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A DSGE Model with Endogenous Entry and Exit

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Abstract

This paper describes a DSGE model where the extensive margin of activity –the number of varieties available for consumption–, depends on micro-founded decisions of entry and exit in the goods market. Both the extended model and a more conventional version have been estimated with US data during the Great Moderation period. Our main findings are two. First, the role of technology shocks for business cycle fluctuations increases significantly due to the flows of entry and exit. Second, the extensive margin of activity explains most of the business cycle reactions to supply-side shocks, whereas the intensive margin (firm-level output) takes most of the adjustment after demand-side shocks.

Key words: entry and exit, DSGE models, US business cycles.

JEL codes: E20, E32.

1 Introduction

The role of entry and exit in the goods market may be crucial to understand short-run economic fluctuations. A substantial fraction of economic activity is driven from the processes of good creation and destruction. Bernard, Redding, and Schott (2010) find that over a five-year period, new products (developed by either incumbents or new firms) represent 46.6% of Gross Domestic Product (GDP) in the US, whereas the value of good destruction represents 44% of that GDP.

Flows of entry and exit bring in the extensive margin of output fluctuations, usually missed in Dynamic Stochastic General Equilibrium (DSGE) models. The scientific literature that has looked into such

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extensive margin can be organized in two main strands. A first series of papers such as Hopenhayn (1992), Campbell (1998), Cooley, Marimón and Quadrini (2004), Samaniego (2008), and Clementi and Palazzo (2013) discuss the variability in the number of firms as an important propagation mechanism for business cycles. Another group of papers, exemplified by Bilbiee, Ghironi and Melitz (2012), Lewis and Poilly (2012), and Lewis and Stevens (2013) show that the preferences and evolution in the menu of goods available for consumption matter to analyze short-run output fluctuations.

Bilbiee *et al.* (2012) is probably the most influential paper of this recent literature. It provides a flexible-price framework for modelling the dynamics of entry and exit, with the assumption that the number of firms is equal to the number of goods.[1] The representative firm operates in a single production line. The free entry condition implies that equity value must be equal to the cost of entry. Meanwhile, exit is determined by an exogenous and constant death rate applied to the total number of goods. Recently, Lewis and Polilly (2012), and Lewis and Stevens (2013) incorporate one productive sector for the creation of new goods in a DSGE model. The decision to create new goods is based on the comparison between the prospective equity value and the cost of producing one additional entry.

This paper brings theoretical and empirical contributions. On the theoretical ground, we introduce an original approach that assumes firm-specific productivity and endogenous exit decisions. Incumbent firms with poor productivity will exit when the expected stream of future dividends is lower than the liquidation value. In this setting, we derive an endogenous exit rate as an inverse function of the productivity cutoff level. This productivity threshold is determined, in a forward-looking fashion, that anticipates real marginal costs and total demand. In turn, the flow of exit depends positively on future expected real marginal costs and negatively on future expected aggregate demand.

On the empirical ground, we estimate both a benchmark DSGE model and the extended version with entry and exit using Bayesian econometrics and US quarterly data from the "Great Moderation" period. The results show a few differences in parameter estimates across models. Moreover, the impulse response functions and the variance decomposition indicate that the extensive margin of activity amplifies the effects of technology shocks. Finally, we show that demand shocks affect activity through adjustments in the intensive (firm-level) margin while supply-side shocks have a main impact on activity by means of changes in the extensive margin (number of varieties).

The rest of the paper is organized as follows. Section 2 presents the general features of the benchmark model with a special attention on the processes of goods creation and destruction. The benchmark DSGE model with a fixed number of goods is presented as a particular case of this general framework. Section 3 introduces the Bayesian estimation strategy and provides a comparison of the estimates of the structural parameters across models. Section 4 is devoted to the analysis of impulse response functions in order to examine the business cycle properties of the model with respect to the standard DSGE model. Section 5 reports business cycle statistics, analyses the variance decomposition of the two models, and evaluates

[1] Broda and Weinstein (2010) report that 92% of product creation occurs within existing firms.

the relative contribution of the intensive and extensive margins of activity. Section 6 concludes with a summary of the main findings of the paper.

2 A DSGE model with entry and exit

The model represents an economy populated by households, firms, and the public sector (government and central bank). There are markets for goods, labor, capital, bonds and equity shares. The number of varieties in the goods market changes over time as a result of flows of entry and exit of differentiated goods. Several sources of rigidities and frictions are assumed to enhance the empirical fit of the model following Christiano *et al.* (2005) or Smets and Wouters (2007). The set of real rigidities include consumption habits, adjustment costs on investment, variable capital utilization, and time-to-build delays. Regarding nominal rigidities, we consider adjustment costs for changes in both prices and wages.

2.1 Law of motion for the number of varieties

As in Bilbiie *et al.* (2012), each intermediate firm is specialized in the production of a specific good. At the beginning of a given period t there are n_t consumption goods. At the end of period t, the production lines of n_t^X goods shut down (exit), while the remaining n_t^A goods survive in the market, such that,

$$n_t = n_t^X + n_t^A. \tag{1}$$

In the meanwhile, n_t^E new goods are created during period t, though their lines of production will begin to operate in $t+1$. Following Lewis and Poilly (2012), new goods may not succeed to the time-to-build period. Hence, there is a $F_{n,t}(.)$ probability of successful entry, so that only $F_{n,t}(.)\, n_t^E$ new goods are effectively created (entry) during period t. At the beginning of period $t+1$, the number of goods is determined by applying the survival rate, $\frac{n_t^A}{n_t}$, to both the active lines of production in period t and the successfully created new goods. In formal terms, we have the following equation of motion for the total number of goods,

$$n_{t+1} = \frac{n_t^A}{n_t}\left(n_t + F_{n,t}(.)\, n_t^E\right). \tag{2}$$

In the referential setup of Bilbiie *et al.* (2012), it is assumed a constant rate of firm survival ($\frac{n_t^A}{n_t} = 1-\delta_n$, where δ_n is the constant death rate) and that goods creation is always successful ($F_{n,t}(.) = 1$).

2.2 Households

All households are identical and allocated across the unit interval. The preferences of the j representative household are defined by a utility function, separable between consumption bundles and (the disutility of) labor, which for period t reads

$$\frac{e^{\varepsilon_t^b}\left(c_t(j) - hc_{t-1}\right)^{1-\sigma_c}}{1-\sigma_c} - \Xi\frac{\left(l_t(j)\right)^{1+\sigma_l}}{1+\sigma_l},$$

where ε_t^b is a consumption preference (exogenous) shifter, $c_t(j)$ is number of bundles currently consumed, c_{t-1} is aggregate lagged consumption, $0 \leq h < 1$ is an external consumption habit parameter, $\sigma_c > 0$ is the risk aversion coefficient, $l_t(j)$ is the amount of labor supplied, $\sigma_l > 0$ is the curvature coefficient in disutility of labor, and $\Xi > 0$ is the coefficient of the weight of labor disutility in overall utility. A constant discount factor per period, $\beta < 1$, is used to bring future utility into present time.

The sources of household income are labor and capital earnings, equity return and the interest service of bonds. The representative household possesses market power to set the nominal wage $W_t(j)$ constrained by a labor demand schedule. Labor income is $\frac{W_t(j)}{P_t^c} l_t(j)$, where the real wage is measured in consumption bundles at the price index, P_t^c. There is a wage adjustment cost, $Wac_t(j)$ in terms of consumption bundles, that must be covered by the household. Capital income is $r_t^k u_t(j) k_{t-1}(j)$ where r_t^k is the market real rental rate, $u_t(j)$ is the variable capital utilization rate and $k_{t-1}(j)$ is the stock of capital installed in the previous period. Another source of income is equity ownership. Let $\widetilde{d}_t$ denote the average real dividend and $\widetilde{v}_t$ the average equity (real) value. The representative household gets $\widetilde{d}_t \frac{n_{t-1}^A}{n_{t-1}} x_{t-1}(j)$ as the total dividends from her previous-period share of portfolio investment $x_{t-1}(j)$, and $\frac{n_{t-1}^A}{n_{t-1}} \widetilde{d}_t F_{n,t-1}(.) n_{t-1}^E(j)$ from the successful entries at the end of their first period of life. There is also some revenue from business destruction, which corresponds to both the liquidation value of the exit share, $lv_t \frac{n_{t-1}^X}{n_{t-1}} x_{t-1}(j)$, where lv_t is the unit liquidation value, and the liquidation of new goods that shut down after the first period of life, $lv_t \frac{n_{t-1}^X}{n_{t-1}} F_{n,t-1}(.) n_{t-1}^E(j)$.

Income net of taxes payments t_t (expressed in consumption bundles), is spent on purchases of bundles of consumption goods, $c_t(j)$, on investment on capital goods, $i_t(j)$, on portfolio investment on incumbent firms, $\widetilde{v}_t \left(x_t(j) - \frac{n_{t-1}^A}{n_{t-1}} x_{t-1}(j) \right)$, on net purchases of government real bonds, $((1+r_t))^{-1} b_{t+1}(j) - b_t(j)$, (where r_t is the real rate of return, and $b_{t+1}(j)$ denotes the purchases of bonds in period t to be reimbursed in $t+1$), and on the total cost of entry, $f^E n_t^E(j)$, (where f^E is the unit real cost of the license for entry). In addition, there is some expenditure on covering the adjustment cost of variable capital utilization, $a(u_t(j))k_t(j)$ where $a()$ is the adjustment cost variable described in Smets and Wouters (2007). As a result, the budget constraint of the representative household in period t becomes,

$$\left[\frac{W_t(j)}{P_t^c} l_t(j) - Wac_t(j)\right] + r_t^k u_t(j) k_{t-1}(j) + \left[\frac{n_{t-1}^A}{n_{t-1}} \left(\widetilde{d}_t + \widetilde{v}_t\right) + \frac{n_{t-1}^X}{n_{t-1}} lv_t\right] \left(x_{t-1}(j) + F_{n,t-1}(.) n_{t-1}^E(j)\right) - t_t =$$
$$c_t(j) + i_t(j) + a(u_t(j))k_t(j) + \widetilde{v}_t x_t(j) + \frac{b_{t+1}(j)}{1+r_t} - b_t(j) + f^E n_t^E(j). \quad (3)$$

Capital accumulation is costly as in Smets and Wouters (2007). Thus, the equation of motion for capital is,

$$k_t(j) = (1-\delta_k) k_{t-1}(j) + e^{\varepsilon_t^i} \left[1 - S\left(\frac{i_t(j)}{i_{t-1}(j)}\right)\right] i_t(j), \quad (4)$$

where δ_k is the constant rate of capital depreciation rate, $S(.)$ is the investment adjustment cost function with the steady-state properties $S(.) = S'(.) = 0$ and $S''(.) = \varphi_k > 0$, and ε_t^i is an stochastic shock to the price of investment relative to consumption goods.

Following Rotemberg (1982), the adjustment cost of changing wages is defined by the quadratic cost function,

$$Wac_t(j) = \frac{\psi_w}{2e^{\varepsilon_t^w}} \left(\frac{W_t(j)}{W_{t-1}(j)} - \left[\lambda_w (1 + \pi_{t-1}^c) + (1 - \lambda_w) \right] \right)^2 \frac{W_t(j)}{P_t^c},$$

where π_{t-1}^c is the lagged rate of consumption price inflation ($\pi_{t-1}^c = \frac{P_{t-1}^c}{P_{t-2}^c} - 1$), and ε_t^w is a exogenous wage-push shock. There is wage indexation as in Ireland (2007) and Lewis and Stevens (2013), with $\lambda_w > 0$ representing the rate of indexation to past inflation.[2] For the natural-rate scenario with flexible wages, let $\psi_w = 0$. As wage setters, households face the labor demand constraint,

$$l_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\theta_w} l_t, \tag{5}$$

where $W_t = \left[\int_0^1 W_t(j)^{1-\theta_w} dj \right]^{\frac{1}{1-\theta_w}}$ and $l_t = \left[\int_0^1 l_t(j)^{\frac{\theta_w - 1}{\theta_w}} dj \right]^{\frac{\theta_w}{\theta_w - 1}}$ are respectively aggregate indices of nominal wages and labor with a constant elasticity of substitution $\theta_w > 0$. Hence, the optimizing program of the household consists of maximizing $E_t \sum_{j=0}^{\infty} \beta^j \left(\frac{e^{\varepsilon_{t+j}^b}}{1-\sigma_c} (c_{t+j}(j) - hc_{t-1+j})^{1-\sigma_c} - \frac{\Xi}{1+\sigma_l} (l_{t+j}(j))^{1+\sigma_l} \right)$ subject to the budget constraint (3), the capital accumulation constraint (4), and the labor demand constraint (5) for current period t and the expected expressions in all future periods. The first order conditions are computed with respect to the choice variables $c_t(j)$, $u_t(j)$, $k_t(j)$, $b_{t+1}(j)$, $W_t(j)$, $x_t(j)$, and $n_t^E(j)$. The consumption Euler equation is the standard expression,

$$\frac{e^{\varepsilon_t^b} (c_t(j) - hc_{t-1})^{-\sigma}}{1 + r_t} = \beta E_t e^{\varepsilon_{t+1}^b} (c_{t+1}(j) - hc_t)^{-\sigma}. \tag{6}$$

The representative household determines the nominal wage $W_t(j)$ as a mark-up over the marginal rate of substitution as follows,

$$\frac{W_t(j)}{P_t^c} = \frac{\theta_w}{(\theta_w - 1)} \frac{\Xi l_t(j)^\gamma}{(c_t(j) - hc_{t-1})^{-\sigma}} + \psi_w \frac{\Upsilon_t(j)}{l_t(j)},$$

where $\Upsilon_t(j)$ depends upon the sticky-wage Rotemberg (1982) pattern.[3] The equilibrium condition for equity investment is,

$$\widetilde{v}_t = \frac{1}{1 + r_t} \left[\frac{n_t^A}{n_t} E_t \left(\widetilde{d}_{t+1} + \widetilde{v}_{t+1} \right) + \frac{n_t^X}{n_t} E_t lv_{t+1} \right], \tag{7}$$

which implies that the average equity value is the discounted sum of the expected returns when surviving, $\frac{n_t^A}{n_t} E_t \left(\widetilde{d}_{t+1} + \widetilde{v}_{t+1} \right)$, and the expected return when dying, $\frac{n_t^X}{n_t} E_t lv_{t+1}$. Remarkably, the equilibrium equity value depends (positively) on the rate of business survival, $\frac{n_t^A}{n_t}$, as the weight for the return on surviving equity, and on the expected next-period liquidation value, $E_t lv_{t+1}$, as the anticipated return from the fraction of goods that shut down.

[2] We slightly depart from the analysis of Lewis and Stevens (2013) by defining the indexation rule in terms of consumption price inflation instead of producer price inflation, as real wages computed by households are defined in terms of the consumption price index.

