Working paper research
n° 103 October 2006

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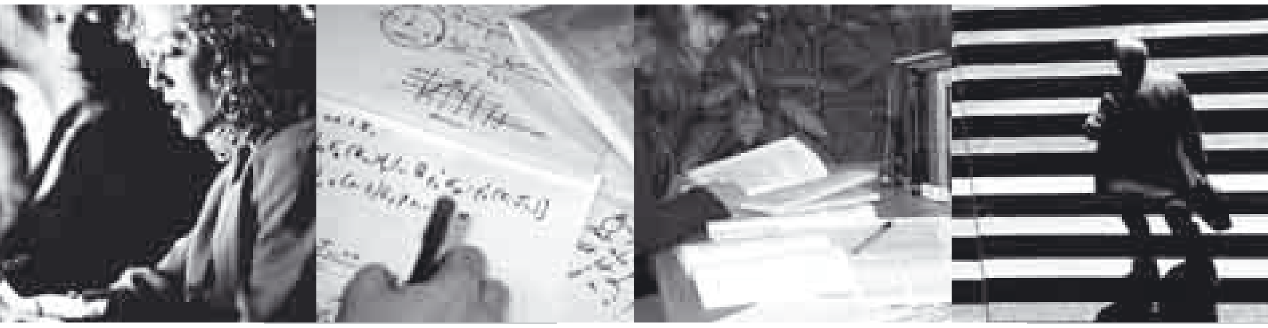

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MACROECONOMIC FLUCTUATIONS AND FIRM ENTRY: THEORY AND EVIDENCE

Vivien Lewis (*)

This paper was written while the author was visiting the National Bank of Belgium. I thank the staff at the NBB for their hospitality. Thanks to Raf Wouters for invaluable guidance. Thanks to Paul de Grauwe, Michael Devereux, Chris Marsh, Philippe Moës, Gert Peersman and Klaus Wälde for useful comments, as well as seminar participants at the NBB, Catholic University Leuven, ZEI Summer School 2006, SCE Conference 2006, 2nd German Macro Workshop at Goethe University Frankfurt. All errors are my own.

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Imprint: Responsibility according to the Belgian law: Jean Hilgers, Member of the Board of Directors, National Bank of Belgium.

ISSN: 1375-680X

Abstract

This paper studies the behaviour of firm entry and exit in response to macroeconomic shocks. We formulate a dynamic stochastic general equilibrium model with an endogenous number of producers. From the calibrated model, we derive a minimum set of robust sign restrictions to identify four kinds of macroeconomic shocks in a vector autoregression, namely supply, demand, monetary and entry cost shocks. The variables entering the VAR are output, inflation, the nominal interest rate, profits and firm entry. The response of firm entry to the various shocks is freely estimated. Our main finding is that entry responds significantly to all types of shocks. The results also show a crowding-in of firm entry following an exogenous rise in demand, consistent with the effect of a consumption preference shock predicted by the model.

JEL classification: E30, E32.

Keywords: firm entry, VAR, business cycles.

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1 Introduction

Since the ground-breaking contribution of Krugman (1979), a growing theoretical literature analyses the interaction between the number of firms and other macroeconomic variables in the context of (dynamic) general equilibrium models.[1] This paper provides an empirical evaluation of this link using model-based sign restrictions to identify the main types of aggregate shocks in a vector autoregression (VAR).

In many macroeconomic models, the number of firms is fixed. In light of evidence of considerable firm entry and exit over the business cycle, this is not a very realistic assumption. There is a need to endogenise the number of firms, for at least three reasons.

Firstly, following Krugman, we equate the number of producers with the number of goods varieties. A constant set of goods rules out any welfare effects through the introduction of new varieties. If such welfare effects are positive and significant, a constant-bundle price index overstates the true cost of living. The more consumers value variety, the greater is the divergence between the constant-varieties-CPI and the welfare-based price index. Hausman (2002) demonstrates that the failure to account for new goods leads to a first-order bias in the CPI. In several micro studies, Hausman estimates the welfare effects of new goods. In an application to mobile phones, Hausman (1999) shows that the exact price index for telecommunications services decreased over the period 1988-97, while the index computed by the US Bureau of Labor Statistics (BLS) rose by 10%. Broda and Weinstein (2004) construct an exact import price index for the US over the period 1972-2001, during which the number of varieties imported by the US quadrupled. They find that the conventional import price index is biased upward by 1.2 percent per year, which translates into a welfare gain of 2.8 percent of GDP. To summarise, there is plenty of evidence that new varieties give rise to substantial welfare gains, which is important for the accurate measurement of price indexes. In our empirical exercise, net entry can be regarded as a proxy for the change in the number of goods varieties.

Secondly, as shown in Bilbiie et al (2005) and Bergin and Corsetti (2005), endogenising the number of firms adds an internal propagation mechanism to macroeconomic models, such that less persistence has to be imposed on exogenous shocks in order to generate realistic dynamics. In addition, optimal monetary policy has to be reconsidered. On the one hand, the issue of measurement error in the price index becomes relevant for a central bank that targets inflation. On the other hand, output stabilisation now has two dimensions: the output per firm can deviate from its optimal level, as can the number of firms.

[1] See Chatterjee and Cooper (1993), Devereux et al (1996), Campbell (1997) or the more recent contributions Gertler and Comin (2003), Bilbiie et al (2005), Bergin and Corsetti (2005).

Finally, the number of producers might influence the degree of competition in an economy. In particular, as more firms enter, products may become more substitutable. This reduces firm markups and thus the monopolistic distortion. See Bergin and Corsetti (2005), Gertler and Comin (2003) and Jaimovich (2004) for models in which markups depend on the number of competitors.

We build a simple dynamic stochastic general equilibrium model with firm dynamics. The combination of variety-loving consumers and a sunk entry cost in production make the number of firms/varieties endogenous. There is no capital in this world. Instead, investment is along the extensive margin; i.e. profit opportunities lead to firm entry. We distinguish between two types of productivity. Manufacturing productivity determines the variable costs of an established firm. Startup productivity affects entry costs. Shocks to entry costs are similar to investment-cost shocks in the standard model with capital. Agents respond to investment opportunities by financing new firm startups. The introduction of a nominal rigidity in wage setting allows for an effect of monetary policy on firm entry. A subset of the short run impulse responses predicted by our calibrated model are used as sign restrictions to identify shocks in a vector autoregression. Four classes of shocks are identified: supply, demand, monetary and entry cost shocks. Our identifying restrictions are robust to varying the model parameters within sensible ranges. The responses of firm entry, which we include as a variable in the VAR, are left unrestricted. The model evaluation exercise consists of comparing the estimated responses with the theoretical ones.

