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The Effects of Endogenous Firm Exit on Business Cycle Dynamics and Optimal Fiscal Policy*

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Abstract

We explore the implications of endogenous firm entry and exit for business cycle dynamics and optimal fiscal policy. We first show that when the firm exit rate is endogenous, negative technology shocks lead to reductions in the number of firms. Technology shocks therefore have additional effects on household welfare relative to an economy with only endogenous entry. Second, endogenous firm exit creates a new channel for monetary policy when debt contracts are written in nominal terms, as monetary shocks affect the rate of firm defaults. Monetary shocks therefore have real effects also when prices and wages are flexible. Third, we show that endogenous firm exit creates a new role for fiscal policy to increase efficiency and welfare by subsidizing firms and decreasing the number of defaults. Finally, we demonstrate that endogenous firm exit implies that non-persistent shocks to technology and money supply have persistent effects on labor productivity. This has implications for the estimated persistence of technology shocks.

Keywords: firm defaults, money supply shock, labor productivity
JEL classification: E32, E52

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1 Introduction

DSGE models have become the standard tool for analyzing monetary policy. These models are widely used in central banks as a support for policy making and in academic discussions about monetary policy and business cycles. One common feature of these models is monopolistic competition, which generates persistent profits for firms. This feature makes it possible to add price rigidity to the model and to establish a role for monetary policy. Permanent positive profits should, however, induce more firms to enter the market. But standard DSGE models ignore firm dynamics caused by positive profits and assume a constant number of producers. Therefore, these models miss a potentially important feature of the business cycle fluctuations and the transmission mechanism of monetary policy.

Recently, several authors have introduced endogenous firm entry into an otherwise standard DSGE model.[1] Bilbiie et al. (2007a) find that "the sluggish response of the number of producers generates a new and potentially important mechanism for real business cycle models". This literature assumes that all changes in firm dynamics are caused by endogenous changes in firm entry while firm exit rate remains constant. In practice, however, firm exit rates are volatile and strongly countercyclical, a feature that has been ignored in previous research.

In this paper, we build a DSGE model in which both firm entry and exit are fully endogenous. Firms are founded by households subject to a fixed entry cost as in Bergin and Corsetti (2008), Bilbiie et al. (2007a,b, 2008) and Lewis (2006). In addition, firms have to pay a fixed cost each period to be able to produce in the next period. To finance this cost, they borrow funds from a fully competitive banking sector. Banks issue liabilities to households and issue the loans to the firms. Idiosyncratic shocks to firm productivity imply that the least efficient firms fail in repaying their loans. These firms default and exit the market. This friction generates financial accelerator mechanism whereby higher expected default rates in a downturn lead to higher market interest rates and a more severe economic slowdown. Thus, as in Bernanke et al. (1999), the irrelevance theorem of financial structure by Modigliani and Miller (1958) does not hold if credit markets are characterized by asymmetric information and agency problems.

The primary purpose of this paper is to study how endogenous exit rates affect business cycle dynamics in an economy subject to shocks to technology and money supply. In particular, we study the impact of shocks on labor productivity. A secondary purpose is to examine the role of fiscal policy in reducing the inefficient destruction of firms. When exit rates are endogenous, fiscal policy can affect firm defaults by an appropriate combination of subsidies and taxes. This policy effect does not exist in Bilbiie et al. (2008), who show that a market economy is efficient when only firm entry is endogenous, so there is no role for fiscal policy. The introduction of endogenous firm exit, therefore, has implications for the optimal design of fiscal policy.

[1]See, for example, Bilbiie et al. (2007a), Bergin and Corsetti (2008) and Lewis (2006).

This paper presents four main results. First, we show that negative technology shocks cause firms to default and, therefore, destroy part of the firm stock. This destruction generates a larger negative effect on welfare than in the case where changes in the number of firms are solely due to changes in firm entry. Endogenous exit implies a larger fall in household consumption, and households have to increase their labor supply to achieve even this lower consumption level. Second, we identify a new channel for monetary policy. As debt contracts are assumed to be written in nominal terms, the deflationary impulse (caused by a contractionary monetary shock) increases the real value of debt. Thus, more firms are unable to repay their loans and face bankruptcy. A contractionary monetary shock therefore increases firm defaults and has real effects, even if there are no nominal rigidities in price or wage setting. Third, we find that it is optimal for policy makers to affect exit rates. In our model, firm defaults exist due to a moral hazard problem between banks and firms. Banks cannot observe the financial situation of their debtors. Therefore, they have to bankrupt those firms that default on repayment. This inefficiency is closely related to the costly state verification problem present in Bernanke et al. (1999). By subsidizing firms, policy makers can decrease the number of defaults, increase investments in the new firms and increase the number of firms producing in the economy. We find that the Ramsey optimal fiscal policy subsidizes firms and decreases the number of bankruptcies in the economy.

Finally, we find that changes in the number of producing firms affect total factor productivity, which, in our model framework, is comparable to aggregate labor productivity. Therefore, non-persistent shocks to technology or money supply have persistent effects on labor productivity. Endogenous firm dynamics can therefore explain part of the measured changes in total factor productivity (TFP). As a consequence, traditional models that ignore endogenous firm dynamics may misinterpret movements in TFP and labor productivity and overestimate the importance of persistent exogenous shocks

Recently, there has been a growing interest in firm dynamics over the business cycle. Based on the international trade model by Melitz (2003), Bilbiie et al. (2007a) build a real business cycle model consistent with the empirically observed procyclical number of producers and profits and countercyclical markups. Their model performs at least as well as the benchmark model with respect to the implied second-moment properties of key variables. Bergin and Corsetti (2008) show that firm entry alters the transmission of monetary policy innovations. In their model, stabilization policy has an additional role in regulating the optimal number of firms. Additionally, Bilbiie et al. (2007b) show that monetary policy affects firm entry by changing asset prices. This channel restores the Taylor principle in the presence of capital accumulation. According to their analysis producer price inflation acts as a distortionary tax on profits, and distorts the allocation of resources to firm entry. Therefore, optimal monetary policy stabilizes individual product prices.

Most of the earlier literature on firm dynamics has concentrated on the dynamics of endogenous firm entry while assuming a constant exit rate. Despite the lack of theoretical

DSGE models with endogenous firm exit, strong empirical evidence indicates that firm exit rates vary over time. Jaimovich and Floetotto (2008) show that firm failures are strongly countercyclical but also vary substantially across industries. According to Dunne et al. (1988), approximately 30 to 50 percent of operating firms exit during a five year period. Thus, firm exit is a major force driving firm dynamics. One of the few theoretical DSGE models that takes into account endogenous firm exit is Ghironi and Melitz (2005). In this paper, firms enter and exit the export market depending on macroeconomic conditions. The authors show that endogenous changes in firm exit alter the composition of the consumption basket, leading to persistent deviations from purchasing power parity.

Jaimovich and Floetotto (2008) build a model in which labor productivity varies endogenously with the number of firms producing in the industry. They also provide evidence that the greater part of variability in the total factor productivity is due to an endogenous mechanism embedded by firm entry and exit. However, in their model, the endogenous response of labor productivity only exists if resources used to produce fixed costs are not calculated into total output. Contrary to their model, the endogenous reaction of labor productivity in our model stems from the effect of more firms developing new intermediate goods for the production of final goods. Our model also has a richer process for firm dynamics that includes entry costs and endogenous firm exit.

The rest of the paper is organized as follows. In section 2, we provide empirical facts on firm dynamics. Section 3 presents our theoretical model. Section 4 analyzes the dynamic effects of money supply and technological shocks. In this section, we also discuss how macroeconomic shocks affect labor productivity and cause persistent movements in labor productivity. Section 5 studies optimal fiscal policy, and section 6 concludes.