[3] Specifically, $\Upsilon_t(j) = -\frac{1}{(\theta_w - 1)} \left(\frac{1}{e^{\varepsilon_t^w}} (\pi_t^w(j) - \lambda_w \pi_{t-1}^c)(1 + \pi_t^w(j)) w_t(j) \right)$
$-\frac{1}{2(\theta_w - 1)} \left(\frac{1}{e^{\varepsilon_t^w}} (\pi_t^w(j) - \lambda_w \pi_{t-1}^c)^2 w_t(j) \right)$
$+\beta E_t \left(\frac{1}{(\theta_w - 1)} \frac{(c_{t+1}(j) - hc_t)^{-\sigma}}{(c_t(j) - hc_{t-1})^{-\sigma}} \frac{1}{e^{\varepsilon_{t+1}^w}} ((\pi_{t+1}^w(j) - \lambda_w \pi_t^c)(1 + \pi_{t+1}^w(j))) w_{t+1}(j) \right).$

2.3 Firms

There are both intermediate-good and final-good firms in the goods market. Intermediate-good firms combine labor and capital within a production technology to supply heterogeneous consumption goods that are sold in a monopolistically competitive market to the final-good firm. Intermediate-good producers are price setters constrained by demand conditions and price adjustment costs. Entry and exit take place in the production of intermediate consumption goods. The final-good firm aggregates all the varieties of intermediate consumption goods to make them available as consumption bundles.

Intermediate-good firms

In period t, the intermediate firm of type ω produces a quantity $y_t(\omega)$ of this good using the Cobb-Douglas production function,

$$y_t(\omega) = e^{\varepsilon_t^a} z(\omega) k_t^{\alpha}(\omega) \left(e^{\gamma t} l_t(\omega)\right)^{1-\alpha}, \tag{8}$$

where $0 < \alpha < 1$ is the capital share parameter, $l_t(\omega)$ and $k_t(\omega)$ are respectively the demand for labor and capital at firm ω, ε_t^a is a labor-augmenting technology shock, $z(\omega)$ is a firm-specific productivity level, and γ is the long-run rate of economic growth. The shock ε_t^a is homogeneous to all firms. Nevertheless, there is firm heterogeneity determined by $z(\omega)$, which is an individual draw from the Pareto distribution characterized by its lower bound $z_{\min} > 0$ and the shape parameter $\kappa > (\theta_p - 1)$.[4]

Intermediate-good firms face adjustment costs on price changes that are determined according to a Rotemberg (1992) technology. The real cost $Pac_t(\omega)$ incurred by firm ω in adjusting her price in period t is,

$$Pac_t(\omega) = \frac{\psi_p}{2e^{\varepsilon_t^p}} \left(\frac{P_t(\omega)}{P_{t-1}(\omega)} - [\lambda_p(1+\pi_{t-1}) + (1-\lambda_p)]\right)^2 \frac{P_t(\omega)}{P_t} y_t(\omega), \tag{9}$$

where ψ_p is a scale parameter and ε_t^p is a price-push shock (i.e., a positive realization of ε_t^p reduces the cost of adjusting prices, thus inducing a stronger inflation pressure). In this expression, λ_p is the coefficient that measures the rate of indexation to past rate of inflation of intermediate goods, $\pi_{t-1} = (\widetilde{P}_{t-1}/\widetilde{P}_{t-2}) - 1$, where $\widetilde{P}$ is the average price set across the heterogeneous intermediate-good producers (to be defined below). If $\lambda_p = 0$, we get the original Rotemberg (1982) scheme.

Firms operate in a monopolistically competitive market as in Dixit and Stiglitz (1977). Hence, the amount of firm-specific output, $y_t(\omega)$, is demand-determined in response to its relative price $\frac{P_t(\omega)}{P_t^C}$ and to the aggregate demand for goods, y_t, as follows,

$$y_t(\omega) = \left(\frac{P_t(\omega)}{P_t^C}\right)^{-\theta_p} y_t, \tag{10}$$

[4] The probability distribution function and the cumulative distribution function of $z(\omega)$ are respectively $g(z(\omega)) = \kappa z_{\min}^{\kappa}/z(\omega)^{\kappa+1}$ and $G(z(\omega)) = 1 - (z_{\min}/z(\omega))^{\kappa}$. The shape parameter κ must be higher than $(\theta_p - 1)$ to have a well-defined average productivity.

where $\theta_p > 1$ is the constant elasticity of substitution across goods. Using (10) in the total revenue term, the real dividend of the representative firm becomes,

$$d_t(\omega) = \left(\frac{P_t(\omega)}{P_t^C}\right)^{1-\theta_p} y_t - w_t l_t(\omega) - r_t^k k_t(\omega) - Pac_t(\omega). \tag{11}$$

Let $\overline{\beta} = \beta \frac{n^A}{n}$ denote the deterministic discount factor that includes the steady-state survival rate, $\frac{n^A}{n}$. In period t, the firm seeks to maximize $E_t \sum_{j=0}^{\infty} \overline{\beta}^j d_{t+j}(\omega)$ subject to the expected schedule of Dixit-Stiglitz constraints,

$$e^{\varepsilon^a_{t+j}} z(\omega) k^{\alpha}_{t+j}(\omega) \left(e^{\gamma(t+j)} l_t(\omega)\right)^{1-\alpha} = \left(\frac{P_{t+j}(\omega)}{P^C_{t+j}}\right)^{-\theta_p} y_{t+j} \text{ for } j = 0, 1, 2, ...$$

Defining $mc_t(\omega)$ as the Lagrange multiplier of the demand constraint (real marginal cost of firm ω), the first order conditions are,

$$\begin{aligned}
(1-\theta_p)\left(\frac{P_t(\omega)}{P_t^C}\right)^{-\theta_p} \frac{y_t}{P_t^C} + mc_t(\omega)\theta_p\left(\frac{P_t(\omega)}{P_t^c}\right)^{-\theta_p-1}\frac{y_t}{P_t} - \frac{\partial Pac_t(\omega)}{\partial P_t(\omega)} - \overline{\beta} E_t \frac{\partial Pac_{t+1}(\omega)}{\partial P_t(\omega)} &= 0, \quad (P_t(\omega)) \\
-w_t + mc_t(\omega)\alpha\left(y_t(\omega)/l_t(\omega)\right) &= 0, \quad (l_t(\omega)) \\
-r_t^k + mc_t(\omega)(1-\alpha)\left(y_t(\omega)/k_t(\omega)\right) &= 0. \quad (k_t(\omega))
\end{aligned}$$

As shown in Lewis and Stevens (2013), the first order conditions imply an optimal pricing policy in which the relative price is set as a mark-up over the marginal cost of production,

$$\frac{P_t(\omega)}{P_t^C} = \mu_t(\omega) mc_t(\omega), \tag{12}$$

where the mark-up is computed in the following way,

$$\mu_t(\omega) = \frac{\theta_p}{(\theta_p - 1)\left(1 - \frac{\psi}{2e^{\varepsilon_t^p}}(\pi_t - \lambda_p \pi_{t-1})^2\right) + \frac{\psi}{e^{\varepsilon_t^p}}\Psi_t(\omega)}, \tag{13}$$

for a function $\Psi_t(\omega)$ that depends on the Rotemberg (1982)-type cost of price adjustment.[5]

Final-good firms

Final-good firms act as packers of intermediate goods and sell the final bundles of consumption goods at a flexible price. The representative final-good firm, indexed as i within the unit interval, produces bundles of consumption of type i in quantity $y_t(i)$ using the production technology that combines each of the n_t intermediate varieties as follows,

$$y_t(i) = \left[\int_0^{n_t} y_t(\omega)^{\frac{\theta_p - 1}{\theta_p}} d\omega\right]^{\frac{\theta_p}{\theta_p - 1}}, \tag{14}$$

where the elasticity of substitution of across intermediate goods in the aggregate production function (θ_p) is the same as the elasticity of substitution between individual goods in household consumption. Thus, the corresponding price of a consumption basket is obtained from the Dixit-Stiglitz aggregate,

$$P_t(i) = \left[\int_0^{n_t} P_t(\omega)^{1-\theta_p} d\omega\right]^{\frac{1}{1-\theta_p}}. \tag{15}$$

[5]Specifically, $\Psi_t(\omega) = (\pi_t - \lambda_p \pi_{t-1})(1+\pi_t) - E_t\left\{\beta\left((\pi_{t+1} - \lambda_p \pi_t)(1+\pi_{t+1})^2\left(\frac{P_t(\omega)}{P_{t+1}(\omega)}\right)\frac{y_{t+1}(\omega)}{y_t(\omega)}\right)\right\}$.

2.4 Entry and exit

As implied by the dynamic equations (1) and (2), the flows of good creation and destruction determines the total number of active goods, n_t, through the influence of both the effective number of good entries, n_t^E, and the effective number of exiting goods, n_t^X. Let us describe separately the endogenous determination of entry and exit.

Good creation (entry)

The decision to create a new good is based on the comparison between the prospective average equity value and the cost of entry. Following Lewis and Stevens (2013), there is a probability of successful entry, $F_{n,t}\left(n_t^E(j), n_{t-1}^E(j)\right) = 1 - S_n\left(\frac{n_t^E(j)}{n_{t-1}^E(j)}\right)$ where $S_n(.)$ is an increasing congestion cost function that determines the failure rate for prospective entrants with the steady-state properties $S_n(.) = S_n'(.) = 0$ and $S_n''(.) = \varphi_E > 0$. Recalling the household budget constraint (3), the optimality condition for the choice of $n_t^E(j)$ is,

$$\begin{aligned} &-\lambda_t f^E + \beta E_t \lambda_{t+1}\left[\frac{n_t^A}{n_t}E_t\left(\widetilde{d}_{t+1} + \widetilde{v}_{t+1}\right) + \frac{n_t^X}{n_t}E_t l v_{t+1}\right]\left[F_{n,t}(.) + \tfrac{\partial F_{n,t}(.)}{\partial n_t^E(j)} n_t^E(j)\right] \\ &\qquad + \beta^2 E_t \lambda_{t+2}\left[\frac{n_{t+1}^A}{n_{t+1}}E_t\left(\widetilde{d}_{t+2} + \widetilde{v}_{t+2}\right) + \frac{n_{t+1}^X}{n_{t+1}}E_t l v_{t+2}\right]\left[\tfrac{\partial F_{n,t+1}(.)}{\partial n_t^E(j)} n_{t+1}^E(j)\right] = 0, \end{aligned} \tag{16}$$

where λ_t is the Lagrange multiplier of the budget constraint in period t. The first order condition of bonds implies $\frac{\lambda_t}{1+r_t} = \beta E_t \lambda_{t+1}$, which can be used sequentially in (16) to get rid of the Lagrange multipliers and reach,

$$\begin{aligned} &-f^E + \tfrac{1}{1+r_t}\left[\frac{n_t^A}{n_t}E_t\left(\widetilde{d}_{t+1} + \widetilde{v}_{t+1}\right) + \frac{n_t^X}{n_t}E_t l v_{t+1}\right]\left[F_{n,t}(.) + \tfrac{\partial F_{n,t}(.)}{\partial n_t^E(j)} n_t^E(j)\right] \\ &\qquad + E_t \tfrac{1}{(1+r_t)(1+r_{t+1})}\left[\frac{n_{t+1}^A}{n_{t+1}}E_t\left(\widetilde{d}_{t+2} + \widetilde{v}_{t+2}\right) + \frac{n_{t+1}^X}{n_{t+1}}E_t l v_{t+2}\right]\left[\tfrac{\partial F_{n,t+1}(.)}{\partial n_t^E(j)} n_{t+1}^E(j)\right] = 0. \end{aligned} \tag{17}$$

Next, inserting in (17) both the first order condition on equity share (7) and its corresponding expression for $t+1$, we obtain the equilibrium condition,

$$f^E = \widetilde{v}_t\left[F_{n,t}(.) + \tfrac{\partial F_{n,t}(.)}{\partial n_t^E(j)} n_t^E(j)\right] + E_t \widetilde{v}_{t+1}\left[\tfrac{\partial F_{n,t+1}(.)}{\partial n_t^E(j)} n_{t+1}^E(j)\right]. \tag{18}$$

According to (18), entry of new varieties takes place until the marginal cost of entry (left side) is equal to the marginal revenue (right side). There are two terms that sum up for the marginal revenue of entry in (18). The first one picks up the value gain of the effective entry, $\widetilde{v}_t F_{n,t}(.)$, and the decrease in the probability of successful entries due to congestion, $\widetilde{v}_t \frac{\partial F_{n,t}(.)}{\partial n_t^E(j)} n_t^E(j)$ where it should be noticed that $\frac{\partial F_{n,t}(.)}{\partial n_t^E(j)} < 0$. The second term adds the increase in equity value due to a higher probability of successful entries for the next period, $E_t \widetilde{v}_{t+1}\left[\frac{\partial F_{n,t+1}(.)}{\partial n_t^E(j)} n_{t+1}^E(j)\right]$ where the partial derivative is in this case positive, $\frac{\partial F_{n,t+1}(.)}{\partial n_t^E(j)} > 0$.

Introducing the standard hat-shape label to refer to the log deviation with respect to the detrended steady-state level, the log-linearized version of (18) in the symmetric equilibrium across households is[6],

$$\widehat{n}_t^E = \frac{1}{\left(1+\overline{\overline{\beta}}\right)}\widehat{n}_{t-1}^E + \frac{\overline{\overline{\beta}}}{\left(1+\overline{\overline{\beta}}\right)}E_t\widehat{n}_{t+1}^E + \frac{1}{\varphi_E\left(1+\overline{\overline{\beta}}\right)}\widehat{\widehat{v}}_t, \tag{19}$$

where $\overline{\overline{\beta}} = \overline{\beta}(1+\gamma)^{(1-\sigma_c)}$ is the discount factor in the balanced-growth steady state. Entry follows a slow-adjustment reaction to the prospective average equity. The dynamics of entry combines backward-looking and forward-looking patterns. Households decide to spend on the creation of a new goods when they observe a positive value of $\widehat{\widehat{v}}_t$ because it implies a expected return higher than the (constant) marginal cost of entry f^E.

Good destruction (exit)

As one of the main contributions of this paper, exit is determined from rational behavior.[7] Intermediate-good firms produce with firm-specific productivity dealt from a Pareto distribution. The productivity draw, $z(.)$, marks the relative position of each firm and her capacity to obtain high dividends. Those intermediate goods produced under low-efficiency technologies are at risk of business termination due to the lack of profitability over the prospective business cycles.

We assume that at the end of the production period, there is a survival test for each incumbent firm. If the present value of all expected dividends exceeds the liquidation value the household will continue with the production line.[8] In the opposite case, the household will decide to shut down that firm and the production of that variety ends. Formally, any given firm in period t would face the following choice,

$$\begin{aligned} E_t \sum_{j=1}^{\infty} \overline{\beta}^j d_{t+j}(.) \quad &> \quad lv_t, \quad \rightarrow \text{ Survive,} \\ E_t \sum_{j=1}^{\infty} \overline{\beta}^j d_{t+j}(.) \quad &< \quad lv_t, \quad \rightarrow \text{ Exit,} \end{aligned}$$

where $\overline{\beta}$ is the deterministic discount factor and lv_t is the liquidation value. At the margin, there would be a minimum value of firm-level productivity, z_t^c, for which the dividend stream exactly coincide with the liquidation value,

$$E_t \sum_{j=1}^{\infty} \overline{\beta}^j d_{t+j}^c = lv_t, \tag{20}$$

that denotes the real dividends with the c superscript to identify the critical (cutoff) point of the last exit. Hence, the critical value of productivity, z_t^c, splits up the fraction of varieties that survive from those that

[6] See the technical appendix of Lewis and Stevens (2013) for the details.