The contribution of this paper is twofold. First, we build a model with endogenous firm entry featuring all the main types of macroeconomic disturbances. Second, we take this model to the data in a rigorous way. Bergin and Corsetti (2005) focus on stabilisation policy; in a VAR exercise, they identify only one type of shock (a monetary policy shock). To our knowledge, no other attempts have been made in the literature to analyse empirically the conditional properties of firm entry. Our theoretical model is inspired by Bilbiie et al (2005). In contrast to their model, however, we assume monopolistic competition in labour markets and sticky wages, which introduces a role for monetary policy. In addition, we consider productivity shocks in manufacturing that do not directly affect firm startup costs. This is because manufacturing and startup activities use labour inputs with different technologies. This contrasts with Bilbiie et al (2005), who assume that labour productivity affects the production of goods and the production of firms in the same way. See also Corsetti et al (2005), who make the same assumption as we do, but in an open economy setting. Finally, we introduce adjustment costs to firm entry, in order to match the dynamic profile of entry in the data.

2 Firm entry and exit over the business cycle: some evidence

The number of firms varies over the business cycle. For the US, the cyclical properties of net entry have been documented by Chatterjee and Cooper (1993), Devereux et al (1996) and Campbell (1997). Bilbiie et al (2005) show that net entry and profits comove, and both are strongly procyclical. As shown in Figures 1 and 2, the cyclical components of US (net) entry and real GDP comove. The correlation between output and net entry measured as net business formation (NBF) is 0.71, while the correlation between output and new incorporations (NI) is 0.35. Similar to capital investment, firm entry is more volatile than GDP over the cycle, the standard deviation of NBF and NI relative to that of output is 2.19 and 3.13, respectively.

Further evidence on firm dynamics in the macroeconomy come from vector autoregressions. Bergin and Corsetti (2005) estimate a 5-variable VAR, using a recursive method to identify monetary policy shocks. When firm entry is measured as an index of net business formation, they find that entry responds positively to expansionary monetary policy shocks. We replicate their exercise; the results and details of the VAR ordering are given in Figure 3. The response of the entry-variable to monetary policy shocks is significant and exhibits a hump-shaped profile.

3 A macro model with firm dynamics

In this section, we present a dynamic stochastic general equilibrium (DSGE) model of a closed economy. In contrast to contributions such as Christiano et al (2005) and Smets and Wouters (2003) who assume a variable capital stock and a fixed number of producers, we abstract from variations in capital and instead endogenise the number of firms. This requires two assumptions: firstly, love of variety in consumption and secondly, a sunk entry cost and free entry in production.

3.1 Preferences and intratemporal optimisation

The economy is populated by a continuum of infinitely-lived households, indexed by $h \in (0, 1)$. Each household maximises expected lifetime utility

$$E_t \sum_{s=0}^{\infty} \beta^s U_{t+s}(h)$$

where β is the subjective discount factor. Period t utility is a positive function of consumption, $C_t(h)$, and a negative function of labour effort, $L_t(h)$,

$$U_t(h) = \frac{\varepsilon_t^b}{1-\gamma} C_t(h)^{1-\gamma} - \frac{\kappa_t}{1+\varphi} L_t(h)^{1+\varphi}$$

where γ is the inverse of the intertemporal elasticity of substitution and φ is the inverse of the elasticity of labour supply with respect to the real wage. ε_t^b and κ_t are shocks to consumption and labour supply, respectively, and both follow AR(1) processes. The consumption utility enjoyed by household h is defined over a fixed set Ω of differentiated varieties, indexed by ω

$$C_t(h) = A_t \left(\int_{\omega \in \Omega} c_t(\omega, h)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}} \tag{1}$$

where

$$A_t \equiv N_t^{\xi - \frac{1}{\theta-1}}$$

θ is the elasticity of substitution between goods, N_t is the number of varieties consumed and $\xi \geqslant 0$ is the degree of love of variety (LOV).[2] We do not consider the case where $\xi < 0$, which implies that consumers dislike variety. If $\xi = 0$, agents are indifferent between consuming more or fewer varieties. Note that $A_t > 1$ if the love of variety is higher than the Dixit-Stiglitz (1977) benchmark, i.e. if $\xi > \frac{1}{\theta-1}$. Only a subset of goods $\Omega_t \subset \Omega$ is available at time t. The consumption-based price index is the minimum cost of one unit of the consumption bundle $C_t(h)$. With the specification of utility in (1), the associated price index is

$$P_t = \frac{1}{A_t} \left(\int_{\omega \in \Omega_t} p_t(\omega)^{1-\theta} d\omega \right)^{\frac{1}{1-\theta}} \tag{2}$$

where $p_t(\omega)$ is the price of variety ω. The intratemporal optimisation problem for the representative agent h is to choose $c_t(\omega, h)$ to maximise $C_t(h)$, given total expenditure $\int_{\omega \in \Omega_t} p_t(\omega) c_t(\omega, h) d\omega$. Household demand for each individual good is

$$c_t(\omega, h) = A_t^{\theta-1} \left(\frac{p_t(\omega)}{P_t} \right)^{-\theta} C_t(h) \tag{3}$$

3.2 Government

For simplicity, we suppose that the government has the same consumption preferences as the household, with elasticity of substitution θ and love of variety ξ.

$$G_t = A_t \left(\int_{\omega \in \Omega} g_t(\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}}$$

This implies that the price of one unit of G_t is given by (2) and that government demand for variety ω is analogous to private demand

$$g_t(\omega) = A_t^{\theta-1} \left(\frac{p_t(\omega)}{P_t} \right)^{-\theta} G_t \tag{4}$$

The government budget constraint is $G_t = T_t$, where government spending G_t is exogenous and follows an AR(1) process (in logs). T_t denotes net lump sum taxes.

[2] This definition of the consumption bundle disentangles the elasticity of substitution, which captures the degree of competition, from the taste for variety, which is a preference parameter. More details on this distinction can be found in Dixit and Stiglitz (1975) or Bénassy (1996). Ethier (1982) interprets equation (1) as a production function with increasing returns to specialisation.