2 Empirical Evidence on Firm Dynamics

In Figure 1, we plot time series for new business incorporations and business failures in the United States with real gross domestic product (GDP).[2] Both firm entry (measured by new business incorporations) and business failures are volatile and correlated with GDP over the business cycle. Firm entry is procyclical, and business failure is countercyclical. These observations are confirmed by the high correlations of the series with real GDP. Correlations of firm entry and business failures with real GDP are 0.43 and -0.45 and are significantly different from zero. In addition, the registration of new business incorporations decreases during the recessions announced by the Business Cycles Dating Committee of the National Bureau of Economic Research, and the number of business failures typically peak toward the end of a contraction.

A strong increase in business failures also occurs during periods without recession. Thus, there seem to be factors other than business cycles that affect business failures. One purpose of this paper is to study the effects of monetary shocks on firm dynamics and

[2] The data source for the series of firm dynamics is the Economic Report of the President. Our data are seasonally adjusted. Data for firm dynamics are available only until 1998:2.

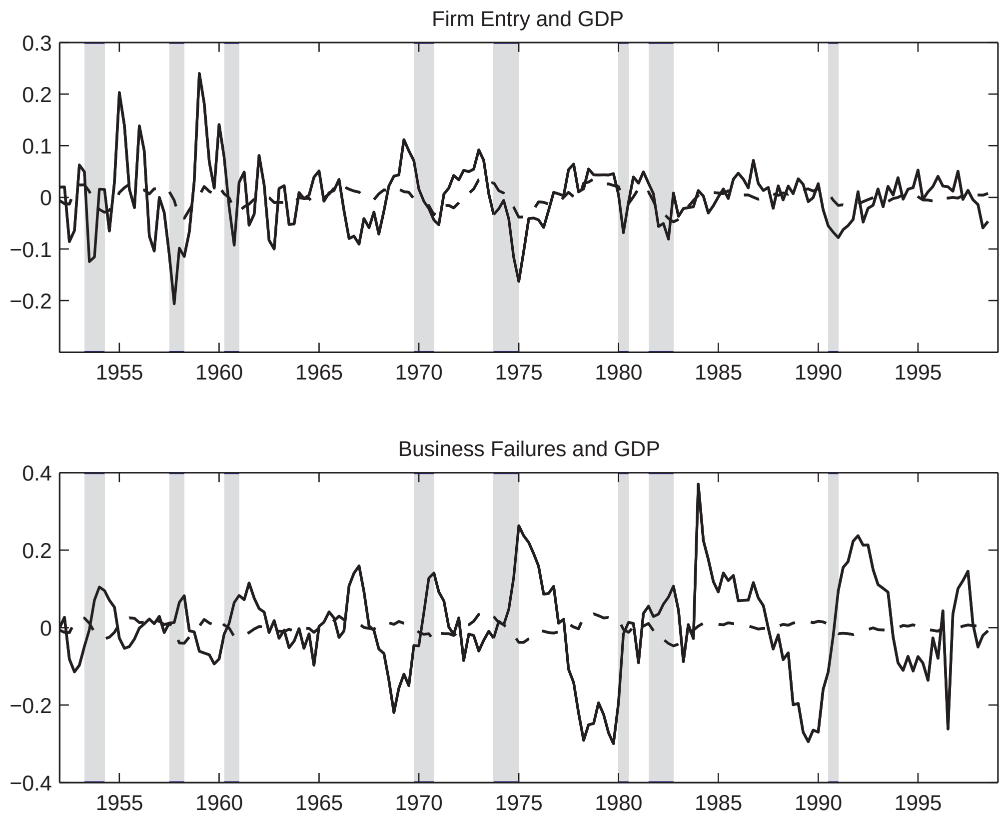

Figure 1: Real GDP (dashed lines), new business incorporations (solid line) and business failures (solid line). All series are HP-filtered log deviations from the trend. Shaded areas show contractions announced by the Business Cycle Dating Committee of the National Bureau of Economic Research.

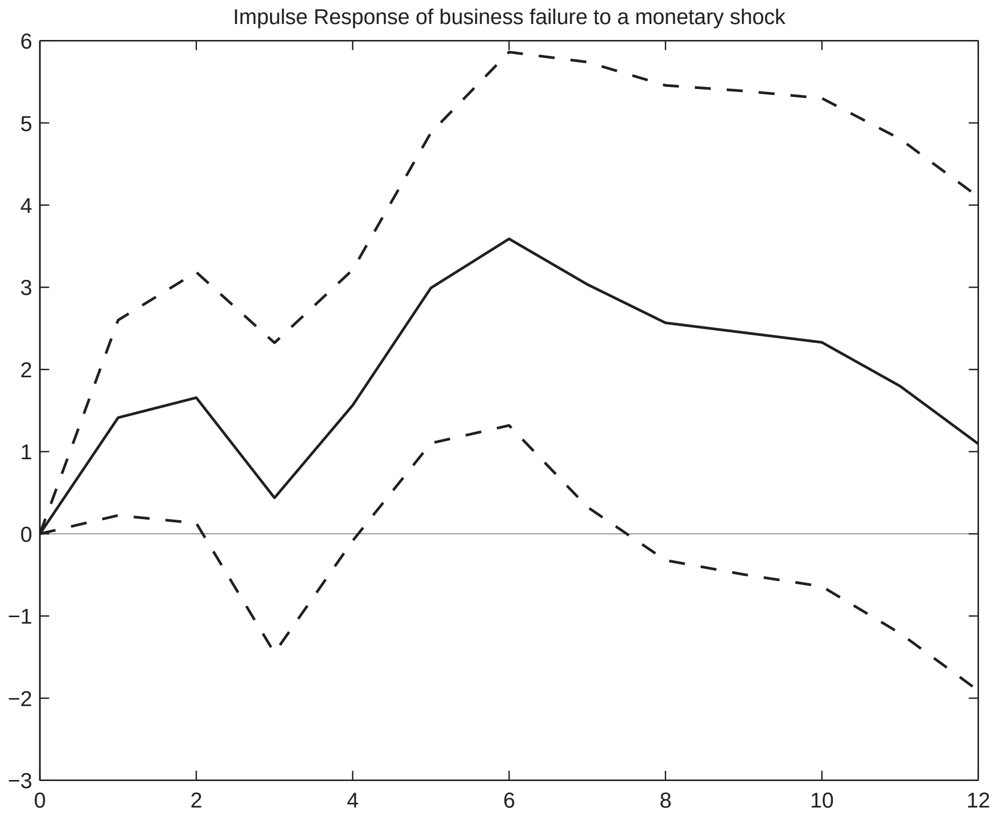

Figure 2: The impulse response of business defaults to a positive interest rate shock. Dashed lines show 95 percent confidence intervals about VAR-based estimates.

on business defaults in particular. Therefore, we apply vector autoregressive regressions (VAR) to arrive at further evidence of the effect of monetary policy on firm dynamics.

Bergin and Corsetti (2008) and Lewis (2006) provide evidence that contractionary monetary policy has negative effects on firm entry. We estimate the effects of monetary policy on firm exit using an identified VAR model. The vector of variables used in the analysis is denoted by X_t. This vector can be divided into three subvectors: $X_{1,t}$, R_t and $X_{2,t}$:

$$X_t = [X_{1,t}, R_t, X_{2,t}]' .$$

$X_{1,t}$ is composed of variables that are assumed not to respond contemporaneously to a monetary policy shock, R_t is the monetary instrument, and $X_{2,t}$ consists of all the other variables. Christiano et al. (1999) use a similar recursive scheme to study the responses to monetary policy shocks.

In our VAR specification, the variables in $X_{1,t}$ are business defaults, gross domestic product, new business incorporations, inflation measured by the GDP deflator, commodity prices, consumption, investments and wages. We assume that monetary policy reacts contemporaneously to these variables. We include commodity prices to control the price puzzle (see Christiano et al. (1999)). We measure the monetary instrument R_t using the federal funds rate. The only variable in $X_{2,t}$ is real profits. All of the variables in

X_t except for the federal funds rate and inflation are expressed in log-levels. We use quarterly data, and our sample period is 1964:1-1995:2.