[7] To our knowledge, other papers that introduce this assumption are Totzek (2009), Vilmii (2011), and Hamano (2013). The closest paper to the analysis conveyed in this section is Totzek (2009) that develops a sticky-price DSGE model. However, the exit decision is only based upon current value of profits and it neglects the liquidation cost associated to goods market exit.

[8] It should be noticed that households make decisions about exit (and entry) of goods as they are equity owners.

exit, according to the properties of the Pareto distribution (see Ghironi and Melitz, 2005, page 876). In particular, the exit rate, n_t^X/n_t, depends positively on the cutoff productivity threshold z_t^c as follows,

$$\frac{n_t^X}{n_t} = 1 - \left(\frac{z_{\min}}{z_t^c}\right)^{\kappa}, \tag{21}$$

where the shape parameter κ provides a measure of the sensitivity of the exit rate to the cutoff productivity level, z_t^c. Given its crucial role for business destruction, let us find some expression for the dynamics of z_t^c. The dividend function of the firm that operates with z_t^c productivity (last exit) is,

$$d_{t+j}^c = \left(\mu_{t+j}^c - 1\right)\left(\mu_{t+j}^c\right)^{-\theta_p}\left(mc_{t+j}^c\right)^{1-\theta_p} y_{t+j} - Pac_{t+j}^c,$$

that can be plugged in (20) to obtain,

$$E_t \sum_{j=1}^{\infty} \overline{\beta}^j \left[\left(\mu_{t+j}^c - 1\right)\left(\mu_{t+j}^c\right)^{-\theta_p}\left(mc_{t+j}^c\right)^{1-\theta_p} y_{t+j} - Pac_{t+j}^c\right] = lv_t, \tag{22}$$

where $mc_{t+j}^c = \frac{1}{e^{\varepsilon_{t+j}^a} z_t^c}\left(\frac{r_{t+j}^k}{\alpha}\right)^{\alpha}\left(\frac{w_{t+j}}{1-\alpha}\right)^{1-\alpha}$ is the marginal cost of the cutoff firm. It is important to see that even though the firm-specific productivity level is time invariant, the productivity threshold implied by (20) is time dependent. The average real marginal cost is defined at the average productivity $\widetilde{z}$ as $\widetilde{mc}_{t+j} = \frac{1}{e^{\varepsilon_{t+j}^a}\widetilde{z}}\left(\frac{r_{t+j}^k}{\alpha}\right)^{\alpha}\left(\frac{w_{t+j}}{1-\alpha}\right)^{1-\alpha}$. In turn, $mc_{t+j}^c = \widetilde{mc}_{t+j}\frac{\widetilde{z}}{z_t^c}$ and (22) becomes,

$$E_t \sum_{j=1}^{\infty} \overline{\beta}^j \left[\left(\mu_{t+j}^c - 1\right)\left(\mu_{t+j}^c\right)^{-\theta_p}\left(\widetilde{mc}_{t+j}\frac{\widetilde{z}}{z_t^c}\right)^{1-\theta_p} y_{t+j} - Pac_{t+j}^c\right] = lv_t, \tag{23}$$

which can be solved for the critical firm-level productivity z_t^c. Finally, let us assume that the liquidation value is a fraction $(1-\tau)$ of the unit cost of entry,

$$lv_t = (1-\tau) f^E, \tag{24}$$

where $0 \leq \tau \leq 1$ is the part of the license that is forgone when exiting. In loglinear deviations from steady-state, $\widehat{lv}_t = \widehat{lv}_{t+1} = 0$ according to (24). After loglinearization of (21), (23), and (24), the following pair of equations govern exit dynamics,[9]

$$\begin{aligned}
\widehat{z}_t^c &= \overline{\overline{\beta}} E_t \widehat{z}_{t+1}^c + \left(1 - \overline{\overline{\beta}}\right) E_t \left(\widehat{\widetilde{mc}}_{t+1} - (\theta_p - 1)^{-1}\widehat{y}_{t+1}\right), \\
\widehat{n}_t^X &= \widehat{n}_t + \kappa\left(\frac{1-\delta_n}{\delta_n}\right)\widehat{z}_t^c.
\end{aligned}$$

Hence, the exit decision is affected by both supply-side and demand-side conditions respectively through the expectations of the average real marginal costs and the aggregate demand. The number of exits exceeds that of the change in the number of varieties whenever $\widehat{z}_t^c$ is positive (due to a net combination of lower expected marginal costs and higher expected demand for consumption goods). The elasticity of the exit response increase with the shape parameter κ of the productivity distribution, and falls with the steady-state exit rate δ_n.

[9] The algebra for the loglinearized expression of $\widehat{z}_t^c$ is described in Appendix C. The expression of $\widehat{n}_t^X$ can be obatined from taking logs in (21) and using the steady-state relation $\frac{n^X}{n} = 1 - \left(\frac{z_{\min}}{z^c}\right)^{\kappa} = \delta_n$.

2.5 Central bank and government

The monetary policy of the model is described by a Taylor-type (1993)'s rule, of the kind used in standard DSGE models. Thus, we follow Smets and Wouters (2007) and consider that the central bank adjusts the nominal interest rate to stabilize inflation and (both current and the change in) the output gap, with a partial-adjustment pattern that includes lagged nominal interest rate to smooth down monetary policy actions,

$$R_t = R+\mu_R\left(R_{t-1}-R\right)+(1-\mu_R)\left[\mu_\pi\left(\pi_t-\pi\right)+\tfrac{\mu_y}{4}\left(\widehat{y}_t-\widehat{y}_t^p\right)\right]+\mu_{dy}\left[\left(\widehat{y}_t-\widehat{y}_t^p\right)-\left(\widehat{y}_{t-1}-\widehat{y}_{t-1}^p\right)\right]+\varepsilon_t^R, \quad (25)$$

where R_t is the nominal rate of interest in period t while R is that in steady state, $(\pi_t-\pi)$ is the difference between current and steady-state rates of producer price inflation, $(\widehat{y}_t-\widehat{y}_t^p)$ is the output gap between the cyclical component of output $(\widehat{y}_t)$ and its potential (natural-rate) realization $(\widehat{y}_t^p)$, $0\leq\mu_R<1$ is a smoothing parameter and ε_t^R is an exogenous monetary policy shock.

As for the role of the government, its fiscal policy consists of holding the budget constraint,

$$\varepsilon_t^g = t_t+\left(f^E n_t^E - lv_t\left(n_{t-1}^X+\tfrac{n_{t-1}^X}{n_{t-1}}F_{n,t-1}\left(.\right)n_{t-1}^E\right)\right)+\tfrac{b_{t+1}}{1+r_t}-b_t, \quad (26)$$

which implies that the exogenous public expenditures on consumption goods, ε_t^g, are financed within the period by either collecting lump-sum taxes, t_t, by obtaining net revenues from selling operating licenses, $f^E n_t^E - lv_t\left(n_{t-1}^X+\tfrac{n_{t-1}^X}{n_{t-1}}F_{n,t-1}\left(.\right)n_{t-1}^E\right)$, and by newly issued bonds b_{t+1} that yield the real return $1+r_t$ in the equilibrium of the bonds market.

2.6 Aggregation and general equilibrium

The optimal pricing of the firm that receives the average productivity, $\widetilde{P}_t$, is obtained rewriting (12) as for the average values of the price, mark-up and real marginal cost,

$$\tfrac{\widetilde{P}_t}{P_t^C} = \widetilde{\mu}_t\widetilde{mc}_t, \quad (27)$$

where $\widetilde{mc}_t$ has been introduced above, and $\widetilde{\mu}_t$ is also evaluated at the average productivity $\widetilde{z}$. Similarly, the average output produced $\widetilde{y}_t$ is,

$$\widetilde{y}_t = e^{\varepsilon_t^a}\widetilde{z}\widetilde{k}_t^\alpha\left(e^{\gamma t}\widetilde{l}_t\right)^{1-\alpha}, \quad (28)$$

where $\widetilde{k}_t$ and $\widetilde{l}_t$ are, respectively, average-productivity capital and labor. Let us define $\widetilde{\rho}_t=\frac{\widetilde{P}_t}{P_t^C}$ as the relative average price. Then, using (27) and (28), the average-productivity real dividend across intermediate firms is,

$$\widetilde{d}_t = \left(\widetilde{\rho}_t\right)^{-\theta_p}y_t\left(\widetilde{\rho}_t-\widetilde{mc}_t\right)-\widetilde{Pac}_t, \quad (29)$$

where $\widetilde{Pac}_t$ is the average price adjustment cost. Since households are identical, perfect symmetry can be assumed and the entry condition (18) writes,

$$f^E = \widetilde{v}_t\left[\tfrac{\partial F_{n,t}(.)}{\partial n_t^E}n_t^E+F_{n,t}\left(.\right)\right]+E_t\widetilde{v}_{t+1}\left[\tfrac{\partial F_{n,t+1}(.)}{\partial n_t^E}n_{t+1}^E\right]. \quad (30)$$

In the final-good sector, there is also symmetric equilibrium because all the packing firms are alike. The price of one consumption bundle is $P_t^c = P_t(i) = \left(\int_0^{n_t} P_t(\omega)^{1-\theta_p} d\omega\right)^{\frac{1}{1-\theta_p}}$ so that, in terms of the average price of the intermediate goods, $P_t^c = \left(n_t \widetilde{P}_t^{1-\theta_p}\right)^{\frac{1}{1-\theta_p}}$. Hence, the average relative price, $\widetilde{\rho}_t$, is an increasing function of the total number of goods (variety effect) as follows,

$$\widetilde{\rho}_t = n_t^{\frac{1}{\theta_p - 1}}. \tag{31}$$

Using (31) in the average demand of intermediate goods, $\widetilde{y}_t = (\widetilde{\rho}_t)^{-\theta_p} y_t$, the aggregate activity can be related to plant-level production as follows

$$y_t = n_t^{\frac{\theta_p}{\theta_p - 1}} \widetilde{y}_t,$$

and turning terms around and plugging (31) the average firm-level production becomes,

$$\widetilde{y}_t = \frac{y_t}{\widetilde{\rho}_t n_t}. \tag{32}$$

The definitions of both final-good inflation, $1+\pi_t^c = \frac{P_t^C}{P_{t-1}^C}$, and intermediate-good average inflation, $1+\pi_t = \frac{\widetilde{P}_t}{\widetilde{P}_{t-1}}$, can be used in (31) to find a link between both rates of inflation as follows,

$$(1+\pi_t^c) = \left(\frac{n_t}{n_{t-1}}\right)^{\frac{1}{1-\theta_p}} (1+\pi_t). \tag{33}$$

Aggregating over symmetric behavior of the households, the aggregate real wage rate becomes,

$$w_t = \frac{\theta_w}{(\theta_w - 1)} \frac{\Xi l_t^{\sigma_c}}{(c_t - h c_{t-1})^{-\sigma_c}} + \frac{\Upsilon_t}{l_t}.$$

In addition, the equilibrium conditions for the labor, capital and equity markets are,

$$\begin{aligned} l_t &= n_t \widetilde{l}_t, \\ k_t &= n_t \widetilde{k}_t, \\ x_t &= n_t, \end{aligned}$$

while the equilibrium condition for the market of bundles of consumption goods is (the overall resources constraint),[10]

$$y_t = c_t + i_t + g_t + n_t \widetilde{Pac}_t + Wac_t. \tag{34}$$

For the exogenous variables of the model, there are four AR(1) generating processes for the shocks of production technology, consumption preference, investment adjustment costs and monetary policy, two ARMA(1,1) processes for both price-push shocks and wage-push shocks, and the fiscal shock is an AR(1) process with a cross correlation to technology innovations. Regarding notation, for any s shock, ρ_s is the

[10] Proof available in the Appendix D.

autoregressive root, μ_s is the moving average coefficient, and η^s is the white-noise innovation with constant variance σ_s^2. Finally, natural-rate variables are required to implement the Taylor-type monetary policy rule (25). The potential variables are obtained by fully eliminating price and wage stickiness (i.e., by imposing $\psi_p = \psi_w = 0$).

The complete model with entry and exit can be written for short-run fluctuations as the log-linearized set of dynamic equations available in Appendix A. The non-linear system of equations that determines the balanced-growth solution in steady state is also displayed there.

2.7 A particular case for a standard DSGE model

Throughout the rest of the paper, we will estimate and carry out a business cycle analysis of the model described above and will compare the results with a conventional DSGE model that does not contemplate fluctuations of the extensive margin of activity. As discussed in Appendix B, the standard DSGE model can be seen as one particular case of the DSGE model with entry and exit. In particular, assuming a fixed number of intermediate-good firms, eliminating the heterogeneous productivity across these firms, and dropping the endogenous choices of optimal entry and exit reduce the extended model into a conventional DSGE model. There would be symmetric equilibrium across the identical intermediate-good firms and the variability in the amount of output produced at the firm level would fully explain the fluctuations of aggregate output. The elements of nominal rigidities, real frictions and sources of exogenous variability (shocks) are left equal on both model settings. The conventional DSGE model is similar to that described in Smets and Wouters (2007), with the minor change of having both sticky prices and sticky wages *a la* Rotemberg (1982), instead of the Calvo-style scheme. It will be our reference of a standard DSGE model.

3 Estimation

Both the DSGE model with entry and exit and the standard version with constant number of goods have been estimated for the US economy. The series of quarterly US data used in the estimation belong to the Great Moderation period 1984:1-2007:4. The selection of this period voluntarily leaves away the quarters of the financial crisis and the Great Recession, because conventional DSGE models are not able to capture the effects of financial frictions/shocks, and we do not incorporate elements of either the banking sector or unconventional monetary policy actions. There are seven time series taken as observables in the estimation: the log difference in per-capita real Gross Domestic Product (GDP), the log difference in per-capita real Personal Consumption Expenditures, the log difference in per-capita real Private Nonresidential Fixed Investment, the rate of change in the GDP price deflator, the rate of change in the Average Hourly Earnings, the 3-month average of the monthly Effective Federal Funds rate, and the log of Hours of All Persons in the Nonfarm Business Sector. All the series were downloaded from the St. Louis Fed website. Appendix D describes the measurement equations used in the estimation procedure.

There are a couple of parameters that are fixed before the estimation: the rate of capital depreciation is set at $\delta_k = 0.025$ as in Smets and Wouters (2007) and the labor elasticity of substitution at $\theta_w = 3.0$ as in Lewis and Stevens (2013), where wage setting features Rotemberg-style rigidity. In addition, the steady-state ratio of government spending to output is set at $\frac{\varepsilon^g}{y} = 0.21$ to match the average value observed during the Great Moderation.

Table 1A. Priors and estimated posteriors of the structural parameters.