3.3 Firms

Each firm uses the whole range of labour types to produce a single variety ω, given the following production technology

$$y_t(\omega) = Z_{C,t} l_{C,t}(\omega) \tag{5}$$

Manufacturing productivity, $Z_{C,t}$, measures the efficiency of one labour unit in producing consumption goods. $Z_{C,t}$ is exogenous and follows an AR(1) process (in logs). The labour input is defined as a bundle over all labour types

$$l_{C,t}(\omega) \equiv \left(\int_0^1 l_{C,t}(h,\omega)^{\frac{\phi-1}{\phi}} dh \right)^{\frac{\phi}{\phi-1}}$$

where $l_{C,t}(h,\omega)$ is the firm's demand for labour type h in the production of variety ω and ϕ is the elasticity of substitution between labour types. The economy-wide wage index is the minimum cost of one unit of the labour bundle $l_{C,t}$, which turns out to be symmetric across firms

$$W_t = \left(\int_0^1 W_t(h)^{1-\phi} dh \right)^{\frac{1}{1-\phi}}$$

where $W_t(h)$ is the wage received by worker h. Profit-maximising firms set prices $p_t(\omega)$ as a constant markup over marginal cost. A firm's relative price, defined as $\rho_t(\omega) \equiv p_t(\omega)/P_t$, is therefore

$$\rho_t(\omega) = \frac{\theta}{\theta-1} \frac{w_t}{Z_{C,t}} \tag{6}$$

where $w_t \equiv W_t/P_t$ is the real wage. Operating profits (not taking into account entry costs) are given by

$$d_t(\omega) = \frac{1}{\theta} \rho_t(\omega) y_t(\omega) \tag{7}$$

The total demand for variety ω, $y_t(\omega)$, is found by summing the private demands (3) over households and adding government demand (4)

$$y_t(\omega) = A_t^{\theta-1} \rho_t(\omega)^{-\theta} Y_t^C \tag{8}$$

where $Y_t^C \equiv C_t + G_t$ denotes aggregate consumption output and $C_t = \int_0^1 C_t(h)\, dh$. The demand for each variety is affected by aggregate consumption and firm entry. On the one hand, a rise in aggregate consumption demand increases the demand for each individual good. In particular, the output of existing firms must rise as long as the number of firms is fixed. On the other hand, firm entry leads to a reallocation of expenditure away from existing goods and towards new goods. This negative externality from firm entry reduces the output and profits of incumbent firms.

Marginal costs are the same across firms (see equation (6)), implying that equilibrium prices, quantities and profits are symmetric: $p_t(\omega) = p_t$, $l_{C,t}(\omega) = l_{C,t}$, $y_t(\omega) = y_t$ and

$d_t(\omega) = d_t$. Aggregate profits are $D_t = d_t N_t$, where N_t is the number of firms. The symmetry of prices implies that the price index (2) reduces to $P_t = N_t^{-\xi} p_t$, such that the relative price can be written as

$$\rho_t = N_t^{\xi} \tag{9}$$

There is a sunk entry cost facing each prospective entrant. Firms must meet this sunk cost one period in advance of producing and selling each firm-specific differentiated variety.

$$F_t = Z_{E,t} l_{E,t} \tag{10}$$

Setting up a new firm requires F_t effective labour units, or $F_t/Z_{E,t}$ units of the labour bundle $l_{E,t}$, which is defined as

$$l_{E,t} \equiv \left(\int_0^1 l_{E,t}(h)^{\frac{\phi-1}{\phi}} dh \right)^{\frac{\phi}{\phi-1}}$$

Startup productivity $Z_{E,t}$ measures the efficiency with which labour services are used to create new firms. Notice that the sunk entry cost is the same for any candidate entrant.

Let $N_{E,t}$ be the number of entrants in period t. Labour is needed for the production activities of the existing firms ($N_t l_{C,t}$), as well as for firm startups ($N_{E,t} l_{E,t}$). Using the production functions (5) and (10), total labour demand at time t can be written as

$$L_t = \frac{N_t y_t}{Z_{C,t}} + \frac{N_{E,t} F_t}{Z_{E,t}} \tag{11}$$

In the two sectors, symmetric firm demand for labour type h is given by

$$\begin{aligned} l_{C,t}(h) &= \left(\frac{W_t(h)}{W_t} \right)^{-\phi} l_{C,t} \\ l_{E,t}(h) &= \left(\frac{W_t(h)}{W_t} \right)^{-\phi} l_{E,t} \end{aligned}$$

Total demand for labour type h is therefore

$$\begin{aligned} L_t(h) &= N_t l_{C,t}(h) + N_{E,t} l_{E,t}(h) \\ &= \left(\frac{W_t(h)}{W_t} \right)^{-\phi} L_t \end{aligned}$$

3.4 Budget constraint and intertemporal optimisation

The household's period budget constraint is

$$\frac{B_t(h)}{P_t} + \frac{w_t N_{E,t}(h)}{Z_{E,t}} + C_t(h) + T_t(h) = R_t \frac{B_{t-1}(h)}{P_t} + d_t N_t(h) + w_t(h) L_t(h) \tag{12}$$

On the income side, we have gross interest income on bond holdings $B_t(h)$, profit income, and wage income. On the expenditure side, we have purchases of bonds, investment in new firms, consumption, and lump-sum taxes. $R_t \equiv 1 + i_t$ denotes the gross interest rate on holdings of nominal bonds between $t-1$ and t.

Maximising utility with respect to consumption $C_t(h)$, subject to the budget constraint, gives the following first order condition

$$\mu_t = \varepsilon_t^b C_t^{-\gamma}$$

where μ_t is the Lagrange multiplier on the budget constraint (12). We have dropped the index h from this expression as we assume that there are state-contingent securities markets that allow for complete consumption risk sharing across households, such that $\mu_t(h) = \mu_t$ for all h.

The household further chooses $B_t(h)$ to maximise utility subject to the budget constraint, which yields the familiar Euler equation for bond holdings

$$\mu_t = \beta R_t E_t \left\{ \frac{P_t}{P_{t+1}} \mu_{t+1} \right\} \tag{13}$$

Firm entry displays some inertia in response to monetary policy shocks (see Bergin and Corsetti (2005)). To account for this feature, we introduce a formulation of adjustment costs commonly used in models with physical capital.[3] Here, these adjustment costs apply to firm creation rather than to investment. Without adjustment costs in setting up firms, the response of $N_{E,t}$ to monetary policy shocks is very large on impact, implying a counterfactually large conditional volatility of firm entry. The number of firms in period $t+1$ is given by

$$N_{t+1} = (1-\delta) N_t + F(N_{E,t}, N_{E,t-1}) \tag{14}$$

where firm entry is determined by the function $F(\cdot)$ defined as

$$F(N_{E,t}, N_{E,t-1}) \equiv \left[1 - S\left(\frac{N_{E,t}}{N_{E,t-1}}\right)\right] N_{E,t}$$

There is time-to-build in firm entry as period-t entrants $N_{E,t}$ only start producing in period $t+1$. $S(\cdot)$ is an adjustment cost function with the steady state properties $S(1) = S'(1) = 0$. We define the adjustment cost parameter $S''(1)$ and restrict the S-function in such a way that $S''(1) > 0$. The higher is the adjustment cost parameter $S''(1)$, the lower is the impact effect of a shock on firm entry. Households own the stock of firms. Each household decides how many firm startups to finance today, $N_{E,t}(h)$, and how many producers to support tomorrow, $N_{t+1}(h)$, subject to the constraints given by (12) and (14). Denote by λ_t the Lagrange multiplier on constraint (14) and let $v_t \equiv \lambda_t / U_{C,t}$ be the household's shadow price of one firm, i.e. firm value. Then the two first order conditions for N_{t+1} and $N_{E,t}$ are as