Figure 2 shows that a one percent contractionary shock to the federal funds rate increases business defaults. Our results imply that a one percent increase in federal funds rate increases business failures in the subsequent quarter by approximately one and half percent. The response of firm exits peaks around 6 quarters after the shock and lasts about three years. The response is also statistically significant. The total cumulative increase of business failures is around 25 percent. This implies that on average a one percent positive shock to federal funds rate increases three years firm default rate from 1.94 % to 2.42 %.[3] Thus, our VAR evidence shows that monetary policy affects the financial situation of firms and the rate of defaults. In the next sections, we build a theoretical model to study a mechanism by which monetary policy has an effect on firm dynamics.

3 The Model

In this section, we develop a model with endogenous firm entry and exit. Our starting point is the model of endogenous firm entry developed by Bilbiie et al. (2007b) and Bergin and Corsetti (2008). To this model, we add a banking sector and endogenous defaults. In our model, households consume goods and supply labor. In addition, they make investment decisions to establish new firms and buy shares of existing firms. Firms produce intermediate goods in a monopolistically competitive market, and goods are sold to a fully competitive final goods sector. We assume that prices and wages are flexible. Monetary policy may still have real effects as debt contracts between firms and banks are written in nominal terms. In contrast to the models developed in earlier studies, firms must finance fixed costs to be able to produce in each subsequent period. They acquire this capital from a competitive banking sector. This new channel with external financing determines the endogenous exit rate of firms.

3.1 Households

Each period, a representative household makes consumption, labor supply and money-holding decisions. It also decides how much to invest in new firms and in the shares of incumbent firms and how much to lend to the banking sector. Households obtain utility from money holdings, as is commonly assumed in the money-in-utility models based on Sidrauski (1967).

At time t, the household maximizes the discounted value of expected infinite life-time utility over consumption C_t, labor supply L_t and real money holdings $\frac{M_t}{P_t}$. The

[3]Dunne et al. (1988) show that exit rate is significantly higher than default rate.

household's lifetime utility function is

$$E_t \left[\sum_{s=t}^{\infty} \beta^{s-t} \left(\log C_s + \frac{1}{1-\sigma} \left(\frac{M_s}{P_s} \right)^{1-\sigma} - \chi \frac{L_s^{1+\frac{1}{\phi}}}{1+\frac{1}{\phi}} \right) \right]. \tag{1}$$

Here, E_t stands for expectations, and $\beta \in (0,1)$ is the subjective discount factor. In equation (1), χ is a parameter determining the steady state level of labor supply; ϕ is the Frisch elasticity of the labor supply to wages and $\sigma \leq 1$ is the inverse of the consumption elasticity of money demand.

The household receives wage income w_t for its labor supply, and it can save by buying bonds B_t, the shares of surviving old firms N_t^S or establishing new firms N_t^E. The main difference between new and old firms is that the founding of a new firm requires an entry cost, for example to cover the costs for the research and development of a new product and the building of a new production line, whereas the shares of old firms are traded on the stock market. Thus, the establishment of a new firm uses aggregate resources, which are measured in units of consumption. Households earn profits from firms as dividends d_t^S. Denoting the value of new firms as v_t^E, the value of old firms as v_t^S and the consumer price index as P_t, we can write a household's budget constraint as

$$(v_t^S + d_t^S)N_t^S + L_t w_t + R_t B_{t-1} + M_{t-1} = P_t C_t + B_t + v_t^E N_t^E + v_t^S N_t^S + M_t. \tag{2}$$

For every period t, the household maximizes the intertemporal utility function (1) subject to the budget constraint (2) with respect to the real cash holdings $\frac{M_t}{P_t}$, the holdings of bonds B_t, consumption C_t, labor supply L_t and the investments in incumbent firms N_t^S and new firms N_t^E. This optimization yields the following first-order conditions:[4]

$$\frac{1}{P_t C_t} = \frac{\beta R_t}{P_{t+1} C_{t+1}}, \tag{3}$$

$$\frac{v_t^E}{P_t C_t} = \frac{\beta \left(v_{t+1}^S + d_{t+1}^S \right)}{P_{t+1} C_{t+1}}, \tag{4}$$

$$\frac{v_t^S}{P_t C_t} = \frac{\beta \left(\frac{z_{min}}{\tilde{z}_{t+1}} \right)^k \left(v_{t+1}^S + d_{t+1}^S \right)}{P_{t+1} C_{t+1}}, \tag{5}$$

$$\left(\frac{M_t}{P_t} \right)^{-\sigma} = \frac{R_t}{R_t - 1} C_t \quad \text{and} \tag{6}$$

$$\chi L_t^{\frac{1}{\phi}} = \frac{w_t}{C_t P_t}. \tag{7}$$

Here, equation (3) is the Euler equation for bonds. Equations (4) and (5), in turn, reflect Euler equations for the investments in entrants and incumbent firms. These equations

[4]The transversality conditions for bonds and both equities must also be satisfied to ensure optimality.

imply that the value of firms depends on the expected future flow of dividends. In addition, the expected probability of default $1 - \left(\frac{z_{min}}{\bar{z}_{t+1}}\right)^k$ affects the discount rate of future returns.[5] In addition, we have intratemporal first-order conditions for money demand (6) and labor supply (7).

3.2 Intermediate Good Firms

There is a continuum of monopolistically competitive firms ω where each firm has a single production line producing a different intermediate good variety $\omega \in \Omega$. To enter the market, intermediate good firms must meet the sunk entry cost f^E one period in advance of production. Entrants acquire the financing for the entry cost from investment by households v_t^E. Thus, the free entry condition implies

$$v_t^E = P_t f^E. \tag{8}$$

To be able to produce in the next period, firms must pay a fixed cost f^F, which is also measured in the units of consumption. Firms acquire the financing for fixed costs from the competitive banking sector, and they pay the nominal interest rate R_t^m for this one-period loan. The need for external finance generates a financial accelerator mechanism in which the increased probability of exit in a downturn leads to higher interest rates and creates an extra contractionary effect on the economy. This credit market friction generates an inefficiency in the economy due to a moral hazard problem between banks and borrowers. This source of inefficiency in the credit markets is discussed in more detail in section 3.4.

Labor is the only factor required in production. There is a linear production technology $y_t(\omega) = A_t z_t(\omega) l_t(\omega)$, where $l_t(\omega)$ is the labor demand of firm ω, and A_t and $z_t(\omega)$ denote aggregate and idiosyncratic productivity levels. Firms must also pay back the loans from the previous period. It follows that the profits of firm ω in period t is

$$d_t^S(\omega) = \left(p_t(\omega) - \frac{w_t}{A_t z_t(\omega)}\right) y_t(\omega) - R_{t-1}^m P_{t-1} f^F. \tag{9}$$

Firms face a constant price elasticity of demand and, thus, they set their prices as a constant markup over their marginal costs $p_t(\omega) = \frac{\theta}{\theta-1}\frac{w_t}{A_t z_t(\omega)}$. There exists a cut-off level for productivity $\bar{z}_t$ where a firm has zero profits, and firms whose productivity is lower than the cut-off level cannot pay back their loans. These firms default on their loans and leave the market. Banks claim their liquid assets, which amount to the profits before loan payments. Other firms repay their loans, pay the profits as dividends to the owners and borrow the new finances for fixed costs. The shares of these firms are also traded in the stock market with the price v_t.

At the beginning of each period, firms learn their aggregate and individual productiv-

[5] Endogenous exit rate and the accummulation of firm stock are discussed more detailed in sections 3.2 and 3.5.

ity levels A_t and $z_t(\omega)$. Thus, firms are heterogeneous in their productivities. Individual productivities are randomly drawn from a Pareto distribution over $[z_{min}, \infty]$ given by $G(z) = 1 - \left(\frac{z_{min}}{z}\right)^k$, where z_{min} is the lower bound and $k > \theta - 1$ indexes the dispersion of productivity draws.[6] Aggregate productivity A_t follows the process $A_t = \bar{A}e^{\epsilon_t^A}$, where $\bar{A}$ denotes the steady state productivity level and ϵ_t^A denotes an aggregate productivity shock that follows the process $\epsilon_t^A = \rho\epsilon_{t-1}^A + \eta_t^A$. Here η_t^A is a normally distributed i.i.d. shock.