				DSGE with entry/exit		Standard DSGE	
		Priors		Posteriors		Posteriors	
	Distr	Mean	Std D.	Mean	Std D.	Mean	Std D.
h: consumption habits	Beta	0.70	0.10	0.65	0.08	0.69	0.08
σ_c risk aversion	Normal	1.50	0.50	1.21	0.15	1.24	0.15
σ_l: inverse Frisch elasticity	Normal	2.00	0.75	2.27	0.48	2.64	1.45
ψ_p: price rigidity	Gamma	50.0	7.50	56.3	6.1	54.9	6.3
ψ_w: wage rigidity	Gamma	50.0	7.50	53.2	6.4	51.8	6.4
λ_p: price indexation	Beta	0.50	0.15	0.51	0.09	0.28	0.08
λ_w: wage indexation	Beta	0.50	0.15	0.42	0.11	0.47	0.12
φ_k: capital adj. cost elasticity	Normal	4.00	1.50	5.95	1.10	6.04	0.98
σ_a capital utilization cost elasticity	Beta	0.50	0.15	0.81	0.05	0.68	0.08
δ_n: exit rate in steady-state	Gamma	0.029	0.002	0.0285	0.007	–	–
φ_E: entry congestion elasticity	Normal	1.00	0.50	1.02	0.51	–	–
κ: exit shape	Normal	4.00	0.75	2.73	0.60	–	–
α:capital share in production	Beta	0.36	0.05	0.26	0.02	0.31	0.03
θ_p: Dixit-Stigitz elasticity	Normal	4.00	0.50	3.53	0.31	2.26	0.42
μ_π: inflation in Taylor rule	Normal	1.50	0.25	1.89	0.16	1.86	0.15
μ_y: output in Taylor rule	Normal	0.12	0.05	0.07	0.02	0.06	0.03
$\mu_{\Delta y}$: output change in Taylor rule	Normal	0.12	0.05	0.17	0.03	0.18	0.13
μ_R: inertia in Taylor rule	Beta	0.75	0.15	0.80	0.03	0.80	0.03
$100\left(\beta^{-1}-1\right)$: % steady-state real int. rate	Gamma	0.50	0.15	0.32	0.06	0.27	0.06
100γ: % steady-state growth	Normal	0.50	0.10	0.37	0.03	0.44	0.03
100π: % steady-state inflation	Normal	0.60	0.10	0.62	0.04	0.64	0.06

Table 1B. Priors and estimated posteriors of the exogenous processes with consumption shock

		Priors		DSGE with entry/exit Posteriors		Standard DSGE Posteriors	
	Distr	Mean	Std D.	Mean	Std D.	Mean	Std D.
σ_{η^a}: Std dev of productivity innovation	Invgamma	0.10	2.00	0.52	0.03	0.48	0.03
σ_{η^b}: Std dev of consumption innov.	Invgamma	0.10	2.00	1.93	0.36	2.32	0.55
σ_{η^R}: Std dev of monetary innov.	Invgamma	0.10	2.00	0.13	0.01	0.13	0.01
σ_{η^g}: Std dev of fiscal innov.	Invgamma	0.10	2.00	0.38	0.03	0.37	0.02
σ_{η^i}: Std dev of investment innov.	Invgamma	0.10	2.00	0.39	0.04	0.35	0.04
σ_{η^p}: Std dev of price-push innov.	Invgamma	0.10	2.00	0.12	0.01	0.09	0.01
σ_{η^w}: Std of wage push innov.	Invgamma	0.10	2.00	0.73	0.06	0.67	0.06
ρ_a: Persistence of productivity shock	Beta	0.50	0.20	0.97	0.01	0.97	0.01
ρ_b: Persistence of consumption shock	Beta	0.50	0.20	0.72	0.09	0.61	0.15
ρ_R: Persistence of monetary shock	Beta	0.50	0.20	0.41	0.06	0.40	0.07
ρ_g: Persistence of fiscal shock	Beta	0.50	0.20	0.97	0.02	0.97	0.01
ρ_i: Persistence of investment shock	Beta	0.50	0.20	0.73	0.05	0.73	0.05
ρ_p: Persistence of price-push shock	Beta	0.50	0.20	0.82	0.04	0.90	0.04
ρ_w: Persistence of wage-push shock	Beta	0.50	0.20	0.81	0.10	0.89	0.04
μ_p: moving-average of price-push shock	Beta	0.50	0.20	0.61	0.07	0.65	0.08
μ_w: moving-average of wage-push shock	Beta	0.50	0.20	0.67	0.13	0.68	0.08
ρ_{ga}: cross-correlation productivity-fical	Beta	0.50	0.20	0.42	0.06	0.46	0.06

Tables 1A and 1B display the priors and estimated posteriors found in the Bayesian estimation, for both the model with entry-exit and the standard DSGE model. The selection of priors follows Lewis and Stevens (2013) and Smets and Wouters (2007) and we only mention here the few discrepancies with these papers. Hence, the steady-state quarterly rate of exit is estimated with a prior at $\delta_n = 0.029$ to match the average value found in US data.[11] Both the shape parameter of the Pareto distribution κ and the Dixit-Stiglitz demand elasticity θ_p take a prior mean equal to 4.0 with low standard deviations (0.75 and 0.50 respectively) as a conservative assumption that meets the condition of the Pareto distribution to have a positive average productivity ($\kappa > \theta_p - 1$). Regarding goods creation, the prior for the elasticity of the congestion costs of entry is the linear case ($\varphi_E = 1$).

The methodology is standard to the Bayesian estimations of DSGE models: the posterior distribution combines the likelihood function with prior information. The Metropolis-Hastings algorithm is employed to calculate the posterior distribution and the marginal likelihood of the models. The log data density is

[11] The average quarterly exit rate of establishments in the US over the period 1993-2013 is 2.9%. Source: Bureau of Labor Statistics.

very similar in both models, slightly better in the standard DSGE model (-442.2) than in the model with entry and exit (-448.7). Most of the structural parameters are estimated at a similar range of mean values across models. However, there are a couple of differences worth to comment about. When looking at the posteriors shown in Table 1A and 1B, we see that:

- The mean estimates of the Dixit-Stiglitz elasticity of substitution across consumption goods (θ_p) are 3.53 in the model with entry and exit and 2.26 in the standard model. Therefore, having a variable number of varieties makes consumption more sensitive to the relative price of goods.

- Even though price stickiness is similar across models, the coefficient of inflation inertia (λ_p) turns clearly higher in the model with entry and exit. This might also be a consequence of the variety effect on the relative price and inflation. As shown in the set of dynamic equations displayed in Appendix A, the fluctuations of the markup in the model with entry and exit are positively affected by changes in the total number of goods, which increases the overall variability relative to a conventional model. A higher value of the price indexation parameter smooths down inflation fluctuations to compensate for the additional volatility

Regarding the estimates of the parameters that define entry and exit, the elasticity of the entry congestion costs is close to the linear case assumed in the prior selection. The posterior of the shape parameter in the Pareto distribution is lower than the prior with a mean estimate at $\kappa = 2.73$, which may indicate that the distribution of firm-level productivity cannot have a great concentration of firms with low probability to avoid excessive volatility in the flow of exit. Finally, the mean estimate of the steady-state exit rate is at δ_n =2.86% per quarter close to the prior proposed to match US data.

4 Impulse-response functions

In this section we examine impulse responses to understand how the flows of entry and exit of goods may affect the propagation of shocks to the main variables of the economy. All the shocks have been normalized at the value of one estimated standard deviation. We separate shocks initially affecting the supply-side decisions (Figures 1-3 display technology, price push and wage push shocks), from shocks affecting the demand components (Figures 4 and 5 respectively show the responses to the interest-rate shock and the consumption preference shock).[12] The plots provide the percentage deviation with respect to the steady state level for all the variables except for the rate of price inflation, the rate of wage inflation and the nominal interest rate that are directly given in the difference with respect to their corresponding steady-state rates.

[12] Due to space limitations, the remaining impulse-response functions are plotted in the Appendix F. As reported in Table 3 below, the five shocks discussed in this section explain most of the variability of output growth, inflation and the nominal interest rate in both models.

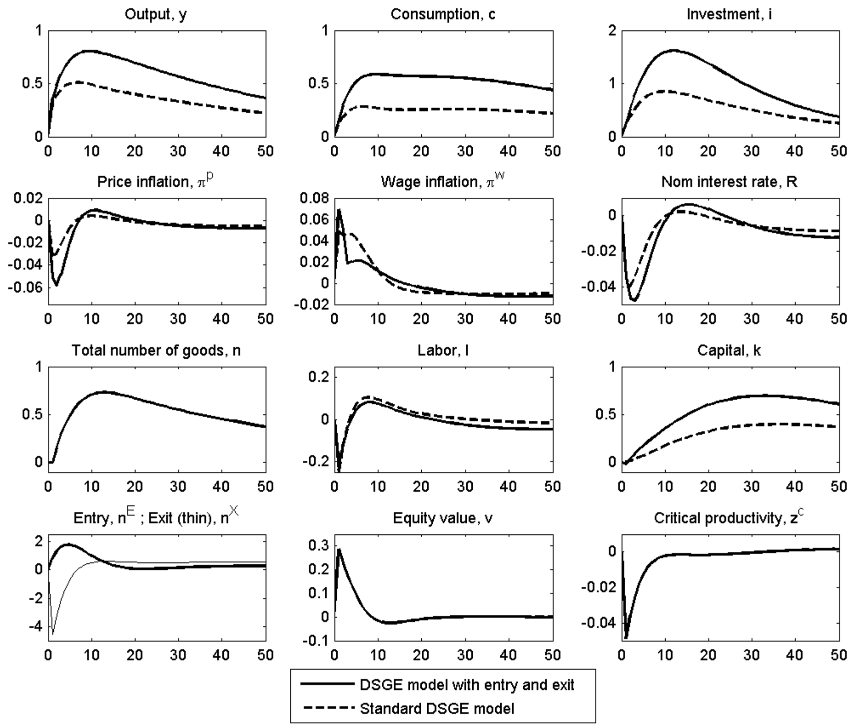

Figure 1: Impulse-response functions. Technology shock.

4.1 Technology shock

Figure 1 shows the responses to a positive technology shock, η^a. In the conventional DSGE model, this shock has well-documented effects. Labor productivity rises, the real marginal cost falls, firms cut prices, and the central bank sets a lower nominal interest rate as inflation decreases. Economic activity thus expands via higher productivity and lower inflation, which stimulate spending on both consumption goods (lower interest rates) and on investment (higher marginal product of capital). The peak effect on aggregate output is observed 5 quarters after the shock with an increase by around 0.5% of the steady-state level.

Taking into account entry and exit on the goods market leads to some interesting results, compared to the standard model. Although the shape of the main curves is not affected, the extensive margin of activity leads to higher macroeconomic variability. As represented in Figure 1, the productivity shock has a stronger effect on output, consumption, and investment, while the responses observed on price inflation, wage inflation and the nominal interest are similar to the standard DSGE mode. Also shown in Figure 1, the technology shock increases the number of entries and reduces the number of exits. Entry rises because the expected return of opening a new variety (higher v) temporarily exceeds the cost of entry. Meanwhile, good destruction diminishes. A positive technology shock reduces the real marginal cost and increases the overall demand, which jointly explain a decrease in the productivity cutoff level for exit, z^c. The exit rate moves down as a lower fraction of intermediate-good firms decide to shut down production.

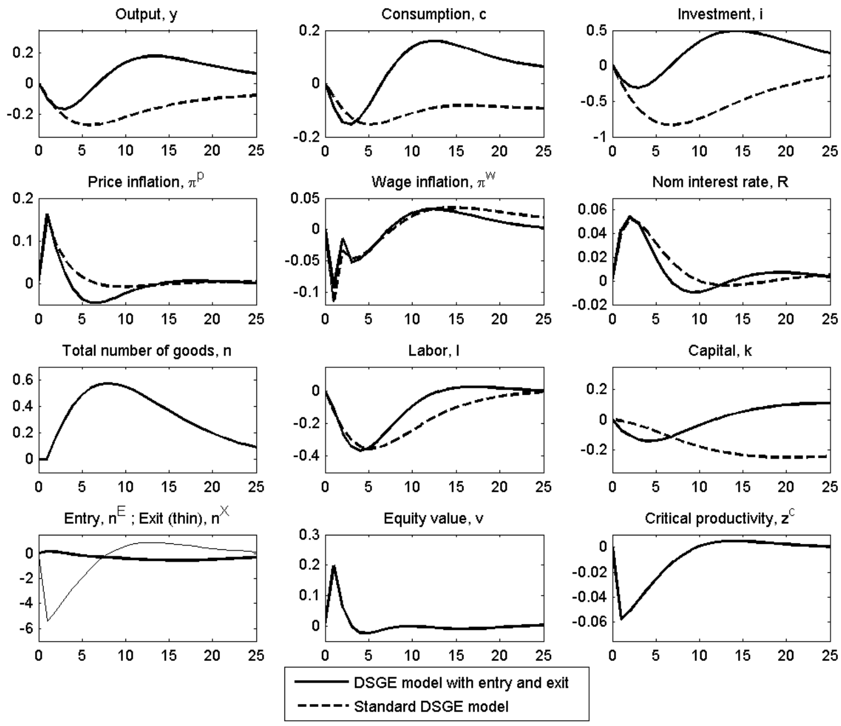

Figure 2: Impulse-response functions. Price-push shock.

The combination of more entry and less exit leads to a significant increase in the number of good-varieties, with a peak value near 0.80% higher than the steady-state level observed 9 quarters after the shock. In turn, the extensive margin of activity (variety creation) amplifies the response of total output, from a peak value at +0.5% in the standard DSGE model to a peak value at +0.8% in the extended model. Even though the initial output response is only based on the firm-level reaction (intensive margin) as the stock of good varieties builds up the effect found in the extended model is much greater and persistent than in the standard model. Such amplifying effect is also observed on the responses of both consumption and investment spending plotted in Figure 1.

4.2 Price-push shock

Figure 2 documents the effects of an inflationary shock, η^p, which scales down the price adjustment cost and brings a more severe response of prices when applying the optimal mark-up policy. In both model, as firms set a higher price and inflation rises, the central bank reacts by setting higher nominal interest rates and planned expenditures on consumption and capital goods fall. Demand-determined output, consumption, and investment move down, describing a u-type pattern due to consumption habits and investment adjustment costs. On the supply side, the economic contraction leads to lower demand for both labor and capital in the factor markets.

In the extended model, the price-push shock has remarkable effects on goods exit that falls by more than 5% (see Figure 2). A reduction in the critical productivity level z^c leads to shut down fewer incumbent firms. The entry response is not very significant though. Firm-level average revenue and dividends increase due to higher selling prices. This raises equity value by around 0.2% and results in some business creation. The opposite direction in the responses of entry (up) and exit (down) leads to a substantial increase in the total number of goods, reaching a peak value nearly 0.6% higher than its steady-state level.

The net creation of varieties affects both the goods market and the factor markets. As the extensive margin builds in, total output produced initiates a quick return to the steady-state level and actually jumps over the positive side as the expansion of varieties continues. The model with entry and exit predicts a quick recovery after the inflation shock because of the increase in the number of goods (extensive margin effect that is absent in the conventional model). Furthermore, the production of new goods requires more units of labor and capital. The effect is clearly noticeable in Figure 2 for the demand of capital: the initial reduction of capital demand is progressively dampened by the increase in the extensive margin of activity. Meanwhile, labor responds similarly across models.

In contrast to the effects of the technology shock, the extensive margin (total number of goods) is countercyclical after an inflationary shock and, therefore, attenuates its contractionary effects. If we ignore this channel, as in conventional DSGE models, the adverse effects of inflation shocks on output, consumption and investment may be overestimated.

4.3 Wage-push shock

Figure 3 shows the responses observed after a wage-push shock, η^w, that reduces the wage adjustment costs and increases the reaction of the nominal wage to any given marginal rate of substitution. In both models, as households set higher nominal wages and wage inflation rises, the marginal cost of production (that depends directly on the real wage) moves up and firms respond setting higher market prices. The central bank observes the inflation hike and announces a higher nominal interest rate when implementing the Taylor-type monetary policy rule. The endogenous components of demand –consumption and investment–, respond to higher interest rates with u-shaped declining patterns as a result of habits and adjustment costs on investment.