[3] See appendix to Christiano, Eichenbaum and Evans (2005).

follows

$$v_t = \beta E_t \left\{ \frac{U_{C,t+1}}{U_{C,t}} \left[d_{t+1} + (1-\delta) v_{t+1} \right] \right\} \quad (15)$$

$$U_{C,t} \frac{w_t}{Z_{E,t}} = U_{C,t} v_t F_{1,t} + \beta E_t \left\{ U_{C,t+1} v_{t+1} F_{2,t+1} \right\} \quad (16)$$

Equation (15) determines firm value, while equation (16) determines the number of entrants. In the special case of no adjustment costs, $S(\cdot) = 0$ and $F(N_{E,t}, N_{E,t-1}) = N_{E,t}$. Then $F_{1,t} = 1$, $F_{2,t+1} = 0$ and from equation (16) we find the free entry condition $v_t = w_t / Z_{E,t}$ (firm value equals the entry cost).

Each worker has monopoly power in supplying a differentiated labour type, which allows him to set his optimal wage. We assume rigidities in wage setting as in the Calvo-model. In any time period, a worker receives a wage-changing signal with probability $(1-\alpha)$. The first order condition for the nominal wage set into the discounted future, conditional on receiving this signal, is given by

$$E_t \sum_{s=0}^{\infty} (\alpha\beta)^s \left\{ \left(\frac{\phi - 1}{\phi} \right) \frac{W_t(h)}{P_{t+s}} - \frac{\kappa_{t+s} L_{t+s}(h)^{\varphi}}{\varepsilon^b_{t+s} C^{-\gamma}_{t+s}} \right\} = 0$$

Generally speaking, when nominal wages are sticky, labour effort reacts more strongly to exogenous shocks compared with a flexible-wage world. As a result, the response of firm entry is also increased.

3.5 Aggregate resource constraint

Aggregating the budget constraints over households, imposing the asset market equilibrium condition $\int_0^1 B_t(h)\, dh = 0$ for all t, and using the government budget constraint $T_t = G_t$ gives the aggregate accounting identity

$$C_t + G_t + \frac{w_t N_{E,t}}{Z_{E,t}} = N_t d_t + w_t L_t$$

Total expenditure on consumption (private plus public) and investment in new firms must be equal to total income (dividend income plus labour income).

3.6 Monetary policy

To close the model, we assume the following linearised interest rate rule, with hats denoting percentage deviations from steady state.

$$\widehat{R}_t = (1-\lambda) \left[\Pi_0 \widetilde{\pi}_t + \Pi_1 \left(\widehat{Y}_t - \widehat{Y}^f_t \right) \right] + \lambda \widehat{R}_{t-1} + \eta^R_t$$

where η^R_t is a white noise monetary policy shock and the parameter λ determines the degree of interest rate smoothing. The interest rate adjusts partially to CPI inflation $\widetilde{\pi}_t \equiv$

$\ln(p_t/p_{t-1})$ and to the output gap $(\widehat{Y}_t - \widehat{Y}_t^f)$. $\widehat{Y}_t^f$ is defined as the level of output under the assumption of perfectly flexible wages, i.e. $\alpha = 0$. We suppose here that the central bank does not observe the welfare-based price index P_t, but instead measures inflation as the change in average prices p_t.[4] See discussion in Section 5. CPI inflation can be written as

$$\widetilde{\pi}_t = \pi_t + \xi(\widehat{N}_t - \widehat{N}_{t-1}) \tag{17}$$

where welfare-based inflation is given by the identity $\pi_t \equiv \omega_t - \Delta\widehat{w}_t$ and ω_t denotes nominal wage inflation, ie. $\omega_t \equiv \ln(W_t/W_{t-1})$. Notice that the measure of the output gap is the same whether P_t or p_t is used as the deflator.

4 Steady state

In the steady state, all endogenous variables are constant. Price and wage inflation are equal to zero, $\pi_t = \omega_t = 0$. Furthermore, all exogenous variables are also constant, $Z_{C,t} = Z_C$, $G_t = G$, $\kappa_t = \kappa$, $\varepsilon_t^b = \varepsilon^b$, $Z_{E,t} = Z_E$ and $\eta_t^R = 0$.

Given that $F(N_E, N_E) = N_E$, the law of motion for firms (14) in steady state becomes $N = N_E/\delta$. The interest rate is obtained from the bond Euler equation (13), $\beta^{-1} = R = 1 + i$. The ratio of profits to firm value is given by $d/v = r + \delta$ through the firm value equation (15), where r is the (net) real interest rate. The share of profit income in consumption output is found by combining equations (7) and (8)

$$\frac{dN}{Y^C} = \frac{1}{\theta}$$

Using this result together with the expressions $N = N_E/\delta$ and $d/v = r+\delta$, we get the share of investment in consumption output

$$\frac{vN_E}{Y^C} = \frac{1}{\theta}\frac{\delta}{r+\delta}$$

Noting that $Y = Y^C + vN_E$, the shares of investment and profit income in GDP are respectively

$$\begin{aligned} \frac{vN_E}{Y} &= \frac{\delta}{\delta + \theta(r+\delta)} \\ \frac{dN}{Y} &= \frac{r+\delta}{\delta + \theta(r+\delta)} \end{aligned}$$

The share of labour income in total income is

$$\frac{wL}{Y} = 1 - \frac{r+\delta}{\delta + \theta(r+\delta)}$$

[4] The results are qualitatively unchanged if we assume that the central bank observes P_t.

Denote by Γ the steady state share of government consumption in total consumption output, i.e. $\Gamma \equiv G/Y^C$. The shares of government and private consumption in GDP are respectively

$$\frac{G}{Y} = \frac{\theta (r+\delta)}{\delta + \theta (r+\delta)}\Gamma$$

$$\frac{C}{Y} = \frac{(1-\Gamma)\,\theta (r+\delta)}{\delta + \theta (r+\delta)}$$

Writing the labour demand equation (11) in steady state and substituting the steady state versions of the entry equation (16), the law of motion for firms (14), firm value (15), profits (7), and firm pricing (6), we find the labour shares in the two sectors

$$\frac{L_C}{L} = 1 - \frac{\delta}{(r+\delta)\,\theta - r}$$

$$\frac{L_E}{L} = \frac{\delta}{(r+\delta)\,\theta - r}$$

Note that all these ratios are independent of the steady state productivity levels Z_C and Z_E. The model dynamics are thus unaffected by steady state productivity.