3.3 Final Good Firms

At time t, final goods Y_t are produced in a perfectly competitive market. A representative firm produces final goods by combining intermediate goods $y_t(\omega)$ using the constant elasticity of scale technology

$$Y_t = \left(\int_{\omega \in \Omega} y_t(\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}}, \tag{10}$$

where θ is the elasticity of substitution between varieties. The constant elasticity of scale production technology for final goods makes production more efficient the more intermediate good varieties are used in production. This type of production function is widely used in the international trade literature (e.g., Ethier (1982)). Due to endogenous firm entry and exit, only a subset of varieties $\Omega_t \in \Omega$ is available at time t. As is well known, the Dixit-Stiglitz production technology (10) leads to the price index

$$P_t = \left(\int_{\omega \in \Omega} p_t(\omega)^{1-\theta} d\omega \right)^{\frac{1}{1-\theta}}, \tag{11}$$

where $p_t(\omega)$ is the price of variety ω. Demand for an individual intermediate good variety ω is

$$y_t(\omega) = \left(\frac{p_t(\omega)}{P_t} \right)^{-\theta} Y_t. \tag{12}$$

Final goods are sold to households and to both new and incumbent intermediate good firms. Households consume them as consumption goods; new firms use them to generate the new production lines (the entry cost), and all firms that produce in the next period use them to generate the production facilities for the period $t + 1$:

$$Y_t = C_t + f^E N_t^E + f^F (N_t^S + N_t^E), \tag{13}$$

where f^E and f^F denote the entry cost and the periodical fixed cost.

[6] A Pareto distribution generates a distribution of idiosyncratic productivity levels, where a large portion of firms has low productivity and only a small subset of firms has high productivity. This fits firm-level data quite well. Also Ghironi and Melitz (2005) assume that firm productivity is Pareto distributed.

3.4 Banking Sector

The banking sector is perfectly competitive. Banks collect deposits from households at the interest rate R_t and lend it to the firms at the interest rate R_t^m. We assume that banks do not participate in financial arrangements other than the liabilities issued to households and the loans issued to the firms.

Debt contracts between banks and firms are written in nominal terms. Thus, inflation affects the real value of debt. We assume that banks do not observe the borrower's financial situation. The only signal that the bank observes is whether the borrower repays the loan. This asymmetric information leads to a moral hazard problem similar to the costly state verification problem first analyzed by Townsend (1979). Thus, it is optimal for banks to bankrupt firms that default on repayment. The behavior of the financial sector in our model is a modification of that described by Bernanke et al. (1999), who assume that banks pay an auditing cost and force entrepreneurs who default on repayment into bankruptcy.

Perfect competition in the banking sector implies that the interest rate for firms is determined by the expected zero profit condition for the banking sector:

$$E_t \left(R_t^m B_t \left(\frac{z_{min}}{\bar{z}_{t+1}} \right)^k + \left(1 - \left(\frac{z_{min}}{\bar{z}_{t+1}} \right)^k \right) N_{t+1} d_{t+1}^F P_{t+1} \right) = R_t B_t, \tag{14}$$

where d_{t+1}^F is the expected liquidity of an average defaulting firm in the period $t+1$. The left hand side of equation (14) denotes the expected revenues of the banking sector. The first term reflects the revenue from the firms that repay their loans. A fraction $1 - \left(\frac{z_{min}}{\bar{z}_{t+1}} \right)^k$ of firms defaults on repayment. These firms are forced into bankruptcy and lose any liquidity they have to lending banks. The second term in the left hand side reflects this revenue for banks. The right hand side is, in turn, the cost of borrowing from the households. Financial markets must clear: the number of bonds issued to the market must be equal to the demand for the bonds

$$P_t N_{t+1} f^F = B_t. \tag{15}$$

3.5 Aggregate Production

Aggregate production in our economy is $Y_t = A_t z^A N_t^{\frac{1}{\theta-1}} L_t$, where term $N_t^{\frac{1}{\theta-1}}$ stems from the effect of more intermediate good varieties making final good production more efficient. The number of firms in the economy at period t is $N_t = \left(\frac{z_{min}}{\bar{z}_{t-1}} \right)^k N_{t-1} + N_{t-1}^E$, where the first term in the right hand side is the number of surviving firms from the period $t-1$ and the second term is the number of entrants. In our model, the number of firms represents the capital stock of the economy. It is a state variable that behaves much like physical capital in the standard business cycle model, but it has endogenously fluctuating depreciation and dividend rates.

Ghironi and Melitz (2005) show that if productivities are Pareto distributed, the average productivity of intermediate good firms is

$$z^A = \left[\frac{k}{k-\theta+1} z_{min}^{\theta-1}\right]^{\frac{1}{\theta-1}}. \tag{16}$$

Similarly, the average productivities of surviving and defaulting firms are

$$z_t^{SA} = \left[\frac{k}{k-\theta+1} \bar{z}_t^{\theta-1}\right]^{\frac{1}{\theta-1}} \quad \text{and}$$

$$z_t^{DA} = \left[\frac{k}{k-\theta+1} z_{min}^{k} \left(z_{min}^{\theta-1-k} - \bar{z}_t^{\theta-1-k}\right)\right]^{\frac{1}{\theta-1}}.$$

3.6 Money Supply

The money supply M_t follows the process

$$M_t = M_{t-1} e^{\epsilon_t^M}, \tag{17}$$

where ϵ_t^M is an i.i.d. shock. Thus, in our model, money supply is a random walk process.

4 The Response to Macroeconomic Shocks

4.1 Solution Method and Parameterization

We log-linearize the model around its steady state and solve it using the method of undetermined coefficients (see e.g., Uhlig (1995)).[7] The period in our model is a quarter. We set the discount factor β to be 0.99, which is a standard choice for quarterly business cycle models. Mankiw and Summers (1986) estimate the consumption elasticity of money demand $\frac{1}{\sigma}$ to be near 1. Thus, we set $\sigma = 1$. We set the labor supply elasticity ϕ equal to 2. We also tried other values for ϕ, but the exact value of the labor supply elasticity does not affect our main results. We set the parameter χ such that the steady state value of labor supply is one, and we follow earlier studies on firm entry (e.g., Lewis (2006) and Bilbiie et al. (2007b)) in setting the entry cost f^E equal to 1.

Bernard et al. (2003) calibrate the elasticity of substitution θ to fit U.S. plant and macro trade data. We follow them in setting $\theta = 3.8$. We assume the distribution parameters k and z_{min} to be equal to 6 and 1, respectively. We set the fixed cost f^F such that in the steady state, 10 percent of jobs are destroyed per year, implying $f^F = 0.067$.[8] This value matches the empirical job destruction rate in the United States.[9] In the steady state 4.6 percent of all firms default every period.

[7]The steady state and the log-linearized equations are reported in the appendix.
[8]The exact values of k and f^F do not have significant impact on our main results.
[9]In our model, all job destruction is induced by firm defaults.

4.2 Impulse Responses to a Money Supply Shock

Figure 3 plots impulse responses to an unanticipated 1 percent contractionary shock to nominal money supply. The vertical axes measure percentage deviations from the steady state. In the standard model with endogenous firm entry and nominal debt contracts, a monetary shock does not have any real effects on the economy, as prices and wages are flexible. A decrease in the nominal money supply would induce deflation, and real money holdings would stay constant. Deflation would increase the real value of firm debt and decrease real profits, but this would be compensated by a higher return on bonds. Therefore, monetary shocks do not have any effect on a household's assets or welfare.