The adverse effects of the wage-push shocks are larger with entry and exit. Figure 3 plots the peak of the output fall by 0.2% more than in the standard model. Consumption and investment also fall deeper in the model with entry and exit. The reason can be found in the procyclical decline of the number of goods, which a maximum fall around 0.5% of its steady state level obtained 7 quarters after the shock. The responses of both entry and exit explain the decrease in the total number of varieties. Entry moves down because the average equity value is lower as a result of the fall in dividends explained by a higher labor cost. Meanwhile, a greater number of intermediate-good firms shut down; higher marginal costs and

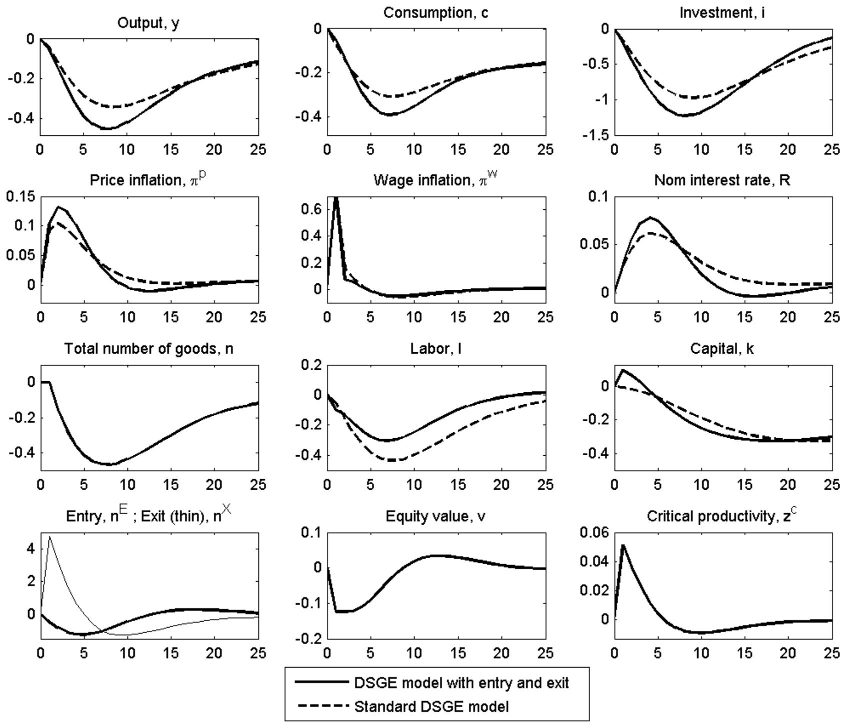

Figure 3: Impulse-response functions. Wage-push shock.

lower aggregate demand make the critical productivity rise and a higher fraction of firms are liquidated. Finally, the decline of labor is higher in the standard model, as firm-level production downsizes to fully accommodate the economic contraction and labor demand moves down accordingly.

4.4 Interest-rate shock

Figure 4 displays the responses of the model variables after a positive interest-rate shock, η^R. Some effects in both models are the commonly reported of a monetary policy tightening in a sticky-price model: there is a contraction of the components of demand (purchases of consumption goods and investment spending), which results in a decline of both output and inflation. As output falls, the demands for labor and capital goods shrink in the factor markets. The peak decrease in output is observed 2 periods after the shock due to consumption habits and adjustment costs on investment. Both models report maximum declines of output around 0.25% of its steady-state value while the quarterly interest rate rises nearly 7-8 basis points.

In the model with variable number of goods, higher interest rates depress goods entry, as the average equity value decreases due to lower dividends and higher rates of discount. Goods exit also moves down as the critical productivity value z^c decreases with lower real marginal costs. After a few quarters, the fall in entry is deeper than the fall in exit, which in turn reduces the total number of goods. The response of the total number of goods is quantitatively small (with a bottom value of -0.04% after 8 periods),

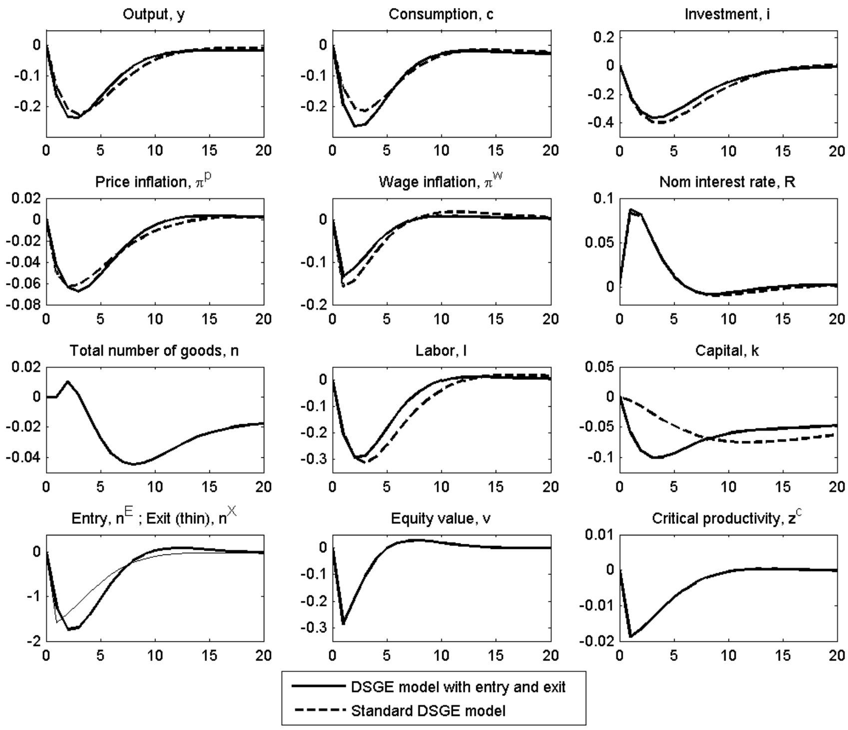

Figure 4: Impulse-response functions. Interest-rate shock.

because of the co-movement between the flows of entry and exit falling together between 1.5% and 2% of the steady-state levels. Hence, the introduction of variable number of goods has very little effects on the responses to a monetary shock because of the close co-movement between entry and exit.

4.5 Consumption preference shock

Figure 5 plots the responses of the model variables after a positive consumption preference shock, η^b, that raises the marginal utility of consumption and makes households transfer some of their savings into current consumption. The presence of consumption habits explains the hump-shaped response displayed. As observed in both models, the demand-driven expansion brings a positive effect on both output and labor, of similar size to that of consumption. Price inflation rises as a consequence of lower productivity and higher marginal costs of production The central bank raises the interest rate which crowds out investment spending.

Entry and exit bring little effects on the transmission of the consumption preference shock. Figure 5 shows how the total number of goods barely changes, reporting a small decline observed with a long delay. So, the bulk of the adjustment of production to higher demand takes place through the intensive margin: incumbent firms hire more labor and increase their levels of production. Anyways, both entry and exit fall. Entry diminishes because higher interest rates reduce the average equity value. The flow of entry responds

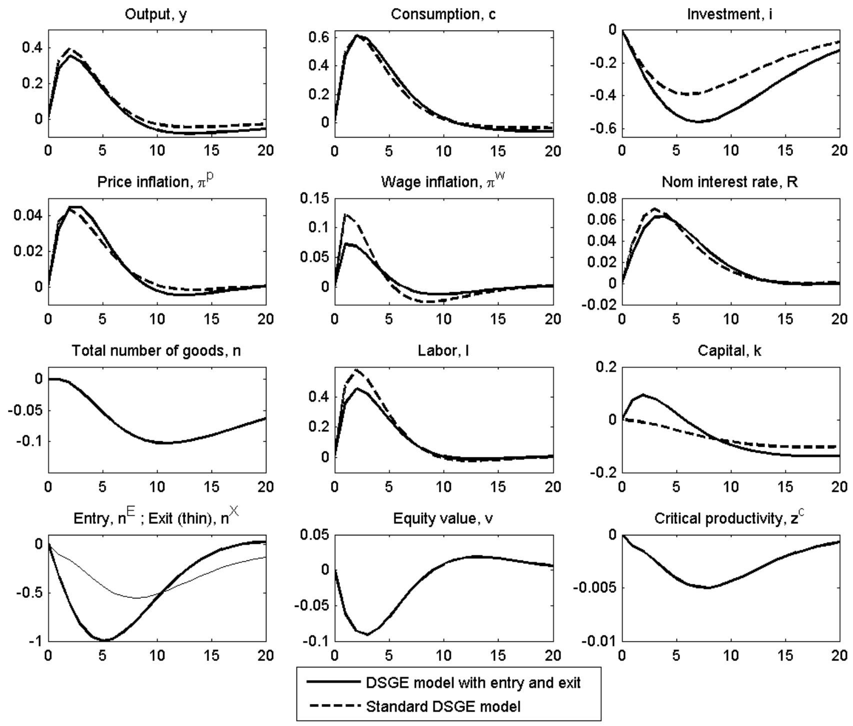

Figure 5: Impulse-response functions. Consumption preference shock.

slowly due to the congestion costs, with a trough point at -1% observed four quarters after the shock. Exit also falls, in this case due to a reduction in the level of critical productivity. The latter is explained by the increase in total demand which dominates over higher real marginal costs. Since entry falls further than exit, the total number of varieties shows a small (countercyclical) decline.

5 Business cycle analysis

In this section, we report the second moment statistics, analyze the variance decomposition, and examine the relative contribution of the intensive and extensive margins of activity on output fluctuations.

5.1 Second-moment statistics and variance decomposition

Table 2 informs on the second moment statistics of the US Great Moderation series used in the estimation, and the corresponding values obtained in simulations with the estimated models. Overall, both models perform fairly well regarding the matching to US data. The volatility (standard deviations) are higher in the DSGE models than in the data for output growth, $\Delta\widehat{y}$, consumption growth, $\Delta\widehat{c}$, investment growth, $\Delta\widehat{i}$, and producer price inflation, π, whereas that of the nominal interest rate, R, is underestimated by the models.[13] The excess volatility is slightly higher in the model with entry and exit, probably due to the introduction of extensive margin as another source for the propagation of shocks over the business cycles.

The correlation along business cycles is well matched with the models. The rates of change of both consumption and investment are procyclical while the rate of price inflation and the nominal interest rate are mildly countercyclical. The model with entry and exit brings more intense countercyclical dynamics of price inflation and the nominal interest rate due to its greater reliance on technology shocks. Labor (in log fluctuations, l) is mildly procyclical in the models and the data and wage inflation, π^w, is acyclical in US Great Moderation data and mildly procyclical in the models.

Regarding persistence, the nominal interest rate and log fluctuations of labor report the highest coefficients of autocorrelation (near the upper bound of 1.0) both in the data and in the estimated models. Price inflation shows a moderate inertia in the data (coefficient of autocorrelation at 0.61), which is somehow greater in the models (around 0.8). Remarkably, the autocorrelation of both output and consumption growth is very close to zero (lower than 0.1) during the US Great Moderation. In the estimated DSGE models, however, we find higher persistence in the growth rates of output, consumption and investment (coefficients of serial correlation between 0.3 and 0.65) as a result of the endogenous inertia produced by consumption habits and the adjustment costs on investment.

Table 2. Second-moment statistics

	$\Delta\widehat{y}$	$\Delta\widehat{c}$	$\Delta\widehat{i}$	π	R	π^w	$\widehat{l}$
U.S. Great Moderation data, 1984:1-2007:4							
Std deviation, %	0.51	0.47	1.64	0.23	0.59	0.71	2.43
Corr. with Δy	1.0	0.51	0.42	−0.16	−0.04	0.00	0.11
Autocorrelation	0.07	0.08	0.46	0.61	0.98	0.09	0.97
Estimated model with entry and exit:							
Std deviation, %	0.72	0.66	2.07	0.39	0.38	0.82	2.15
Corr. with Δy	1.0	0.61	0.56	−0.23	−0.18	0.20	0.13
Autocorrelation	0.38	0.51	0.64	0.81	0.94	0.25	0.94
Estimated standard DSGE model:							
Std deviation, %	0.67	0.59	2.04	0.32	0.36	0.85	2.31
Corr. with Δy	1.0	0.58	0.51	−0.12	−0.13	0.24	0.18
Autocorrelation	0.30	0.43	0.64	0.79	0.94	0.35	0.95

Table 3 shows the variance decomposition in both estimated models. Technology shocks have a deeper impact on output growth in the model with entry and exit. As Table 3 reports consumption growth, and investment growth on the demand side, and the log fluctuations of labor and capital on the supply side

[13] As extensively documented in the business cycle literature, the Great Moderation is a period of exceptionally low macroeconomic volatility.

report higher percentages of contribution of the technology shocks in the variance decomposition. The introduction of the extensive margin in a DSGE model amplifies the short-run effects of technology shocks, with an increase from 29% to 34% in the contribution to output growth variability, $\Delta\widehat{y}$; and from 64% to 75% in the contribution to fluctuations in the level of output, $\widehat{y}$. In other words, the conventional DSGE model underestimates the role of technology shocks during the US Great Moderation.

Table 3. Long-run variance decomposition, %

Estimated model with entry and exit:								
Innovations	$\Delta\widehat{y}$	$\Delta\widehat{c}$	$\Delta\widehat{i}$	π^p	R	π^w	$\widehat{l}$	$\widehat{y}$
Technology, η^a	34.1	17.0	7.6	6.6	10.9	3.6	5.2	75.0
Consumption, η^b	15.3	48.7	1.4	4.2	10.5	1.9	11.3	1.0
Fiscal, η^g	17.4	6.0	0.2	1.8	5.6	0.5	16.3	1.7
Investment, η^i	13.5	3.3	80.3	15.9	39.6	10.4	18.2	5.0
Interest rate, η^R	6.8	11.1	1.6	15.2	9.9	7.5	6.7	0.5
Wage-push, η^w	7.3	8.1	5.4	33.8	19.1	71.5	28.8	15.5
Price-push, η^p	5.6	5.8	3.4	22.5	4.4	4.5	13.6	1.3
Estimated standard DSGE model:								
Innovations	$\Delta\widehat{y}$	$\Delta\widehat{c}$	$\Delta\widehat{i}$	π^p	R	π^w	$\widehat{l}$	$\widehat{y}$
Technology, η^a	29.0	10.1	2.9	3.2	6.4	3.1	1.9	64.1
Consumption, η^b	19.5	56.8	0.9	4.0	11.3	2.8	11.2	2.4
Fiscal, η^g	19.6	8.2	0.3	2.1	5.4	0.4	14.4	1.8
Investment, η^i	13.8	2.9	85.0	14.6	39.7	11.6	14.7	12.4
Interest rate, η^R	8.8	13.4	2.3	12.6	13.2	8.0	6.5	1.8
Wage-push, η^w	4.0	5.5	3.4	28.7	15.4	70.0	37.9	9.9
Price-push, η^p	5.2	5.2	5.3	34.9	8.8	4.2	13.3	7.5

Wage-push shocks also become more influential on business cycle variability when introducing entry and exit. The extensive-margin effects of wage innovations increase the share in the variance decomposition of $\Delta\widehat{y}$ from 4% to 7.3% and of $\widehat{y}$ from 9.9% to 15.5%, compared to the standard DSGE model. Demand-side shocks are still quite important for business cycle variability in both models, though their contribution is lower in the extended model to balance the higher impact of supply-side shocks. The consumption shock has substantial effects on consumption growth, and moderate participation shares in the variability of output growth, the nominal interest rate and labor. The monetary policy shock drives between 10% and 15% of fluctuations of R, π^p and $\Delta\widehat{c}$ and below 10% of $\Delta\widehat{y}$, in both models. The fiscal shock takes nearly 20% of variability of the output growth in the standard model an 17% in the extended model. This exogenous spending shock also explains around 15% of fluctuations of output growth and labor in both models, and lower percentages in all the other variables. Finally, the investment shock plays a similar role in both models, with effects that take more than 80% of variability of $\Delta\widehat{i}$, and around 13% of that of $\Delta\widehat{y}$.