5 Model dynamics

To compare the model with data, we need to strip out the effect of varieties on the price index. At present, CPI data does not account (adequately) for changes in consumption utility arising from more or fewer available varieties. For any variable X_t in units of consumption, the data-consistent counterpart is obtained as $\widetilde{X}_t \equiv P_t X_t / p_t = X_t/\rho_t = X_t N_t^{-\xi}$. The effect on the relative price ρ_t is removed, because ρ_t is always equal to 1 when changes in the number of varieties are disregarded. Since ρ_t is predetermined with respect to all shocks, the impact effect on the data-consistent variables does not differ from that on the welfare-based variables. In general, the transition dynamics of the data-consistent variables are qualitatively similar to the dynamics of the welfare-based variables. However, as can be deduced from Table 4, there is no effect of entry cost shocks, government spending shocks, consumption preference shocks or monetary policy shocks on the data-consistent real wage, $\widetilde{w}_t$. Also, a government spending shock has no effect on the empirical measure of firm value $\widetilde{v}_t$. In the dynamic analysis below, we therefore focus on the following observable variables that react to all six shocks: $\widetilde{C}_t$, L_t, $\widetilde{y}_t$, $\widetilde{D}_t$, $N_{E,t}$, $\widetilde{Y}_t$, R_t, $\widetilde{\pi}_t$. We describe the short run impulse responses of those variables, assessing the effects of transitory shocks to $Z_{C,t}$, κ_t, G_t, ε_t^b, η_t^R and $Z_{E,t}$.

Figure 4 displays the impulse responses implied by the model for the variables $\widetilde{Y}_t$, $\widetilde{\pi}_t$, R_t, $\widetilde{D}_t$, $N_{E,t}$ which are the ones used in the empirical analysis in Section 6. The choice of variables will become clear later on. We perform a Monte Carlo simulation exercise as in Peersman and Straub (2006). For each parameter, we choose a uniform distribution over a range of values reflecting previous estimates found in the literature. For details on the parameter ranges, see Table 6. We take joint draws for all parameters and compute the associated impulse responses. We report the median impulse response and the 16th and 84th percentile error bands based on 10,000 replications. Table 1 below summarises the signs of the theoretical impulse responses, where the shocks have been given more general names.

Table 1: **Signs of impulse responses predicted by DSGE model**

	output	inflation	int. rate	profits	entry
supply	↑	↓	↓	↑	↑
demand	↑	↑	↑	↑	↓ or ↑
monetary	↑	↑	↓	↑	↑
entry cost	↑	↑	↑	↓	↑

Note that the effect of a demand shock on firm entry is ambiguous in the model. In response to a government spending shock, entry decreases, while following a consumption preference shock, entry increases.

5.1 Supply shocks

Manufacturing productivity shock

A rise in manufacturing productivity ($Z_{C,t}$) has a direct impact on the firm's pricing decision. Each firm will lower its price in proportion to the fall in marginal costs. As the number of producers (and through equation (9) also the relative price ρ_t) is predetermined, this results in an equiproportionate drop in the aggregate price level. The welfare-based real wage rises as the price level falls, which represents a spillover from the production sector to the investment sector. On the one hand, the increase in the real wage implies a rise in entry costs, which has a negative effect on entry. On the other hand, the demand for each existing variety increases due to a rise in aggregate consumption demand. This has a positive effect on profits, which encourages entry. For a plausible set of parameter values, this second effect dominates and firm entry is positive on impact.[5] Output rises and inflation falls in response to a manufacturing productivity shock. The decrease in inflation dominates the increase in the output gap in our interest rate rule, resulting in a monetary policy expansion.

Labour supply shock

In boosting the economy's productive capacity, a positive labour supply shock (κ_t) has similar effects as a productivity shock. Additional labour effort allows for an increase in

[5] The effect of productivity shocks on entry is unambigously positive if productivity affects the creation of firms and the production of goods in the same way. This is the modelling approach followed by Bilbiie et al. (2005). The responses of output, inflation, interest rates and profits to such shocks are not much different from the responses to a Z_C-shock.

both consumption and firm entry, leading to an overall output expansion. Production initially rises along the intensive margin (existing firms produce more), and later on along the extensive margin (new firms enter). Firm output and profits rise on impact. There is a drop in prices, which brings about a loosening of the monetary policy stance.

5.2 Demand shocks

Government spending shock

On impact, a government spending shock (G_t) crowds out private consumption. This crowding out is only partial, such that output rises. The resulting positive output gap and inflation induce the monetary authority to raise the interest rate. Since the number of producers is fixed initially, the rise in aggregate demand pushes up firm output and profits. As productivity is unchanged, the increased production by existing firms is achieved through a rise in labour effort. Assuming realistic values for the labour supply elasticity, the extra demand from government spending has to be met by reallocating labour away from the entrepreneurial sector to the production sector. As a consequence, firm entry falls.

Consumption preference shock

Suppose that an exogenous shock to private consumption demand (ε_t^b) hits the economy. This rise in demand can be satisfied in two different ways. Agents can raise their current consumption of existing varieties, which requires an increase in the labour input of producing firms. An alternative way to raise consumption utility is through the introduction of new varieties (at least if the shock is persistent). Here, additional labour is needed for firm startups. Both consumption and firm entry are positively affected by the preference shock, giving rise to a positive output gap and inflation. The central bank responds by increasing the interest rate. Initially, incumbents benefit from higher profits, because the stock of firms is slow to adjust. Gradually, however, these excess profits are eroded as new entrants claim market share.

5.3 Monetary policy shocks

An expansionary monetary policy shock (η_t^R) is modelled as a drop in the interest rate. This creates a boost to consumption and firm entry. Given that flexible-wage output has not changed, the output gap becomes positive. With constant productivity, an increase in production requires an increase in labour effort. As all firms raise prices, inflation becomes positive. In the shock period, the increased consumption demand induces firms to raise their output, which they sell at the predetermined relative price ρ_t. Thus, profits increase on impact.

5.4 Entry cost shocks

A positive shock to startup productivity ($Z_{E,t}$) lowers entry costs. Similar to an investment-specific productivity shock, it does not affect the productivity of existing firms, but makes investment into new ones more attractive. Consumption falls initially in order to finance the entry of new firms. Labour effort rises to accommodate the increased demand of entrants. As aggregate consumption demand falls, each incumbent sees his firm-specific demand curve shift inwards, such that firm output drops. Since relative prices (ρ_t), are unchanged initially, lower firm output also implies lower (real) profits. A shock to $Z_{E,t}$ leads to a positive output gap (driven by an expansion in firm startups) and inflation, which induces a monetary tightening by the central bank.