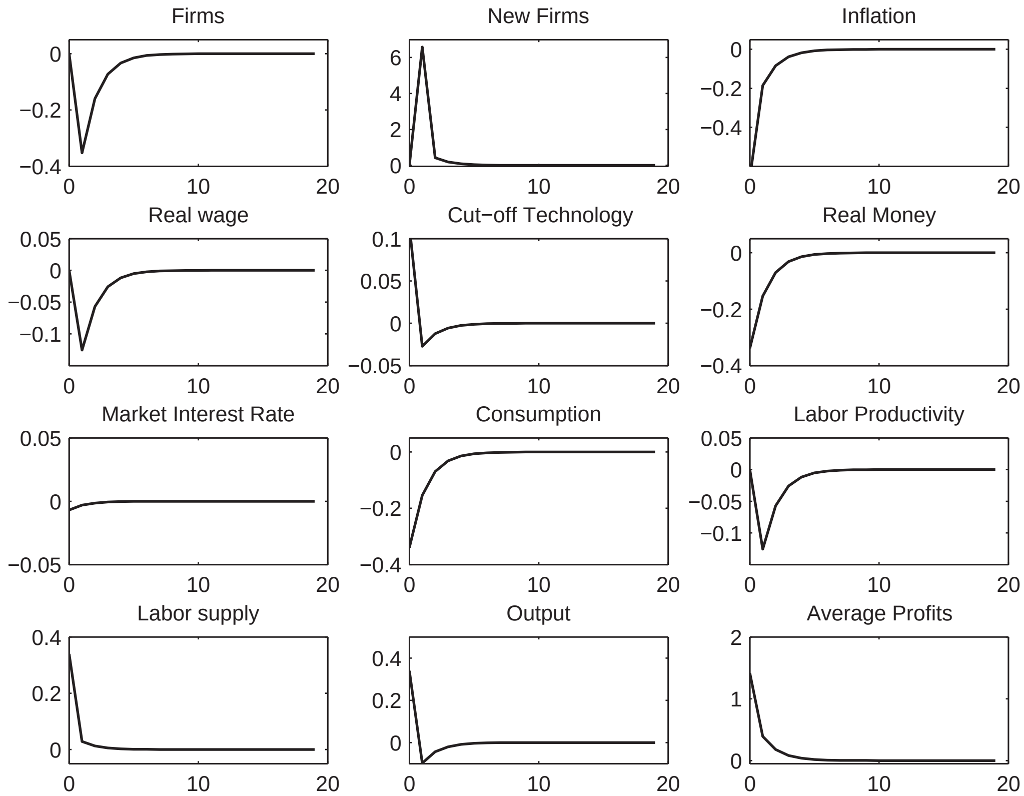

Figure 3: Impulse responses to a 1 percent negative and non-persistent monetary policy shock.

Contrary to the standard model, when firm exit is endogenous monetary shocks have important effects on the real economy, even if prices and wages are flexible. A contractionary monetary shock generates deflation, which raises the real value of nominal debt contracts between banks and firms. Therefore, more firms default on the repayment of their liabilities. This response is manifested as an increase in the variable cut-off technology ($\bar{z}_t$) in the impulse responses of Figure 3. Most importantly a contractionary money supply shock leads to a decrease in consumption. This response occurs for two reasons. First, a larger fraction of firms default, and the number of firms in the economy decreases. This decrease has a negative impact on labor productivity, which, in turn, has a negative effect on output.[10] A monetary policy shock therefore affects the measured productivity and causes persistent changes in labor productivity. A second and, in the short run, more important effect on consumption comes from the increased investments in new firms. The profits of surviving firms increase after the defaults, and, therefore, households are more willing to invest in new firms. This increases total output and decreases consumption because more resources are used for investments in the new firms.

Overall, our results imply that endogenous firm exit creates a new channel for monetary policy. An unanticipated contractionary monetary shock destroys part of the firm stock and decreases consumption and increases labor supply. Therefore, this shock has more severe negative effects on welfare when firm exit rate is endogenous. This effect exists, even if there are flexible prices and wages as debt contracts are written in nominal terms.

4.3 Impulse Responses to a Technology Shock

In this section, we consider how technology shocks affect firm dynamics and how the response in the number of producers affects the economy. First, we compare the effects of endogenous entry on the business cycle dynamics to the effects of endogenous exit. Then, we combine these two channels for firm dynamics and present the impulse responses to a technology shock for the case where both firm entry and exit are endogenous.

In Figure 4, we compare the impulse responses of the standard model with endogenous entry but constant exit rate with those from a model with endogenous firm exit and constant firm entry when both models are subject to a negative i.i.d. technology shock. The dashed lines designate the impulse responses of the standard model where firm entry is endogenous but the exit rate is constant. The solid lines, in turn, indicate the response of the model, where all changes in firm dynamics occur due to changes in firm exit rates. The standard model is reparameterized such that the initial response of the number of producers is the same in the two models. This is achieved by assuming a lower fixed cost for the standard model.

A negative technology shock decreases labor productivity and output. In the standard model, households smooth consumption by decreasing investments in the new firms. In the model where only firm exit is endogenous consumption smoothing is not possible but a decrease in the firm stock occurs due to increased firm defaults. Similarly to the monetary policy shock, this forces households to supply more labor and decrease consumption. Therefore, negative technology shocks have more severe effects on welfare when only firm exit is endogenous than when only firm entry is endogenous. Thus, the dynamic response of consumption and labor supply depend on whether endogenous change in the number of producers is due to decreased entry or increased exit. In particular, household welfare varies dramatically between two models. In the exit model, household welfare is lower

[10]According to the Dixit-Stiglitz production technology, a lower number of firms implies that the economy is less productive in producing final goods. This trend is manifested in decreasing productivity of a labor unit, which can be interpreted in our model as total factor productivity.

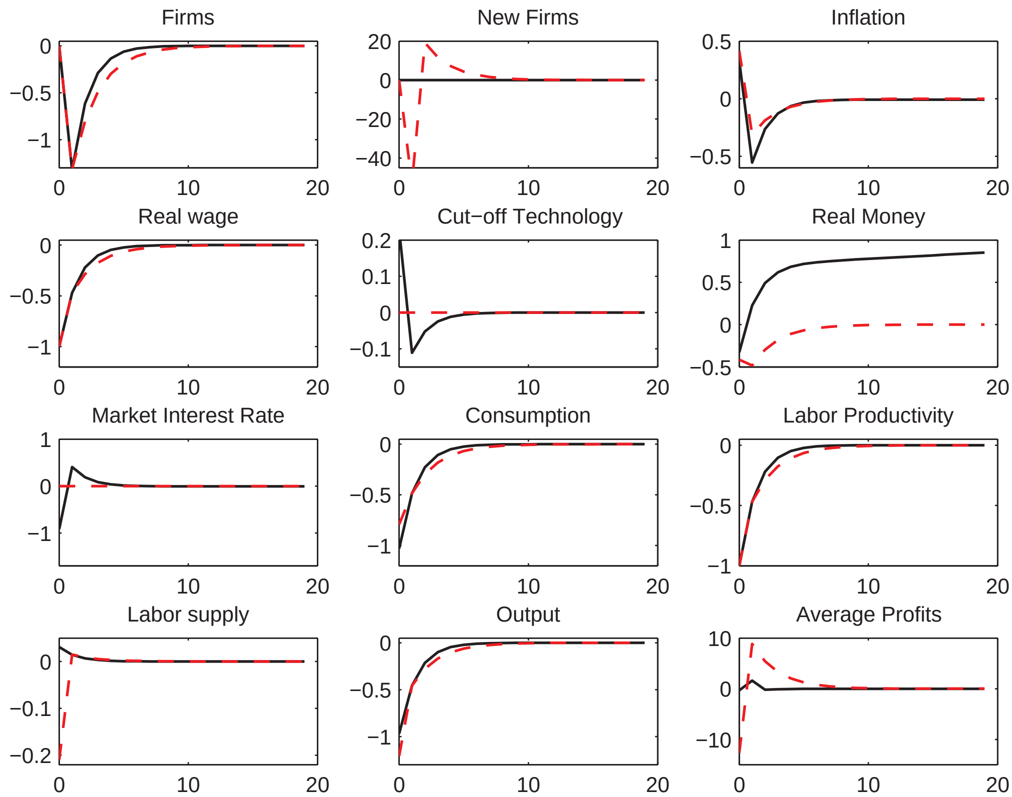

Figure 4: Impulse responses to a 1 percent negative and non-persistent technology shock for the model with endogenous exit (black solid line) and for the model with endogenous entry (red dashed line).

because households consume less and work more than in the case where firm entry is the sole channel influencing firm dynamics.