5.2 The role of extensive and intensive margin fluctuations

The introduction of entry and exit provides the extensive margin of cyclical fluctuations: the amount of aggregate output may rise because there is either more goods produced in the economy (extensive rate) or because incumbent firms increase their production level (intensive rate). This subsection deals with the variability of these two margins relative to output, as observed from simulations in the estimated model with entry and exit. From equation (32) and the definition $\widetilde{\rho}_t = \widetilde{P}_t/P_t^c$, we have,

$$y_t = n_t \left(\frac{\widetilde{P}_t}{P_t^c} \widetilde{y}_t \right),$$

which measures the value of real output as the product of the total number of goods (n_t) multiplied by the average production of intermediate-good firms ($\frac{\widetilde{P}_t}{P_t^c}\widetilde{y}_t$). The value of $\frac{\widetilde{P}_t}{P_t^c}\widetilde{y}_t$ represents the intensive-margin production of the firm that operates with the average productivity $\widetilde{z}$ expressed in units of the consumption bundle. Changes in n pick up the extensive margin of fluctuations, since the number of goods varies as a combined result of the flows of entry and exit.

Figure 6 shows the relative contribution of the two margins in the responses of output to shocks. The size of each shock is normalized to the estimated mean of its standard deviation. The graphical display indicates a strong co-movement between total output and the number of goods in the presence of either a technology shock or a wage-push shock. In these two cases, the adjustment of aggregate output to the shock is mostly taken through the extensive margin. The technology shock brings significant and persistent responses of both total output and the number of goods: they both peak at approximately 0.8% between 8 and 12 quarters after the shock. There is some lag observed in n. Firm-level average output covers all the adjustment at the quarter of the shock (let us remember that n is one-period predetermined) but quickly returns to the vicinity of its steady-state value.

By contrast, in the case of both interest-rate and consumption shocks most output variability is explained by adjustment in the firm-level production intensity and very little comes from the reaction on the number of goods. The other demand-side shocks (on fiscal and investment spending) are initially absorbed with the intensive margin but 10-15 quarters after the shock most of the effect left is explained by a procyclical extensive-margin adjustment.

The responses after a price-push shock are different from all the others. As shown in Figure 6, the contribution of the two margins go in the opposite direction, thus dampening the overall effect on total output. The price-push shock brings a strong countercyclical response in the total number of goods. The increase in n is more modest than the decline in the intensive margin adjustment, which finally brings a reduction of total output. Nevertheless, the variety effect dominates 8-10 quarters after the shock, and the response of output jumps over the positive side.

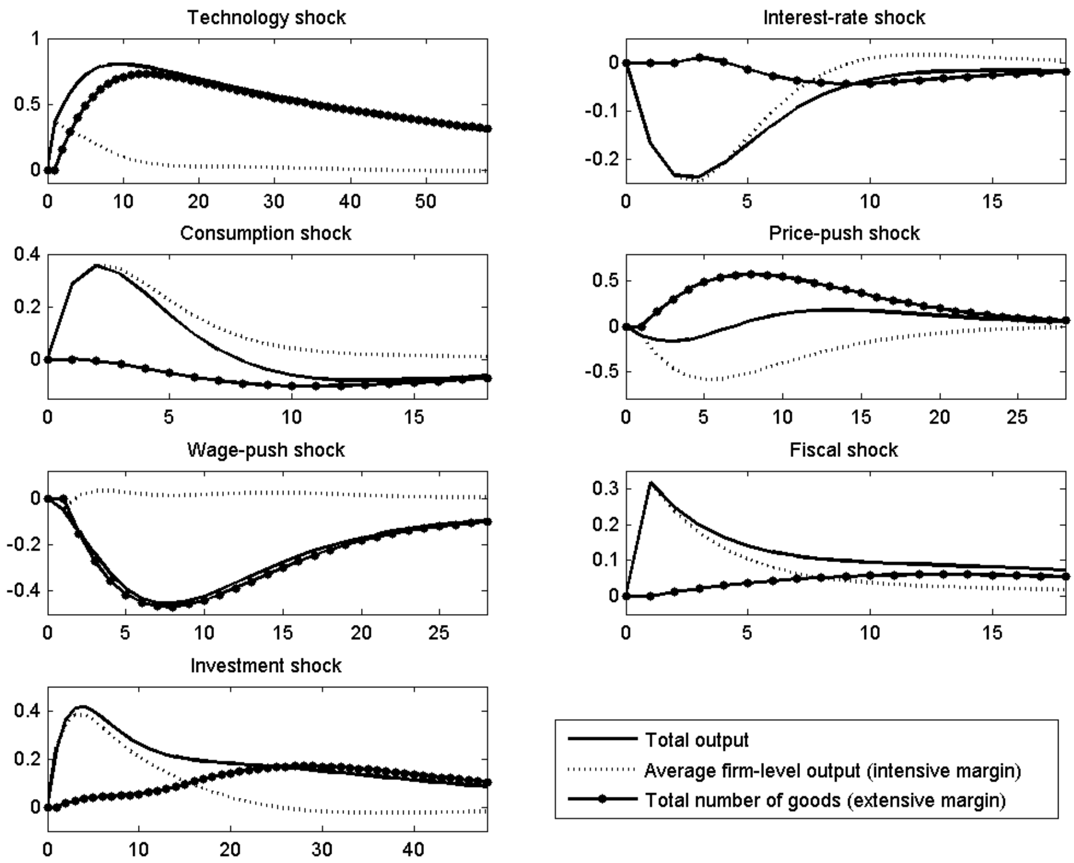

Figure 6: Shocks and business cycle fluctuations: decomposition between the extensive margin and the intensive margin.

Table 4 summarizes the contributions of the shocks to the relative variability on the margins of activity. The results have been obtained from model simulations at the estimated mean value of the structural parameters for 116 periods and the first 20 periods were discarded for a random start.[14] We repeated the simulation for 10,000 times and took the average ratios of the standard deviations of each margin of activity relative to output.

Table 4. Relative variability of the activity margins

	Extensive, $\frac{Std(\widehat{n})}{Std(\widehat{y})}$		Intensive, $\frac{Std\left(\widehat{\frac{\widetilde{P}}{P^c}\widetilde{y}}\right)}{Std(\widehat{y})}$	
All shocks	0.97		0.45	
Supply-side shocks	1.01		0.38	
Technology, η^a		0.93		0.17
Price-push, η^p		2.79		2.46
Wage-push, η^w		1.07		0.09
Demand-side shocks	0.58		0.81	
Consumption, η^b		0.57		1.01
Interest rate, η^R		0.27		1.22
Fiscal, η^g		0.41		0.77
Investment, η^i		0.63		0.71

As reported in Table 4, the difference in the business cycle variability is noticeable across both margins: the extensive margin is more volatile with a standard deviation that reaches 97% of that of output, while the intensive margin is at 45%. Nevertheless, the relative variability is quite sensitive to the type of shock. Supply-side shocks from either technology innovations or wage pushing bring most of the adjustment in output through changes in the number of goods. The standard deviation of the extensive margin conditional to supply shocks is almost 3 times higher than that of the intensive margin. In contrast, demand-side shocks bring extensive margin variability at 0.58% of total output variability while the variability of the adjustments in firm-level production is higher at 0.81% of total output. Since the estimated model gives more relevance to supply shocks than to demand shocks, the overall picture still shows a higher percentage of variability on the extensive margin than on the intensive margin over the estimated period.

Looking at single innovations, the wage-push shock is the one with stronger dependence on extensive margin adjustment whereas the interest rate shock brings the highest adjustment through the intensive margin.

[14] Furthermore, the sample period covers 96 observations which coincide with that of the US data used in the model estimation.

6 Conclusions

This paper introduces a DSGE model with endogenous creation and destruction of goods, which we refer, respectively, as entry and exit in the goods market. The main theoretical contribution is the endogenous choice of exit, that results from a comparison between the present value of future dividends and the liquidation value. Every period a fraction of low-productivity firms shut down because the expected stream of future dividends is lower than the liquidation value.

In the empirical section, we have carried out a Bayesian estimation of the DSGE model with entry and exit with US data during the Great Moderation and compare the results with a conventional DSGE model. The introduction of entry and exit raises the estimate of the Dixit-Stiglitz elasticity of substitution, which makes consumption be more sensitive to changes in relative prices. The model with entry and exit does not outperform the standard DSGE model but it is able to satisfactory document volatility, cyclical correlation and persistence of the observable series used in the estimation. The business cycle effects of assuming entry and exit have been discussed in the impulse-response functions and the variance decomposition. We found that technology shocks have a higher effect on economic activity in the extended model because of the amplifying effect of the total number of varieties. Thus, a positive technology shock increases the number of entries and reduces the number of exits, which results in a higher number of goods and the response of output is around twice what we observe in a standard model. A similar procyclical variety effect explains a greater response of output after a wage-push shock. These propagation mechanisms are not found after either a monetary or a consumption preference shock, because entry and exit react in the same direction and the number of varieties barely changes. A price-push shock brings a countercyclical response of the total number of varieties, which dampens the contractionary effects of exogenous inflation. In the margin decomposition of output, supply-side shocks are mostly absorbed through adjustments in the extensive margin (number of goods), while demand shocks have a deeper impact on the intensive margin (firm-level output).

Finally, we must comment on a limitation of the results. The business cycle analysis relies on a type of DSGE model with neither financial constraints nor a banking sector, which may be crucial elements for the decisions of entry and exit. In future research, we may try to extend this model to account for such financial aspects. Such model may be very useful to think of the contributions of the extensive margin of activity in business cycle fluctuations during the recent period of the Great Recession.

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APPENDIX

A. The DSGE model with endogenous entry and exit

Set of log-linearized (58) dynamic equations for fluctuations around the detrended steady state:

Law of motion for total number of goods:

$$\widehat{n}_{t+1} = \widehat{n}_t^A + \delta_n \left(\widehat{n}_t^E - \widehat{n}_t\right), \tag{A1}$$

where $\delta_n = \frac{n^X}{n}$ is the steady-state exit rate. Decomposition between surviving and exiting goods:

$$\widehat{n}_t = (1-\delta_n)\,\widehat{n}_t^A + \delta_n \widehat{n}_t^X. \tag{A2}$$

Entry dynamic equation:

$$\widehat{n}_t^E = \frac{1}{1+\overline{\overline{\beta}}}\widehat{n}_{t-1}^E + \frac{\overline{\overline{\beta}}}{1+\overline{\overline{\beta}}}E_t\widehat{n}_{t+1}^E + \frac{1}{\varphi_E\left(1+\overline{\overline{\beta}}\right)}\widehat{\widetilde{v}}_t. \tag{A3}$$

Equity accumulation equation (portfolio investment):

$$\widehat{\widetilde{v}}_t = \overline{\overline{\beta}}v_1 E_t\widehat{\widetilde{v}}_{t+1} + \overline{\overline{\beta}}v_2 E_t\widehat{\widetilde{d}}_{t+1} + \overline{\overline{\beta}}\,(v_1+v_2)\,\widehat{n}_t^A + \overline{\overline{\beta}}v_3\left(\widehat{n}_t^X + E_t\widehat{lv}_{t+1}\right) - \left(R_t - E_t\pi_{t+1}^c - r\right) - \widehat{n}_t, \tag{A4}$$

where $v_1 = \frac{\widetilde{v}}{(1-\delta_n)\left(\widetilde{d}+\widetilde{v}\right)+\delta_n lv}$, $v_2 = \frac{\widetilde{d}}{(1-\delta_n)\left(\widetilde{d}+\widetilde{v}\right)+\delta_n lv}$ and $v_3 = \frac{\delta_n lv/(1-\delta_n)}{(1-\delta_n)\left(\widetilde{d}+\widetilde{v}\right)+\delta_n lv}$.

Average firm dividend:

$$\widehat{\widetilde{d}}_t = \widehat{\widetilde{y}}_t + \widehat{\widetilde{\rho}}_t + (\theta_p - 1)\,\widehat{\mu}_t. \tag{A5}$$

Liquidation value:

$$\widehat{lv}_t = 0. \tag{A6}$$

Exit dynamics:

$$\widehat{n}_t^X = \widehat{n}_t + \kappa\left(\frac{1-\delta_n}{\delta_n}\right)\widehat{z}_t^c. \tag{A7}$$

Productivity cutoff point:

$$\widehat{z}_t^c = \overline{\overline{\beta}}E_t\widehat{z}_{t+1}^c + \left(1-\overline{\overline{\beta}}\right)\left(E_t\widehat{\widetilde{mc}}_{t+1} - (\theta_p-1)^{-1}E_t\widehat{\widetilde{y}}_{t+1}\right) + (\theta_p-1)^{-1}\left(\widehat{lv}_t - \overline{\overline{\beta}}E_t\widehat{lv}_{t+1}\right). \tag{A8}$$

Relative prices as a function of number of goods:

$$\widehat{\widetilde{\rho}}_t = \frac{1}{\theta_p - 1}\widehat{n}_t. \tag{A9}$$

Variety effect from producer price inflation to consumer price inflation:

$$\pi_t^c = \pi_t - \tfrac{1}{\theta_p - 1}\left(\widehat{n}_t - \widehat{n}_{t-1}\right). \tag{A10}$$

Output decomposition between intensive and extensive margin of fluctuations:

$$\widehat{y}_t = \widehat{n}_t + \widehat{\widetilde{\rho}}_t + \widehat{\widetilde{y}}_t. \tag{A11}$$

New-Keynesian Phillips curve from price-setting with adjustment costs and indexation:

$$\pi_t = \pi + \tfrac{\lambda_p}{(1+\overline{\overline{\beta}}\lambda_p)}\left(\pi_{t-1} - \pi\right) + \tfrac{\overline{\overline{\beta}}}{(1+\overline{\overline{\beta}}\lambda_p)}\left(E_t\pi_{t+1} - \pi\right) - \tfrac{(\theta_p - 1)}{\psi_p(1+\overline{\overline{\beta}}\lambda_p)}\widehat{\widetilde{\mu}}_t + \varepsilon_t^p. \tag{A12}$$

Mark-up

$$\widehat{\widetilde{\mu}}_t = \widehat{\widetilde{\rho}}_t - \widehat{\widetilde{mc}}_t. \tag{A13}$$

Real marginal cost:

$$\widehat{\widetilde{mc}}_t = (1-\alpha)\widehat{w}_t + \alpha\widehat{r}_t^k - \varepsilon_t^a. \tag{A14}$$