6 A vector autoregression with sign restrictions[6]

Our aim is to study the dynamic effects of exogenous shocks on firm entry and compare them with the model predictions of Section 5. For this purpose, we estimate a vector autoregression (VAR) with subset of the variables of our model

$$X_t = c + \sum_{j=1}^{p} A_j X_{t-j} + B\varepsilon_t \tag{18}$$

where c is a vector of constants and linear trends, X_t is an $n \times 1$ vector of variables, A_j are coefficient matrices and ε_t are normally distributed, mutually and serially uncorrelated innovations with unit variance, i.e. $\varepsilon_t \sim N(0, I)$. More specifically, $\varepsilon_t = \left(\varepsilon_t^S, \varepsilon_t^D, \varepsilon_t^M, \varepsilon_t^E\right)$, where ε_t^S is a supply shock, ε_t^D is a demand shock, ε_t^M is a monetary policy shock and ε_t^E is an entry cost shock. Since we have little empirical evidence on how firm entry responds to aggregate shocks, we do not want to be too specific about the precise nature of the underlying shocks. Instead, we identify classes of shocks. Supply shocks encompass manufacturing productivity shocks and labour supply shocks. Government spending shocks and preference shocks are classified as demand shocks. Note that entry cost shocks look similar to demand shocks as they raise output, inflation and interest rates. However, we want to identify entry cost shocks separately for two reasons. Firstly, these shocks are specific to models with firm endogeneity, which is the focus of the paper. Secondly, in standard models with a variable capital stock and a fixed number of firms, investment-specific technology shocks are an important source of output fluctuations (see Fisher (2002)).

[6] Examples of VARs with sign restrictions can be found in Faust (1998), Uhlig (2005), Canova and De Nicoló (2002).

6.1 Choice of variables and identification

The variables chosen from the theory in Section 3 must satisfy two conditions. Firstly, they must be empirically observable, i.e. the variables that are expressed in real terms must be deflated by the CPI equivalent in the model, which is p_t (rather than the welfare-based price index P_t). Secondly, their short run responses to the exogenous shocks must be sufficiently different from each other as to allow for the identification of each shock. In choosing a subset of variables for our VAR, we are further guided by Peersman and Straub (2006). They summarise the controversies that currently exist in the literature on standard DSGE models with capital. These are, firstly, the effect of government spending on investment and consumption; secondly, the effect of technology shocks on labour effort; and thirdly, the effect of demand side shocks on the real wage. Of these controversial responses, we consider only that of investment (which in our model corresponds to firm entry) to government spending shocks. We do not use data on consumption, labour or wages in our empirical analysis.

Given these considerations, we select four empirically observable variables that provide sufficient information to identify all four types of shocks. These are real GDP, inflation, the interest rate and aggregate profits (in real terms). A description of the data is given in the appendix. Our identification scheme is presented in Table 2 below. We adopt the convention that a positive shock is one that increases output temporarily. We look at the impulse responses of the other three variables in relation to the output response. Firstly, we identify a supply shock by its negative effect on inflation. Secondly, of those shocks that lead to positive inflation, we single out monetary shocks as those that reduce the nominal interest rate. The restrictions used to identify these two shocks are robust across a range of models and as such widely accepted, as noted by Peersman and Straub (2006). Finally, of those shocks that raise inflation and the interest rate, we distinguish entry cost shocks from (other) demand shocks by looking at their effect on aggregate profits. An entry cost shock reduces profits, while a demand shock raises profits. The drop in profits following a reduction in entry costs is a robust implication of the model. One could imagine additional model features that might impact upon this result. On the one hand, if the creation of new firms required not only labour but also intermediate goods as inputs, then firm entry would entail a rise in demand for these goods, with a positive effect on profits. On the other hand, suppose that markups are not constant but depend negatively on the number of firms. Then firm entry lowers markups and thus profits. Which of these two effects dominates requires a more elaborate model and is left for future research. Notice that these restrictions are sufficient to fully identify the shocks. In addition to these four variables, we include a measure of firm entry in the VAR. The responses of firm entry to the various shocks are intentionally left unrestricted and are therefore fully determined by the data. In addition, the response of the nominal interest rate and profits to a supply shock and the response of profits to a monetary shock are left unrestricted. The estimated response can then be compared with the one implied by the model presented in Section 3.

Table 2: **Signs of impulse responses used for VAR identification**

	output	inflation	int. rate	profits	entry
supply	↑	↓			
demand	↑	↑	↑	↑	
monetary	↑	↑	↓		
entry cost	↑	↑	↑	↓	

Note: By construction, the identification method rules out the liquidity and price puzzles. Following Scholl and Uhlig (2005), we set the sign restriction horizon to one year for all variables. The present model lacks inflation persistence due to perfect price flexibility. We nevertheless choose to set a four-quarter horizon for inflation, leaving the introduction of sticky prices for future work.

We set $X_t = \left(\widetilde{Y}_t,\, \widetilde{\pi}_t,\, R_t,\, \widetilde{D}_t,\, N_{E,t}\right)$ in the VAR model (18), where $\widetilde{Y}_t$ is real output, inflation $\widetilde{\pi}_t$ is measured as the percentage change in the implicit GDP deflator, the interest rate R_t is the 3-month Treasury bill rate, $\widetilde{D}_t$ are corporate profits and for $N_{E,t}$ we use net entry given by the net business formation index.[7] Output, profits and net entry are logged and multiplied by 100. These three variables have a strong upward trend. We do not carry out any stationarity-inducing transformations, nor do we impose any cointegrating relationships between the variables. Instead we estimate the VAR in levels. Following Sims et al (1990), this is a valid and consistent estimation method even in the presence of unit roots and cointegrating vectors. It is also preferable, since more harm is done by imposing false stationarity-inducing transformation and cointegrating relationships than by imposing none at all. Our sample period covers 1948q1 to 1995q3. Given that we work with quarterly data, the VAR lag length p is set to four.

6.2 Methodology

In the following, we briefly outline the estimation method of Peersman (2005); more details can be found in that paper. There are two steps to this procedure.