In Figure 5, we plot the effects of a negative i.i.d. technology shock in our benchmark model, one where both firm entry and exit are endogenous. These responses are the combination of the two impulse responses discussed above. Because firm entry is now endogenous, households smooth consumption. However, they decrease investments in new firms much less than in the case where the exit rate is constant. The productivity and profits of firms decrease due to the negative shock. Therefore, more firms default, and there is still a sizeable decrease in the number of firms.

Because the non-persistent shock causes a sluggish response of the firm stock, it has persistent effects on labor productivity. In all three model specifications studied in this subsection, the number of firms in the economy decreases after a negative productivity shock. Dixit-Stiglitz production technology implies that this persistent response has a direct negative and persistent effect on labor productivity. Thus firm dynamics can generate persistent responses of labor productivity to non-persistent technology shocks. This issue is discussed in more detail in the next section.

Part of the measured persistence of shocks can be due to the sluggish response in the number of firms. Whether this persistence is due to decreased entry or increased exit, it

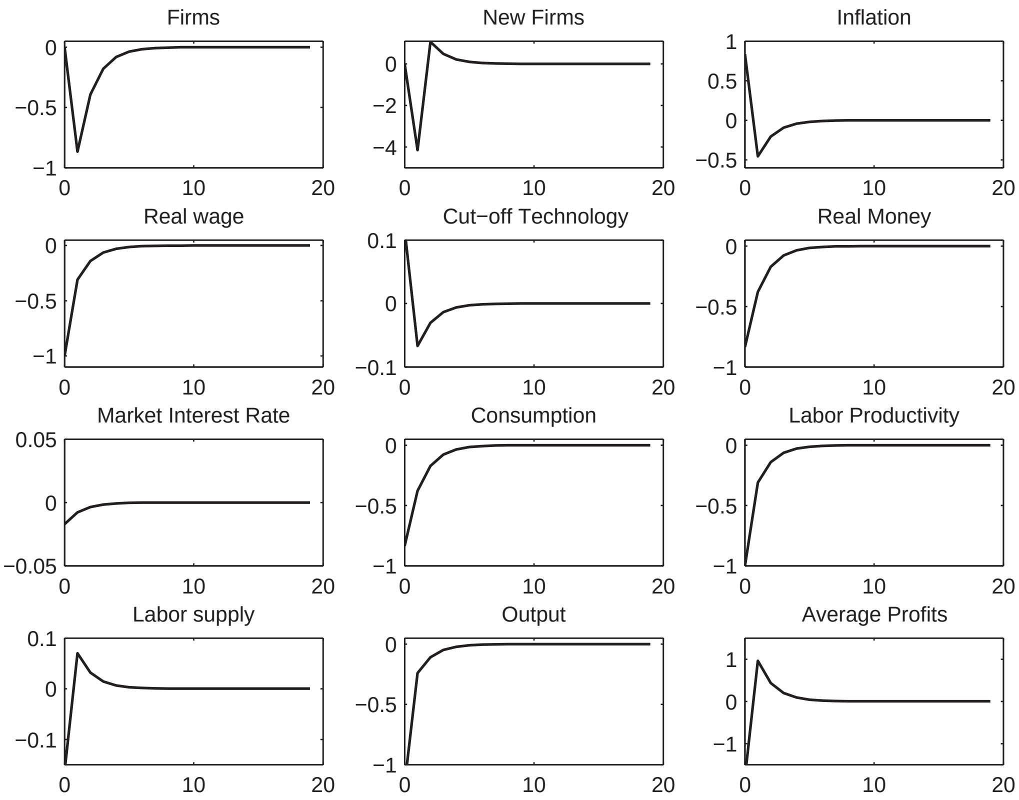

Figure 5: Impulse responses to a 1 percent negative and non-persistent technology shock.

affects household behavior and the response of other variables. Thus, whether changes in the number of firms occur due to entry or exit can have important effects on welfare.

4.4 The Effects of Shocks on Labor Productivity

In this section, we compute the degree of persistence in labor productivity generated by technology and money supply shocks. In the previous sections, we showed that monetary shocks affect productivity and that i.i.d. technology shocks have long-lasting effects on labor productivity.

The business cycle literature has found shocks to the total factor productivity to be persistent. Prescott (1986) estimates the autoregressive parameter ρ to be 0.90, and, more recently, Schmitt-Grohe and Uribe (2005) calibrate it to be 0.8556. In our model, part of the persistence in labor productivity is an endogenous reaction to the shock. In Figure 6, we plot the response of labor productivity to monetary and technological shocks with two different values for ρ: $\rho = 0$ and $\rho = 0.7$. A money supply shock has small but persistent effects on labor productivity, which indicates that the effects of monetary policy shocks last a long time, even if prices and wages are flexible. This response is absent in the model with a constant exit rate. Thus, when firm exit is endogenous, monetary shocks can affect productivity. This channel suggests two new ways of thinking about labor productivity. First, shocks that are measured as technological shocks can

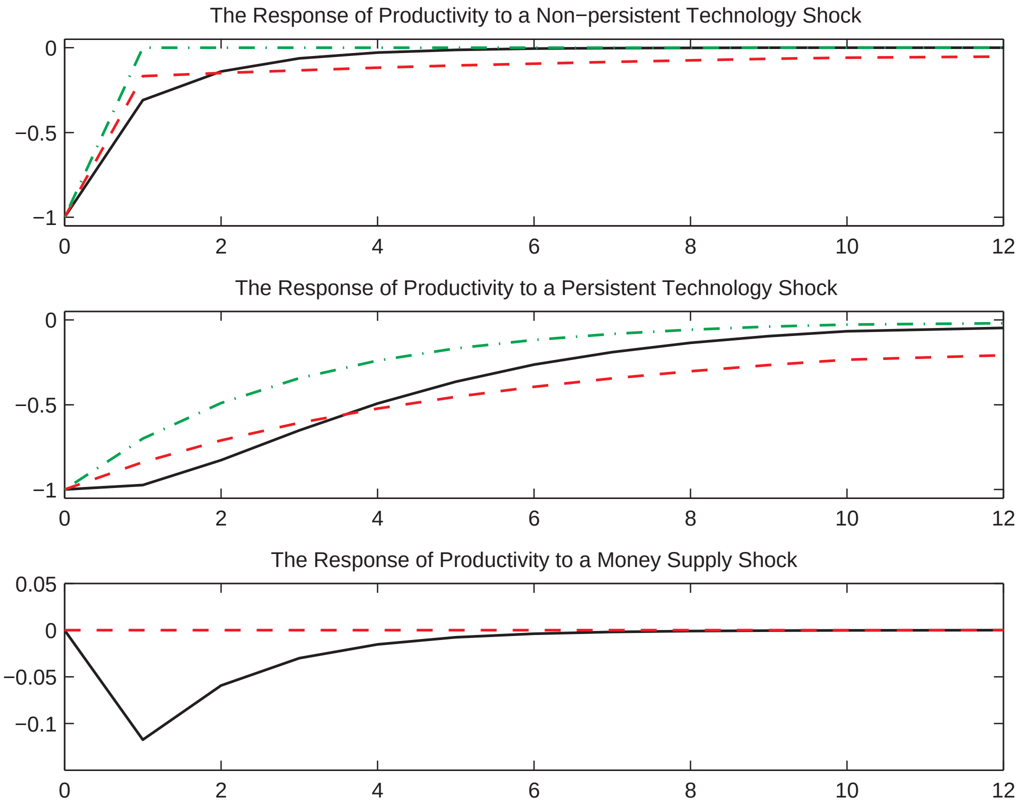

Figure 6: Impulse responses of productivity to technology shocks, $\rho = 0$ and $\rho = 0.7$, and to a money supply shock for models with endogenous entry (red dashed line) and endogenous entry and exit (black solid line). The green dashed lines with dots show the original productivity shocks.

in reality be the result of endogenous response to other shocks - monetary shocks, for example. Second, monetary policy has a potentially important role to play in preventing firm defaults caused by other macroeconomic shocks.