Consumption equation:

$$\widehat{c}_t = \tfrac{h/(1+\gamma)}{1+h/(1+\gamma)}\widehat{c}_{t-1} + \tfrac{1}{1+h/(1+\gamma)}E_t\widehat{c}_{t+1} - \tfrac{1-h/(1+\gamma)}{\sigma_c(1+h/(1+\gamma))}\Big(r_t - (1-\rho_b)\,\varepsilon_t^b\Big). \tag{A15}$$

Taylor-type monetary policy rule:

$$R_t = R + \mu_R\left(R_{t-1} - R\right) + (1-\mu_R)\left[\mu_\pi\left(\pi_t - \pi\right) + \frac{\mu_y}{4}\left(\widehat{y}_t - \widehat{y}_t^p\right)\right] + \mu_{dy}\left[\left(\widehat{y}_t - \widehat{y}_t^p\right) - \left(\widehat{y}_{t-1} - \widehat{y}_{t-1}^p\right)\right] + \varepsilon_t^R. \tag{A16}$$

Goods market equilibrium:

$$\widehat{y}_t = \tfrac{c}{y}\widehat{c}_t + \tfrac{i}{y}\widehat{i}_t + \tfrac{r^k k}{y}\widehat{u}_t + \varepsilon_t^g. \tag{A17}$$

Production technology for the average-productivity firm:

$$\widehat{\widetilde{y}}_t = \alpha\widehat{\widetilde{k}}_t + (1-\alpha)\widehat{\widetilde{l}}_t + \varepsilon_t^a. \tag{A18}$$

Fisher equation:

$$r_t = R_t - E_t\pi_{t+1}^c. \tag{A19}$$

Wage inflation equation with adjustment costs and indexation:

$$\pi_t^w = \pi^w + \tfrac{\overline{\overline{\beta}}}{1-\delta_n}E_t\left(\pi_{t+1}^w - \pi^w - \lambda_w\pi_t^c\right) + \lambda_w\pi_{t-1}^c + \tfrac{(\theta_w - 1)}{\psi_w}\left(\widehat{mrs}_t - \widehat{w}_t\right) + \varepsilon_t^w, \tag{A20}$$

where the log-linearized household marginal rate of substitution is,

$$\widehat{mrs}_t = \sigma_l\widehat{l}_t + \sigma_c\left(\tfrac{1}{1-h/(1+\gamma)}\widehat{c}_t - \tfrac{h/(1+\gamma)}{1-h/(1+\gamma)}\widehat{c}_{t-1}\right) - \varepsilon_t^b, \tag{A21}$$

and the real wage dynamics are determined by the log-linear expression implied by its definition ($w_t = W_t/P_t^C$),

$$\widehat{w}_t = \widehat{w}_{t-1} + \left(\pi_t^w - \pi^w\right) - \left(\pi_t^c - \pi\right). \tag{A22}$$

Labor market equilibrium condition:

$$\widehat{l}_t = \widehat{n}_t + \widehat{\widehat{l}}_t. \tag{A23}$$

Capital market equilibrium condition:

$$\widehat{k}_t = \widehat{n}_t + \widehat{\widehat{k}}_t. \tag{A24}$$

As in Smets and Wouters (2007), the log-linearized investment equation is,

$$\widehat{i}_t = i_1 \widehat{i}_{t-1} + (1 - i_1) E_t \widehat{i}_{t+1} + i_2 \widehat{q}_t + \varepsilon_t^i, \tag{A25}$$

where $i_1 = \frac{1}{1+\overline{\overline{\beta}}/(1-\delta_n)}$, and $i_2 = \frac{1}{\left(1+\overline{\overline{\beta}}/(1-\delta_n)\right)\gamma^2\varphi_k}$, and the value of capital goods (Tobin's q) is given, in log-linear terms by the arbitrage condition,

$$\widehat{q}_t = q_1 E_t \widehat{q}_{t+1} + (1 - q_1) E_t \widehat{r}_{t+1}^k - (r_t - r), \tag{A26}$$

where $q_1 = \frac{(1-\delta_k)}{\left(r^k+1-\delta_k\right)}$. Also, following Smets and Wouters (2007), the loglinear expression for capital accumulation is,

$$\widehat{k}_t = k_1 \widehat{k}_{t-1} + (1 - k_1)\widehat{i}_t + k_2 \varepsilon_t^i, \tag{A27}$$

where $k_1 = \frac{1-\delta_k}{1+\gamma}$ and $k_2 = \left(1 - \frac{1-\delta_k}{1+\gamma}\right)\left(1 + \overline{\overline{\beta}}/(1 - \delta_n)\right)(1 + \gamma)^2 \varphi_k$, where capital can be adjusted in the intensive margin (utilization rate) as well as the extensive margin,

$$\widehat{k}_t = \widehat{u}_t + \widehat{k}_{t-1}, \tag{A28}$$

and the log-linearized variable capital utilization rate is,

$$\widehat{u}_t = \left(\frac{1-\sigma_a}{\sigma_a}\right)\widehat{r}_t^k. \tag{A29}$$

Potential (natural-rate) block

Repeat all the equations with p superscript to denote the values reached under no rigidity on both price and wage adjustments, with the exceptions of the New Keynesian Phillips curve (A12) that is replaced by the constant price mark-up condition,

$$\widehat{\widehat{\rho}}_t^p = \widehat{\widehat{mc}}_t^p, \tag{A12^p}$$

and the wage inflation curve (A20) that is replaced by the constant wage mark-up condition,

$$\widehat{mrs}_t^p = \widehat{w}_t^p. \tag{A20^p}$$

Endogenous variables (58):

The following 29 variables: $\widehat{n}_{t+1}, \widehat{n}_t^E, \widehat{n}_t^X, \widehat{n}_t^A, \widehat{z}_t^c$, $\widehat{lv}_t$, $\widehat{\widehat{v}}_t$, $\widehat{\widehat{d}}_t$, $\widehat{\widehat{\rho}}_t$, $\widehat{y}_t$, $\widehat{c}_t$, $\widehat{i}_t$, $\widehat{u}_t$, $\widehat{q}_t$, $\widehat{k}_t$, $\widehat{l}_t$, $\widehat{\widehat{y}}_t$, $\widehat{\widehat{l}}_t$, $\widehat{\widehat{k}}_t$, $\widehat{\widehat{mc}}_t$, $\widehat{\widehat{\mu}}_t$, r_t, R_t, π_t, π_t^c, π_t^w, $\widehat{r}_t^k$, $\widehat{w}_t$, $\widehat{mrs}_t$, and the same set with p superscript to bring the variables corresponding to the potential block.

Exogenous variables (7):

- technology shock: $\varepsilon_t^a = \rho_a \varepsilon_{t-1}^a + \eta_t^a$ with $\eta_t^a \sim N\left(0, \sigma_{\eta^a}^2\right)$
- risk-premium shock: $\varepsilon_t^b = \rho_b \varepsilon_{t-1}^b + \eta_t^b$ with $\eta_t^b \sim N\left(0, \sigma_{\eta^b}^2\right)$
- monetary policy shock: $\varepsilon_t^R = \rho_R \varepsilon_{t-1}^R + \eta_t^R$ with $\eta_t^R \sim N\left(0, \sigma_{\eta^R}^2\right)$
- fiscal shock: $\varepsilon_t^g = \rho_g \varepsilon_{t-1}^g + \rho_{ga} \eta_t^a + \eta_t^g$ with $\eta_t^g \sim N\left(0, \sigma_{\eta^g}^2\right)$
- investment shock: $\varepsilon_t^i = \rho_i \varepsilon_{t-1}^i + \eta_t^i$ with $\eta_t^i \sim N\left(0, \sigma_{\eta^i}^2\right)$
- price-push shock: $\varepsilon_t^p = \rho_p \varepsilon_{t-1}^p - \mu_p \eta_{t-1}^p + \eta_t^p$ with $\eta_t^p \sim N\left(0, \sigma_{\eta^p}^2\right)$
- wage-push shock: $\varepsilon_t^w = \rho_w \varepsilon_{t-1}^w - \mu_w \eta_{t-1}^w + \eta_t^w$ with $\eta_t^w \sim N\left(0, \sigma_{\eta^w}^2\right)$

Set of non-linear equations that define the detrended steady state

There are 21 endogenous variables: n, n^E, n^X, n^A, r, r^k, $\widetilde{v}$, $\widetilde{d}$, $\widetilde{mc}$, $\widetilde{\rho}$, $\widetilde{y}$, $\widetilde{k}$, $\widetilde{l}$, y, c, i, w, f_E, lv, z^c, and $\widetilde{z}$. We normalize $z_{\min} = 1.0$ and steady-state government spending, ε^g, is assumed to be fixed in the calibration at constant 0.21 share with respect to output in steady-state, $\varepsilon^g = 0.21y$. The capital utilization rate is assumed to be equal to 100% in steady state ($u = 1$) and there are no costs of variable capital utilization ($a(u) = 0$). In addition, the steady state rate of inflation is at zero, which makes both price adjustment costs and wage adjustment costs be also zero in steady state ($Pac = Wac = 0$). The household discount rate adjusted for balanced-path growth is $\beta\left(1+\gamma\right)^{-\sigma_c}$. The value of the share of sunk costs at entry/exit, the parameter τ, is left out to imply that the total number of goods in steady state is normalized at $n = 1$, and the value of the weight of disutility of hours in U (the parameter Ξ) is set to normalize the hours of labor working in the average-productivity firm at $\widetilde{l} = 1$ in the steady-state wage markup.

The non-linear steady-state system to solve is

$$\widetilde{z} = \left(\tfrac{\kappa}{\kappa - (\theta_p - 1)}\right)^{\frac{1}{\theta_p - 1}} z_{\min}, \tag{SSA1}$$

$$n^E = \frac{1 - \left(\frac{z_{\min}}{z^c}\right)^{\kappa}}{\left(\frac{z_{\min}}{z^c}\right)^{\kappa}} n, \tag{SSA2}$$

$$n^A = \left(\tfrac{z_{\min}}{z^c}\right)^{\kappa} n, \tag{SSA3}$$

$$\frac{n^X}{n} = 1 - \left(\tfrac{z_{\min}}{z^c}\right)^{\kappa} = \delta_n, \tag{SSA4}$$

$$r = \beta^{-1}\left(1+\gamma\right)^{\sigma_c} - 1, \tag{SSA6}$$

$$r^k = r + \delta_K, \tag{SSA7}$$

$$\widetilde{v} = \frac{\beta(1+\gamma)^{-\sigma_c}\left((1-\delta_n)\widetilde{d} + \delta_n lv\right)}{1 - \beta(1+\gamma)^{-\sigma_c}(1-\delta_n)}, \tag{SSA8}$$

$$lv = \frac{\beta(1+\gamma)^{-\sigma_c}(1-\delta_n)}{1 - \beta(1+\gamma)^{-\sigma_c}(1-\delta_n)} \left(\frac{\widetilde{z}}{z^c}\right)^{1-\theta_p} \widetilde{d}, \tag{SSA9}$$

$$f_E = \widetilde{v}, \tag{SSA10}$$

$$lv = (1-\tau) f_E, \tag{SSA11}$$

$$y = c + i + \varepsilon^g, \tag{SSA12}$$

$$y = n\widetilde{\rho}\widetilde{y}, \tag{SSA13}$$

$$\widetilde{\rho} = n^{\frac{\theta_p}{\theta_p - 1}}, \tag{SSA14}$$

$$\widetilde{d} = \left(\frac{1}{\theta_p}\right) y, \tag{SSA15}$$

$$\widetilde{y} = \widetilde{z}\left(\widetilde{k}\right)^{\alpha}\left(\widetilde{l}\right)^{1-\alpha}, \tag{SSA16}$$

$$\widetilde{mc} = \frac{\theta_p - 1}{\theta_p}, \tag{SSA17}$$

$$\frac{1}{\widetilde{z}}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha} = \widetilde{mc}, \tag{SSA18}$$

$$w = \frac{\theta_w}{(\theta_w - 1)} \frac{\Xi\left(n\widetilde{l}\right)^{\sigma_l}}{\left(c - h(1+\gamma)^{-1}c\right)^{-\sigma_c}}, \tag{SSA19}$$

$$\widetilde{k} = \left(\frac{\alpha\widetilde{mc}\widetilde{z}}{r^k}\right)^{\frac{1}{1-\alpha}}, \tag{SSA20}$$

$$i = (\gamma + \delta_k)\, n\widetilde{k}. \tag{SSA21}$$

Numerical values at the mean value of the estimated parameters:

$n = 1.0000$, $n^E = 0.0289$, $n^X = 0.0281$, $n^A = 0.9719$, $r = 0.0068$, $\widetilde{v} = 46.4538$, $\widetilde{d} = 1.3791$, $w = 2.7114$, $\widetilde{mc} = 0.7182$, $\widetilde{y} = 4.8940$, $\widetilde{k} = 24.9335$, $\widetilde{l} = 1.0000$, $\widetilde{\rho} = 1.000$, $y = 4.8940$, $c = 3.1559$, $i = 0.7104$, $\varepsilon^g = 1.0277$, $lv = 4.9140$, $z^c = 1.0100$, and $\widetilde{z} = 2.3462$. In addition, the calibrated parameters are $\tau = 0.8942$ and $\Xi = 1.4257$.

B. Conventional DSGE model

The canonical DSGE model is a particular case of the extended model with entry and exit described in section A of this Appendix. The total number of goods is fixed at $n = 1$ on a quarter-to-quarter basis, there is no entry of goods, no possibility for exiting, all the intermediate-good firms are identical (with no firm-specific productivity), firm-level variables coincide with aggregate variables in symmetric equilibrium, there is no variety effect and no distinction between consumer inflation and producer inflation, and the relative price ρ is constant and equal to 1. In turn, equations (A1)-(A11) are dropped from the system, and the rest of the equations should be rewritten with $\widehat{n}_t = 0$, $\widehat{\widetilde{\rho}}_t = 0$, $\pi_t^c = \pi_t$ and $E_t\pi_{t+1}^c = E_t\pi_{t+1}$. It results in a set of 38 equations that can be used to find solution paths of the 38 endogenous variables: $\widehat{y}_t$, $\widehat{c}_t$, $\widehat{i}_t$, $\widehat{u}_t$, $\widehat{q}_t$, $\widehat{k}_t$, $\widehat{l}_t$, $\widehat{\widetilde{y}}_t$, $\widehat{\widetilde{l}}_t$, $\widehat{\widetilde{k}}_t$, $\widehat{\widetilde{mc}}_t$, $\widehat{\widetilde{\mu}}_t$, r_t, R_t, π_t, π_t^w, $\widehat{r}_t^k$, $\widehat{w}_t$, $\widehat{mrs}_t$, and the same set with p superscript to bring the variables corresponding to the potential block. The exogenous variables are the same as introduced in the extended model.

