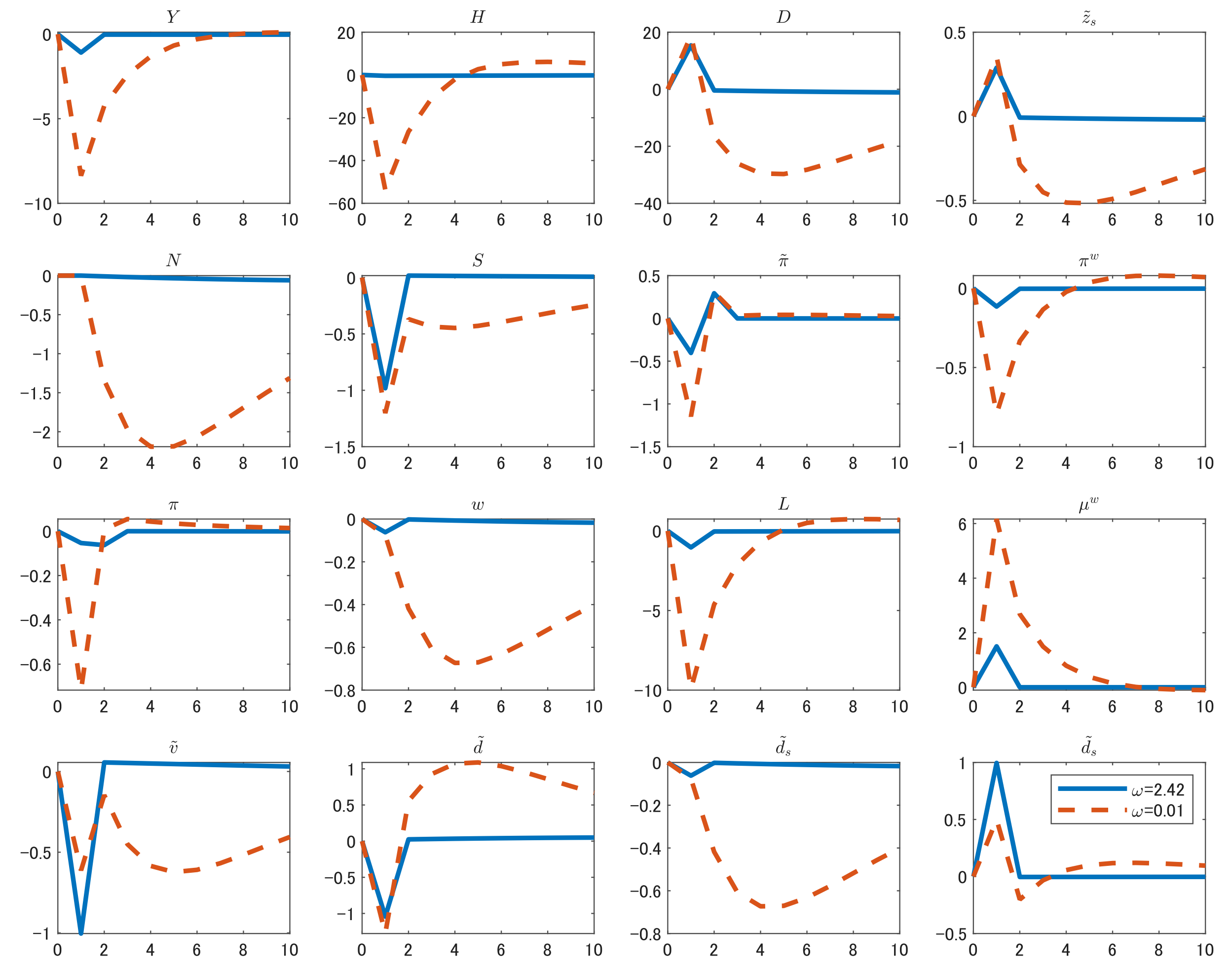

Fig. 7. IRFs with different ω.
Each entry shows the percentage-point response of one of the model's variables to a one-percentage deviation of the contractionary monetary shock for the benchmark economy (solid line with $\omega = 2.42$) and the economy with low a level of entry adjustment cost (dotted line with $\omega = 0.01$).

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 $W_t^{'}(j)$. The first order condition yields:

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

and using

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

it yields Eq. (16).

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 Eq. (16), we obtain the following wage equation:

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

Appendix D. IRFs

See Fig. 7.

Appendix E. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.euroecorev.2022.104089.

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