The responses to technology shocks show that an endogenous response of the number of firms brings significant persistence to labor productivity. Firm dynamics cause this effect irrespective of whether the dynamics are caused by endogenous entry or exit.

Our results show that a significant part of the measured movements in labor productivity can be due to the endogenous response of the economy and the number of producers. Therefore, if we measure technology shocks using the model with firm dynamics, we obtain less persistent shocks than in the traditional model. Jaimovich and Floetotto (2008) decompose variations in total factor productivity (TFP) into those originating from exogenous shocks and those originating from the endogenous response of firm entry and exit. They find that around 40 percent of the movements in measured TFP can be attributed to firm dynamics. However, they do not analyze the effects of the firm dynamics on the persistence of measured TFP.

5 Optimal Fiscal Policy

In this section, we study fiscal policy that maximizes social welfare and implements the Pareto optimal planning equilibrium as a competitive equilibrium. Bilbiie et al. (2008) show that when the firm exit rate and labor supply are constant, the market equilibrium is Pareto optimal and there is no role for fiscal policy (if households have Dixit-Stiglitz preferences regarding varieties).[11] In our model, firm defaults occur partly due to a moral hazard problem connected to the repayment of debt. Due to this problem banks force firms which default on repayment into bankruptcy, even if their expected future profits are positive. Because the exit rate is endogenous, fiscal policy can affect the size of this problem by subsidizing firms. Thus, the social planner has the possibility of controlling the number of defaulting firms and the number of producing firms in the economy. In addition, there is monopolistic competition, which generates markups over marginal costs in the production of intermediate goods. These markups result in a wedge between marginal rate of substitution across consumption and leisure, and distort labor supply. As Bilbiie et al. (2008) show, in this case efficiency can be restored by subsidizing labor supply by the amount $\tau^L = 1/(\theta - 1)$, which aligns markups across consumption goods and leisure. We study the optimal subsidy for firms when lump-sum taxes are available to finance fiscal policy and compare this Ramsey optimal equilibrium to the equilibrium where only labor supply is subsidized.

We study a policy that subsidizes firms at the rate τ^F to cover their fixed costs, and this subsidy is fully financed by lump-sum taxes on consumers. Thus, the profits for firm ω are

$$d_t^S(\omega) = \left(p_t(\omega) - \frac{w_t}{A_t z_z(\omega)} \right) y_t(\omega) - R_{t-1}^m P_{t-1} f^F (1 - \tau^F). \tag{18}$$

This subsidy can be thought of as an investment subsidy that is paid only to the firms that survive to the next period. Accordingly, firms that go bankrupt are not subsidized. Labor supply is also subsidized to align markups across consumption and leisure, and this subsidy is also financed through lump-sum taxes. Thus, the government balanced budget constraint is

$$T_t = \tau^L L_t w_t P_t + \tau^F R_{t-1}^m P_{t-1} f^F \left(\frac{z_{min}}{\bar{z}_t} \right)^k N_t. \tag{19}$$

Increasing the subsidy τ^F reduces fixed costs for the firms and results in fewer bankruptcies. This reduces the cut-off level of productivity, $\bar{z}_t$. Lower exit rates increase the expected return from the investments made in the entrants and stimulates investments in new firms. Therefore, the subsidy increases the number of firms in the market.

We identify the optimal fiscal policy as the time-invariant Ramsey optimal allocation,

[11] In our model Ramsey optimal equilibrium is Pareto optimal.

Model	τ^F	$\bar{z}$	N	C	L	λ
Benchmark	0.000	1.008	4.566	1.636	1.000	0.122
Ramsey optimal	0.273	1.005	7.668	1.911	1.030	

Table 1: The effects of optimal firm subsidy on the equilibrium and welfare.

where the social planner maximizes[12]

$$V_t = E_t \left[\sum_{s=t}^{\infty} \beta^{s-t} \left(lnC_{j,s} - \chi \frac{L_{j,s}^{1+\frac{1}{\phi}}}{1+\frac{1}{\phi}} \right) \right]. \tag{20}$$

We solve the Ramsey optimal allocation by using the methodology and code of Schmitt-Grohe and Uribe (2004, 2007).

Table 1 compares the Ramsey optimal equilibrium to the equilibrium where firms are not subsidized. The results reported in Table 1 indicate that it is optimal to subsidize firms and reduce exit rates. Bilbiie et al. (2008) show that for Dixit-Stiglitz preferences, markups and the social benefits from new firms are aligned and the competitive and planner equilibrium are equivalent. Contrary to this, in our model there is a moral hazard problem in the banking sector that generates firm defaults. The social planner achieves significant welfare improvements by using policy instruments to remove the inefficiency. That said, the optimal cut-off productivity level $\bar{z}$ still stays above one, optimal fiscal policy thus does not prevent all defaults. A decrease in the default rates induces households to invest more; therefore, the number of firms in the economy is higher in the Ramsey optimal equilibrium than in the equilibrium in which firms are not subsidized. As a result output, consumption and labor supply increase as there are more firms in the economy. In the last column of Table 1, we report the welfare measure λ, which measures the percentage increase in consumption households in the benchmark economy would need in order to reach the same welfare as in the Ramsey optimal equilibrium. In our model economy, the optimal subsidy generates significant welfare gains corresponding to a 12 percent increase in consumption.

6 Conclusions

Most dynamic general equilibrium models assume a constant stock of firms and ignore firm dynamics. However, the data show strong co-movement of both firm entry and exit: entry is procyclical while exit is countercyclical. Earlier studies have modeled the variability of the number of producers by assuming endogenous firm entry. They have ignored, however, the effects of endogenous exit rates on the economy. In this paper, we present a model in which entry and exit endogenously react to changes in the macroeconomy. We show that the endogenous reaction of exit increases the effects of

[12] Note that we assume that welfare from real cash holdings is minimal and that the social planner ignores these holdings.

negative productivity shocks. Endogenous exit also creates a new channel for monetary policy. Deflation caused by a negative money supply shock increases the real value of debt. Thus, more firms default and contractionary monetary shocks have a negative effect on the economy even if prices and wages are fully flexible.

We also show that endogenous firm exit creates a new role for economic policy to increase efficiency and welfare. Bilbiie et al. (2008) show that in the case of a constant exit rate, competitive equilibrium is efficient (when households have Dixit-Stiglitz preferences). Thus, there is no role for fiscal policy. Contrary to their findings, in our model, firm defaults exist due to a moral hazard problem between banks and firms. Banks cannot observe the financial situation of their debtors. Thus, they force firms into bankruptcy. However, a social planner has the ability to affect exit rates. By subsidizing firms, the social planner can decrease the rate of defaults, increase the investments in the firms and increase the number of producers in the economy. We find that the optimal fiscal policy subsidizes firms and decreases the number of bankruptcies in the economy.

Finally, we show that endogenous firm dynamics affects the interpration of observed movements in labor productivity. In the business cycle literature, labor productivity (or total factor productivity) has been observed to be subject to persistent disturbances. These disturbances are often supposed to occur because of persistent exogenous shocks. In our model, non-persistent monetary and technological shocks affect the firm default rate and firm entry, causing persistent movements in the number of firms producing in the economy. This, in turn, affects the ability of labor to produce final goods (i.e., labor productivity) and causes persistent movements also in labor productivity. These results indicate that some of the observed movements in the productivity may occur due to the endogenous response of the economy and the number of firms to different shocks.