In the detrended steady-state, the system presented in the extended model simplifies to,

$$r = \overline{\beta}^{-1} - 1, \tag{SSB1}$$

$$r^k = \overline{\beta}^{-1} - (1 - \delta_K), \tag{SSB2}$$

$$y = c + i + \varepsilon^g, \tag{SSB3}$$

$$y = (k)^{\alpha}(l)^{1-\alpha}, \tag{SSB4}$$

$$mc = \frac{\theta_p - 1}{\theta_p}, \tag{SSB5}$$

$$\frac{1}{\tilde{\tilde{z}}}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{r^k}{\alpha}\right)^{\alpha} = mc, \tag{SSB6}$$

$$w = \frac{\theta_w}{(\theta_w - 1)} \frac{\Xi(l)^{\sigma_l}}{\left(c - h(1+\gamma)^{-1}c\right)^{-\sigma_c}}, \tag{SSB7}$$

$$k = \left(\frac{\alpha mc}{r^k}\right)^{\frac{1}{1-\alpha}}, \tag{SSB8}$$

$$i = (\gamma + \delta_k)\, k. \tag{SSB9}$$

Numerical values at the mean value of the estimated parameters:

$r = 0.0082$, $w = 0.9225$, $mc = 0.7297$, $y = 1.6545$, $k = 8.4517$, $l = 1.0000$, $c = 1.0507$, $i = 0.2564$, and $\varepsilon^g = 0.3474$. In addition, the calibrated parameter is $\Xi = 1.1679$.

C. Derivation of the loglinearized equation for fluctuations of critical productivity, z^c

The exit condition at the margin is defined in the text as follows,

$$E_t \sum_{j=1}^{\infty} \overline{\beta}^j d^c_{t+j} = lv_t, \tag{C1}$$

which can be rewritten in log-linear terms to read,

$$d^c E_t \sum_{j=1}^{\infty} \overline{\overline{\beta}}^j \widehat{d}^c_{t+j} = lv\widehat{lv}_t, \tag{C2}$$

where d^c and lv are the steady-state level $\overline{\overline{\beta}} = \overline{\beta}(1-\delta_n)(1+\gamma)$ is the discount factor consistent with a balanced-path detrended steady state. The liquidation value in such detrended steady state is $lv = \frac{\overline{\overline{\beta}}}{1-\overline{\overline{\beta}}} d^c$, that can be used in (C2) to yield,

$$\left(1 - \overline{\overline{\beta}}\right) E_t \sum_{j=0}^{\infty} \overline{\overline{\beta}}^j \widehat{d}^c_{t+1+j} = \widehat{lv}_t. \tag{C3}$$

The real dividend can be written in terms of the mark-up, the real marginal cost, the aggregate consumption demand and the price adjustment cost,

$$d^c_t = (\mu^c_t - 1)(\mu^c_t)^{-\theta_p}(mc^c_t)^{1-\theta_p} y_t - Pac^c_t. \tag{C4}$$

Recalling that the price adjustment costs are zero in steady state, the loglinearized version of (C4) is,

$$\widehat{d}^c_t = \widehat{y}_t + (\theta_p - 1)\,\widehat{mc}^c_t.$$

Generalizing the last expression for any $t+1+j$ period and inserting it into (C3) leads to,

$$\left(1 - \overline{\overline{\beta}}\right) E_t \sum_{j=0}^{\infty} \overline{\overline{\beta}}^j \left(\widehat{y}_{t+1+j} + (\theta_p - 1)\,\widehat{mc}^c_{t+1+j}\right) = \widehat{lv}_t, \tag{C5}$$

As discussed in the main text, there is a link between the real marginal cost of the cut-off business and the average business, $mc^c_{t+1+j} = \widetilde{mc}_{t+1+j}\frac{\widetilde{z}}{z^c_t}$, that can be loglinearized and plugged in (C5) to obtain,

$$\left(1-\overline{\overline{\beta}}\right)E_t\sum_{j=0}^{\infty}\overline{\overline{\beta}}^j\left(\widehat{y}_{t+1+j}+(\theta_p-1)\widehat{\widetilde{mc}}_{t+1+j}-(\theta_p-1)\widehat{z}^c_t\right)=\widehat{lv}_t. \tag{C6}$$

The log fluctuation of the critical productivity $\widehat{z}^c_t$ can be extracted from (C6) and moved alone to the left side in order to get,

$$\widehat{z}^c_t=\left(1-\overline{\overline{\beta}}\right)E_t\sum_{j=0}^{\infty}\overline{\overline{\beta}}^j\left((\theta_p-1)^{-1}\widehat{y}_{t+1+j}+\widehat{\widetilde{mc}}_{t+1+j}\right)-(\theta_p-1)^{-1}\widehat{lv}_t. \tag{C7}$$

Moving $\widehat{z}^c_t$ from (C7) one period ahead and taking the difference $\widehat{z}^c_t-\overline{\overline{\beta}}E_t\widehat{z}^c_{t+1}$ results in the final log-linear equation for the productivity threshold,

$$\widehat{z}^c_t=\overline{\overline{\beta}}E_t\widehat{z}^c_{t+1}+\left(1-\overline{\overline{\beta}}\right)(\theta_p-1)^{-1}\widehat{y}_{t+1}+\left(1-\overline{\overline{\beta}}\right)\widehat{\widetilde{mc}}_{t+1}-(\theta_p-1)^{-1}\left(\widehat{lv}_t-\overline{\overline{\beta}}E_t\widehat{lv}_{t+1}\right).$$

D. Derivation of the overall resources constraint in the model with entry and exit

The household budget constraint is (equation 3 in the main text),

$$\left[\frac{W_t(j)}{P^c_t}l_t(j)-Wac_t(j)\right]+r^k_tu_t(j)k_{t-1}(j)+\left[\frac{n^A_{t-1}}{n_{t-1}}\left(\widetilde{d}_t+\widetilde{v}_t\right)+\frac{n^X_{t-1}}{n_{t-1}}lv_t\right]\left(x_{t-1}(j)+F_{n,t-1}(.)\,n^E_{t-1}(j)\right)-t_t=$$
$$c_t(j)+i_t(j)+a_t(u_t(j))k_t(j)+\widetilde{v}_tx_t(j)+\frac{b_{t+1}(j)}{1+r_t}-b_t(j)+f^En^E_t(j).$$

First, assuming symmetry between households and also the equilibrium condition for the portfolio shares, $x_{t-1}(j)=n_{t-1}$ and $x_t(j)=n_t$, it is obtained,

$$[w_tl_t-Wac_t]+r^k_tu_tk_{t-1}+\left[\frac{n^A_{t-1}}{n_{t-1}}\left(\widetilde{d}_t+\widetilde{v}_t\right)+\frac{n^X_{t-1}}{n_{t-1}}lv_t\right]\left(n_{t-1}+F_{n,t-1}(.)\,n^E_{t-1}\right)-t_t=$$
$$c_t+i_t+a_t(u_t)k_t+\widetilde{v}_tn_t+\frac{b_{t+1}}{1+r_t}-b_t+f^En^E_t.$$

The law of motion for the number of varietiesb $n_t=\frac{n^A_{t-1}}{n_{t-1}}\left(n_{t-1}+F_{n,t-1}(.)\,n^E_{t-1}\right)$ serves to cancel the equity term $\widetilde{v}_tn_t$ in order to yield,

$$[w_tl_t-Wac_t]+r^k_tu_tk_{t-1}+n_t\widetilde{d}_t+lv_t\left[n^X_{t-1}+\frac{n^X_{t-1}}{n_{t-1}}F_{n,t-1}(.)\,n^E_{t-1}\right]-t_t=$$
$$c_t+i_t+a_t(u_t)k_t+\frac{b_{t+1}}{1+r_t}-b_t+f^En^E_t,$$

where plugging the government constraint, $\varepsilon^g_t=t_t+\left(f^En^E_t-lv_t\left(n^X_{t-1}+\frac{n^X_{t-1}}{n_{t-1}}F_{n,t-1}(.)\,n^E_{t-1}\right)\right)+\frac{b_{t+1}}{1+r_t}-b_t$,

we reach,

$$[w_tl_t-Wac_t]+r^k_tu_tk_{t-1}+n_t\widetilde{d}_t=c_t+i_t+a_t(u_t)k_t+\varepsilon^g_t.$$

Next, introducing the input markets equilibria, $l_t=n_t\widetilde{l}_t$, and, $u_tk_{t-1}=n_t\widetilde{k}_t$, yields,

$$\left[w_tn_t\widetilde{l}_t-Wac_t\right]+\left[r^k_tn_t\widetilde{k}_t\right]+n_t\widetilde{d}_t=c_t+i_t+a_t(u_t)k_t+\varepsilon^g_t.$$

The average dividend of firms that produce intermediate goods, $\widetilde{d}_t = \widetilde{\rho}_t \widetilde{y}_t - w_t \widetilde{l}_t - r_t^k \widetilde{k}_t - \widetilde{Pac}_t$, can be substituted in the previous expression to obtain,

$$-Wac_t + n_t \widetilde{\rho}_t \widetilde{y}_t - n_t \widetilde{Pac}_t = c_t + i_t + a_t(u_t)k_t + \varepsilon_t^g,$$

where since, $\widetilde{\rho}_t n_t \widetilde{y}_t = y_t$, we get the market-clearing expression for final-good output,

$$y_t = c_t + i_t + a_t(u_t)k_t + \varepsilon_t^g + n_t \widetilde{Pac}_t + Wac_t.$$

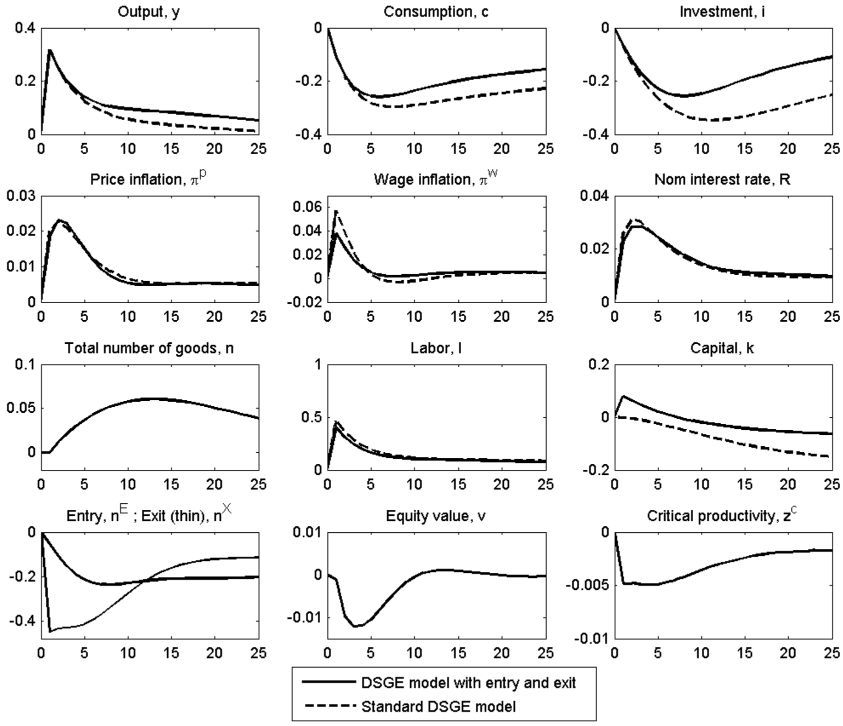
E. Measurement equations for the observable series at the estimation

Series definition	US Data	Model measurement equation
Quarterly % change in per-capita Real Gross Domestic Product, Y/L	$100\log\left(\frac{Y_t/L_t}{Y_{t-1}/L_{t-1}}\right)$	$\gamma + \widehat{y}_t - \widehat{y}_{t-1}$
Quarterly % change in per-capita Real Personal Consumption Expenditures, C/L	$100\log\left(\frac{C_t/L_t}{C_{t-1}/L_{t-1}}\right)$	$\gamma + \widehat{c}_t - \widehat{c}_{t-1}$
Quarterly % change in per-capita Real Private Nonresidential Fixed Investment, I/L	$100\log\left(\frac{I_t/L_t}{I_{t-1}/L_{t-1}}\right)$	$\gamma + \widehat{i}_t - \widehat{i}_{t-1}$
Quarterly % change in GDP Price Deflator, P	$100\log\left(\frac{P_t}{P_{t-1}}\right)$	π_t
Quarterly % change in Average Hourly Earnings of Prod.and Nonsupervisory Employess: Total Private, W	$100\log\left(\frac{W_t}{W_{t-1}}\right)$	$\gamma + \pi_t^w$
Effective Federal Funds Rate (3-month average), R	$R_t/4$	$r + \pi + R_t$

The series of the Civilian Labor Force L has been smoothed for adjustments in population controls, following the data treatment of the Current Population Survey released by the Bureau of Labor Statistics.

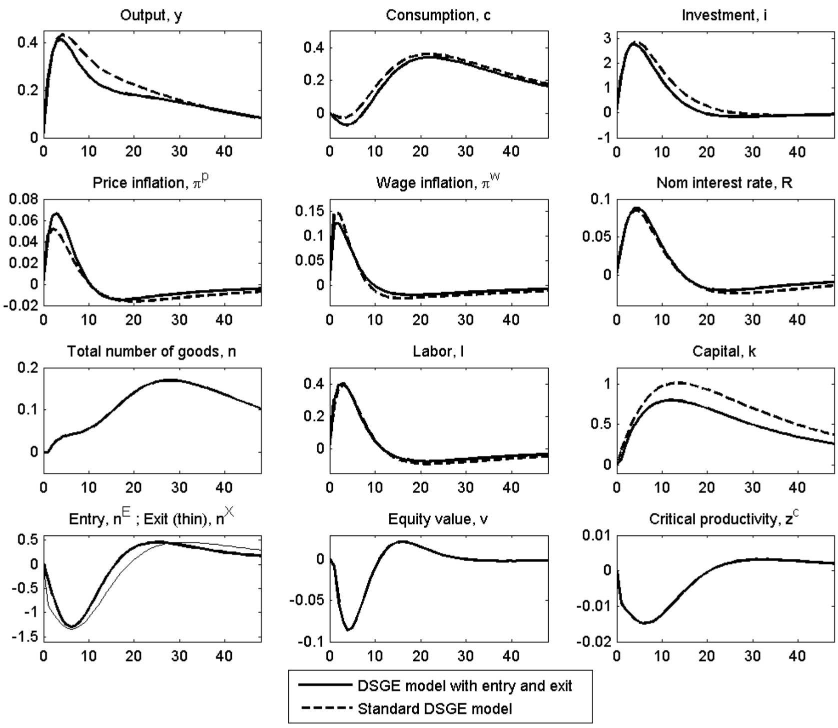
F. Impulse response functions not displayed in the main text.

Exogenous spending shock (fiscal/net exports). A exogenous spending shock provides a procyclical mild response of the total number of goods, basically observed due to the fall in exit. Even though input productivity is rising, the aggregate demand effect dominates on the fluctuation of the critical productivity z^c, which moves down to explain the reduction of business destruction. As a result of the mild procyclical move of the total number of goods, output slightly rises more in the extended model. Price inflation and the nominal interest rate display similar responses across models.



Impulse-response functions. Exogenous spending (fiscal) shock.

Investment shock. The most noticeable effects of the investment shock are observed in the quantity of investment spending. Both entry and exit fall as a reaction, respectively, to lower equity and a lower productivity threshold. The effect on the total number of goods is mostly procyclical, though it shows small and erratic increases with a peak below 0.2% nearly 30 quarters after the shock. All the common variables report similar responses across models with the exception of a greate increase of the stock of capital in the standard model that replaces the increase of varieties observed in the model with entry and exit.



Impulse-response function. Investment spending shock.