Step 1: We estimate the unrestricted VAR in (18) to obtain estimates of the reduced form coefficients $\beta = [c, A_1, A_2, \ldots, A_p]$ and the error covariance matrix Σ. Given an unin-

[7] Notice that the true measure of net entry in the theoretical model corresponds to the variable $N_{E,t} - \delta N_t$. Given that the stock of firms N_t is predetermined, this variable reacts in exactly the same way as $N_{E,t}$ on impact. The slow adjustment in N_t implies that the two measures of entry do not diverge too much. Simulations show that the divergence between the two series is of the order of magnitude 10^{-3}, reflecting the small value of the firm exit rate.

formative prior, the joint posterior distribution for β and Σ belongs to the Normal-Wishart family, as shown in e.g. Uhlig (1992). From the reduced form residuals u_t with covariance matrix Σ, we construct structural innovations $\varepsilon_t = B^{-1}u_t$. An orthogonal decomposition of the residuals amounts to finding a matrix B that satisfies $\Sigma = BB'$ and computing the innovations ε_t. Many such decompositions exist, as for any orthonormal matrix Q (i.e. $QQ' = I$), $\Sigma = BQQ'B'$ is a valid decomposition of Σ. We take joint draws from the posterior distribution of the VAR coefficients and from the space of decompositions given by Q.

Step 2: Given the orthogonal innovations ε_t, the associated impulse responses are compared with the priors given by the sign restrictions in Table 2. We accept a draw if out of the five orthogonal shocks, we identify exactly four distinct fundamental shocks; the fifth shock is interpreted as an unspecified exogenous process in the data absent from the model. Otherwise, the draw is rejected.

Steps 1 and 2 are repeated until 1000 valid decompositions have been found. Inference statements are based on the distribution given by these valid draws. We order the points on the impulse response functions and report the median, as well as the 16th and 84th percentile confidence bands.

7 Results

The estimated impulse response functions are displayed in Figure 5. We find significant positive impulse responses of firm entry to all four identified shocks, though at different horizons. Supply shocks as well as reductions in entry costs have significant effects on entry in the long run, that is, 3 years after the shock. Monetary policy shocks lead to a gradual build-up in the number of firms. The response of entry is significant only at medium run horizons. Consistent with money neutrality, there is no significant long run response. Notice also that the response is hump-shaped, which is consistent with the evidence of the recursive VAR in Bergin and Corsetti (2005). Finally, demand shocks have a positive and significant impact effect on firm entry, lasting about a year. This suggests a complementarity in the data between aggregate demand and entry. A consumption preference shock induces people to work more, such that consumption possibilities are extended along the intensive and extensive margins. In other words, agents consume more of existing varieties and at the same time set up new firms, which raises consumption utility through the variety effect.[8] Contrast this with the effects of government spending. Recall that an exogenous increase

[8] A similar result is presented by Devereux et al (1996), who interpret the increase in entry following a demand shock as an endogenous response of total factor productivity.

in government demand is satisfied by a reallocation of labour services from the production of firms to the production of goods, leading to a drop in entry. Let's compare these results with the more standard DSGE models with capital. Most of these models predict a decline or an insignificant response of investment to a government spending shock (see Galí et al. (2004)). In addition, a similar crowding-out effect is found for preference shocks (see Smets and Wouters (2003)), while in the data, the effect is significantly positive, as shown in Peersman and Straub (2006). In our model, there is instead a crowding-in of entry due to the direct effect of entry on utility. In the standard DSGE model, investment has a positive influence on welfare only indirectly through the expansion of consumption opportunities.

As an additional check of the theoretical model, we consider the other unrestricted impulse responses. We find that the response of the interest rate to a supply shock, while negative in the model, is insignificant in the data. In the case of a manufacturing productivity shock, there are two offsetting influences on the interest rate in the monetary policy rule. On the one hand, a positive output gap calls for a monetary tightening; on the other hand, a fall in prices calls for a monetary easing. The model prediction of a net monetary easing is a consequence of perfect price flexibility. The fall in inflation dominates the rise in the output gap. With flexible prices, the weight on inflation stabilisation should be reduced compared with the sticky-price benchmark on which the parameter ranges of Table 6 are based. Profits react positively to supply shocks at short horizons; the long run effect is insignificant. Following a monetary policy expansion, profits increase in a hump-shaped fashion, first becoming significantly positive, followed by a significantly negative response at longer horizons. At first, the rise in aggregate demand drives up the profits of existing firms. The increase in profitability induces new firm startups, but with some delay. Firm entry leads to some expenditure switching from old to new goods, thereby reducing the profits of incumbent firms.

Turning to the variance decompositions in Table 7, it is worth noting that shocks to entry costs do not explain a large proportion of the variability of firm entry and output. Demand shocks play a much bigger role. This is consistent with the observation that overall, profits are procyclical, whereas entry cost shocks give rise to countercyclical movements in profits. It might also reflect the fact that entry costs depend to a large extent on institutional arrangements, which are slow to change.

8 Conclusion

The aim of this paper is to improve our understanding of the driving forces of firm entry and exit over the business cycle. We have built a DSGE model with an endogenous number of firms, featuring the main classes of macroeconomic shocks. In addition to supply, demand and monetary shocks, we allow for shocks to entry costs. Using a minimum set of robust sign restrictions implied by our model, we identify a VAR. Firm entry is allowed to respond freely to the four shocks. The responses are in line of what our theory predicts. One notable finding is that of a positive effect of an increase in demand on entry, consistent with the impulse response predicted by a consumption preference shock. This shows that aggregate demand disturbances lead to important adjustments in consumption output along the extensive margin. Moreover, firm entry responds significantly to all kinds of macroeconomic shocks. This finding has far-reaching implications. Firstly, if every firm produces a differentiated good, fluctuations in the number of firms proxy fluctuations in the composition of the consumption basket. Such fluctuations entail welfare effects and raise doubts about the measurement of a price index as the price of a static bundle of goods. Secondly, firm entry might influence the degree of competition. Although beyond the scope of the present paper, endogenous markups that depend on the number of firms are an interesting topic for future research. Thirdly, how are stabilisation policies affected by the insights that a) output fluctuations have an intensive as well as an extensive margin, and b) that the (correctly measured) price index reflects average prices as well as the number of consumption varieties? A first attempt to answer this question is given in Bergin and Corsetti (2005). This paper provides evidence of the importance of their enquiry. Finally, another challenge is to extend the analysis to an open economy. A fast-growing country can channel its productivity into the increased production of existing goods, or it can expand the gamma of varieties it produces. Whether export growth is along the extensive margin (more varieties) or the intensive margin (greater volumes) has very different implications for the terms of trade and for international spillovers.

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Appendix

Data

Data series are taken from the St. Louis Fed Economic Database, except for the data on firm entry. Net business formation (NBF) and New business incorporations (NI) are from the BEA's Survey of Current Business. These series have been discontinued; data run from January 1948 to September 1995 (for NBF) and to September 1996 (for NI). VAR with sign restrictions: Inflation is measured as the percentage change in the implicit GDP deflator. The interest rate is the 3-month Treasury bill rate. Profits are deflated using the GDP deflator. The commodity price variable in the recursive VAR is the change in the index of sensitive materials prices, which is obtained from the Christiano et al (1999) data set.