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A APPENDIX Steady State Conditions

We assume that there is no inflation in the steady state. All the variables but money holdings M are expressed in real terms.

$$N = \frac{N^E}{1 - \left(\frac{z_{min}}{\bar{z}}\right)^k}$$

$$B = f^F N$$

$$v^E = f^E$$

$$\bar{p} = \frac{\theta}{\theta - 1} \frac{w}{A\bar{z}}$$

$$R^m = \frac{1}{\theta - 1} \frac{w}{A\bar{z}} \frac{\bar{y}}{f^F}$$

$$\bar{y} = \bar{p}^{-\theta} Y$$

$$Y = C + f^E N^E + f^F N$$

$$Y = Az^A N^{\frac{1}{\theta - 1}} L$$

$$\left(\frac{M}{P}\right)^{-\sigma} = \frac{R}{R-1} C$$

$$\frac{M}{P} = q$$

$$d^S = \theta^{-\theta} \left(\frac{w}{(\theta - 1)\, Az^{HA}}\right)^{1-\theta} Y - R^m f^F$$

$$d^F = \theta^{-\theta} \left(\frac{w}{(\theta - 1)\, Az^{LA}}\right)^{1-\theta} Y$$

$$p = N^{\frac{1}{1-\theta}}$$

$$d^S = \frac{1 - \beta \left(\frac{z_{min}}{\bar{z}}\right)^k}{\beta \left(\frac{z_{min}}{\bar{z}}\right)^k} v^S$$

$$\chi L^{\frac{1}{\phi}} = \frac{w}{C}$$

$$R = \frac{1}{\beta}$$

$$v^E = v^S$$

$$RB = R^m B \left(\frac{z_{min}}{\bar{z}}\right)^k + \left(1 - \left(\frac{z_{min}}{\bar{z}}\right)^k\right) N d^F$$

Here bar over variables denotes the value for the cut-off firm and q is the real money holdings.

B APPENDIX Log-Linearized Equations

All the other variables but price and wage inflations and interest rates are expressed in real terms.

$$\hat{N}_t - \left(\frac{z_{min}}{\bar{z}}\right)^k \hat{N}_{t-1} - \left(1 - \left(\frac{z_{min}}{\bar{z}}\right)^k\right) \hat{N}^E_{t-1} + k \left(\frac{z_{min}}{\bar{z}}\right)^k N\hat{\bar{z}}_t = 0$$

$$B\hat{B}_t - f^F N^E \hat{N}^E_t - f^F \left(\frac{z_{min}}{\bar{z}}\right)^k N\hat{N}_t + kf^F \left(\frac{z_{min}}{\bar{z}}\right)^k N\hat{\bar{z}}_t = 0$$

$$\hat{v}^E_t = 0$$

$$\hat{\bar{p}}_t - \hat{w}_t + \hat{A}_t + \hat{\bar{z}}_t = 0$$

$$\hat{R}^m_{t-1} - \hat{w}_t - \hat{\pi}_t + \hat{A}_t + \hat{\bar{z}}_t - \hat{\bar{y}}_t = 0$$

$$\hat{\bar{y}}^F_t + \theta\hat{\bar{p}}^F_t - \hat{Y}_t = 0$$

$$Y\hat{Y}_t - C\hat{C}_t - f^E N^E \hat{N}^E_t - f^F N^E \hat{N}^E_t - f^F \left(\frac{z_{min}}{\bar{z}}\right)^k N\hat{N}_t = 0$$

$$\hat{Y}_t - \hat{A}_t + \frac{1}{\theta - 1}\hat{N}_t - \hat{L}_t = 0$$

$$\hat{\pi}_t - \hat{\pi}^w_t + \hat{w}_t - \hat{L}_t = 0$$

$$\sigma\hat{q}_t - \hat{C}_t + \frac{1}{R-1}\hat{R}_t = 0$$

$$\hat{q}_t - \hat{q}_{t-1} + \hat{\pi}_t + \epsilon^M_t = 0$$

$$\hat{\pi}_t - \frac{1}{1-\theta}\left(\hat{N}_t - \hat{N}_{t-1}\right) - \hat{\pi}^w_t + \hat{A}_t - \hat{A}_{t-1} = 0$$

$$v^S\hat{v}^S_t - v^S\hat{C}_t + v^S\hat{C}_{t+1} + kv^S v^S \hat{z}_{t+1} - \beta\left(\frac{z_{min}}{\bar{z}}\right)^k v^S \hat{v^S}_{t+1} - \beta\left(\frac{z_{min}}{\bar{z}}\right)^k d^S \hat{d^S}_{t+1} = 0$$

$$\frac{1}{\phi}\hat{L}_t - \hat{w}_t + \hat{C}_t = 0$$

$$\hat{C}_{t+1} - \hat{C}_t - \hat{R}_t + \hat{\pi}_{t+1} = 0$$

$$\hat{v}_t^E - \hat{v}_t^S = 0$$

$$d^S \hat{d}_t^S - \theta^{-\theta} \left(\frac{w}{A(\theta-1)(\frac{k}{k-\theta+1}\bar{z}^{\theta-1})^{\frac{1}{\theta-1}}} \right)^{1-\theta} Y\hat{Y}_t - R^m f^F \hat{\pi} t -$$
$$\theta^{-\theta}(1-\theta) \left(\frac{w}{A(\theta-1)(\frac{k}{k-\theta+1}\bar{z}^{\theta-1})^{\frac{1}{\theta-1}}} \right)^{1-\theta} Y\hat{w}_t + R^m f^F \hat{R}_{t-1}^m +$$
$$\theta^{-\theta}(1-\theta) \left(\frac{w}{A(\theta-1)(\frac{k}{k-\theta+1}\bar{z}^{\theta-1})^{\frac{1}{\theta-1}}} \right)^{1-\theta} Y\hat{\bar{z}}_t +$$
$$\theta^{-\theta}(1-\theta) \left(\frac{w}{A(\theta-1)(\frac{k}{k-\theta+1}\bar{z}^{\theta-1})^{\frac{1}{\theta-1}}} \right)^{1-\theta} Y\hat{A}_t = 0$$

$$d^F \hat{d^F}_t - d^F \hat{C}_t - (1-\theta) d^F \hat{w}_t + (1-\theta) d^F \hat{A}_t -$$
$$\theta^{-\theta} \left(\frac{w}{\theta-1} \right)^{\frac{1}{1-\theta}} Y \left[\frac{k}{k-\theta+1} z_{min}^k \frac{\left(z_{min}^{\theta-1-k} - \bar{z}^{\theta-1-k} \right) \left(\frac{z_{min}}{\bar{z}} \right)^k}{\left(1 - \left(\frac{z_{min}}{\bar{z}} \right)^k \right)^2} - \frac{k z_{min}^k \bar{z}^{\theta-1-k}}{1 - \left(\frac{z_{min}}{\bar{z}} \right)^k} \right] \hat{\bar{z}}_t = 0$$

$$R\hat{R}_t - R^m \left(\frac{z_{min}}{\bar{z}} \right)^k \hat{R}_t^m + kR^m \left(\frac{z_{min}}{\bar{z}} \right)^k \hat{\bar{z}}_{t+1} - \left(1 - \left(\frac{z_{min}}{\bar{z}} \right)^k \right) \frac{Nd^F}{B} \hat{d}_{t+1}^F -$$
$$\frac{Nd^F}{B} k \left(\frac{z_{min}}{\bar{z}} \right)^k \hat{\bar{z}}_{t+1} + \frac{Nd^f}{B} \left(1 - \left(\frac{z_{min}}{\bar{z}} \right)^k \right) \hat{B}_t - \frac{N^E d^f}{B} \left(1 - \left(\frac{z_{min}}{\bar{z}} \right)^k \right) \hat{N}_t^E -$$
$$\left(\frac{z_{min}}{\bar{z}} \right)^k \frac{Nd^f}{B} \left(1 - \left(\frac{z_{min}}{\bar{z}} \right)^k \right) \hat{N}_t + k \left(\frac{z_{min}}{\bar{z}} \right)^k \frac{Nd^f}{B} \left(1 - \left(\frac{z_{min}}{\bar{z}} \right)^k \right) \hat{\bar{z}}_t -$$
$$\frac{Nd^f}{B} \left(1 - \left(\frac{z_{min}}{\bar{z}} \right)^k \right) \hat{\pi}_{t+1} = 0$$

Here, hat and bar over variables denote percentage deviations from the steady state and the value of variable for the cut-off firm. In addition, π and π^w denote price and wage inflations, and q denotes real money holdings $\frac{M}{P}$.

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