Table 3: **Data**

Variable	Units, Freq, Seas. adj.	Series ID
Real Gross Domestic Product, 1 Decimal	Bil. Chn. 2000 $, Q, SAAR	GDPC1
CPI For All Urban Consumers: All Items	Index 1982-84=100, M, SA	CPIAUCSL
Corporate Profits with IVA and CCAdj	Bil. $, SAAR, Q	CPROFIT
3-Month Treasury Bill: Second. Mkt. Rate	%, M	TB3MS
Effective Federal Funds Rate	%, M	FEDFUNDS
GDP: Implicit Price Deflator	Index 2000=100, Q, SA	GDPDEF
Net business formation	Index 1967=100, M	-
New business incorporations	Thousands, M	-
Industrial Production Index	Index 2002=100, M, SA	INDPRO
Non-Borrowed Reserves of Depository Inst.	Bil. $, M, SA	BOGNONBR
Aggr. Reserves of Dep. Inst. & Monet. Base	Bil. $, M, SA	TRARR
Change in sensitive materials prices		CHGSMPS

Variable CHGSMPS from data appendix to Christiano, Eichenbaum and Evans (1999). IVA = Inventory Valuation Adjustment, CCAdj = Capital Consumption Adjustment.

Linearised DSGE model

The model has sixteen endogenous variables: $\widehat{A}_t$, $\widehat{\rho}_t$, $\widehat{d}_t$, $\widehat{y}_t$, $\widehat{Y}_t^C$, $\widehat{w}_t$, $\widehat{L}_t$, $\widehat{C}_t$, $\widehat{N}_t$, $\widehat{v}_t$, $\widehat{N}_{E,t}$, ω_t, $\widehat{Y}_t$, $\widehat{R}_t$, π_t, $\widetilde{\pi}_t$. We have seventeen equations; invoking Walras' law we can drop one of the market clearing conditions. Potential output Y_t^f is defined as the level of output under perfectly flexible wages. In practice, the model is extended by a flexible wage block where $\alpha = 0$.

Table 4: **Summary of the linearised model equations**

$\widehat{A}_t = \left(\xi - \frac{1}{\theta-1}\right)\widehat{N}_t$	auxiliary variable
$\widehat{\rho}_t = \widehat{w}_t - \widehat{Z}_{C,t}$	price setting
$\widehat{d}_t = \widehat{\rho}_t + \widehat{y}_t$	profits
$\widehat{y}_t = (\theta - 1)\,\widehat{A}_t - \theta\widehat{\rho}_t + \widehat{Y}_t^C$	firm output
$\widehat{Y}_t^C = (1-\Gamma)\left(\widehat{C}_t + \widehat{G}_t\right)$	consumption output
$\widehat{\rho}_t = \xi\widehat{N}_t$	relative price
$\widehat{L}_t = \frac{L_C}{L}\left(\widehat{N}_t + \widehat{y}_t - \widehat{Z}_{C,t}\right) + \frac{L_E}{L}\left(\widehat{N}_{E,t} - \widehat{Z}_{E,t}\right)$	labour demand
$\widehat{\varepsilon}_t^b - \gamma\widehat{C}_t = \widehat{R}_t - E_t\left\{\pi_{t+1} - \widehat{\varepsilon}_{t+1}^b + \gamma\widehat{C}_{t+1}\right\}$	bonds
$\widehat{N}_t = (1-\delta)\,\widehat{N}_{t-1} + \delta\widehat{N}_{E,t-1}$	firm law of motion
$\widehat{v}_t = E_t\left\{\gamma\left(\widehat{C}_t - \widehat{C}_{t+1}\right) + \frac{1-\delta}{1+r}\widehat{v}_{t+1} + \frac{r+\delta}{1+r}\widehat{d}_{t+1}\right\}$	firm value
$\widehat{N}_{E,t} = \frac{1}{1+\beta}\left(\widehat{N}_{E,t-1} + \beta E_t\left\{\widehat{N}_{E,t+1}\right\} + \frac{1}{S''(1)}\left[\widehat{v}_t - \left(\widehat{w}_t - \widehat{Z}_{E,t}\right)\right]\right)$	free entry
$\omega_t = \dfrac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\phi\varphi)}\left(\widehat{\kappa}_t + \varphi\widehat{L}_t - \widehat{\varepsilon}_t^b + \gamma\widehat{C}_t - \widehat{w}_t\right) + \beta E_t\omega_{t+1}$	wage inflation
$\widehat{Y}_t = \frac{dN}{Y}\left(\widehat{N}_t + \widehat{d}_t\right) + \frac{wL}{Y}\left(\widehat{w}_t - \widehat{L}_t\right)$	aggr. income
$\widehat{Y}_t = \frac{Y^C}{Y}\widehat{Y}_t^C + \frac{vN_E}{Y}\left(\widehat{w}_t + \widehat{N}_{E,t} - \widehat{Z}_{E,t}\right)$	aggr. expenditure
$\widehat{R}_t = (1-\lambda)\left[\Pi_0\pi_t + \Pi_1\left(\widehat{Y}_t - \widehat{Y}_t^f\right)\right] + \lambda\widehat{R}_{t-1} + \eta_t^R$	monetary policy
$\pi_t = \omega_t - \Delta\widehat{w}_t$	welfare-based infl.
$\widetilde{\pi}_t = \pi_t + \xi(\widehat{N}_t - \widehat{N}_{t-1})$	CPI inflation

The model has six exogenous shocks: $\widehat{Z}_{C,t}$, $\widehat{\kappa}_t$, $\widehat{G}_t$, $\widehat{\varepsilon}_t^b$, $\widehat{Z}_{E,t}$, η_t^R. The first five are AR(1) processes. Following Smets and Wouters (2004), the η_t's are assumed to be normally distributed with mean zero and standard deviation 0.25.

Table 5: **Summary of the exogenous shock processes**

$\widehat{Z}_{C,t} = \phi_{zc}\widehat{Z}_{C,t-1} + \eta_t^{zc}$	manufacturing productivity shock
$\widehat{\kappa}_t = \phi_\kappa\widehat{\kappa}_{t-1} + \eta_t^\kappa$	labour supply shock
$\widehat{G}_t = \phi_g\widehat{G}_{t-1} + \eta_t^g$	government spending shock
$\widehat{\varepsilon}_t^b = \phi_b\widehat{\varepsilon}_{t-1}^b + \eta_t^b$	consumption preference shock
$\widehat{Z}_{E,t} = \phi_{ze}\widehat{Z}_{E,t-1} + \eta_t^{ze}$	entry cost shock
η_t^R	monetary policy shock

Calibration

The model is calibrated to a quarterly frequency. Assuming a steady state interest rate of 4% per annum implies a discount factor $\beta = 0.99$. In setting ranges for the preference parameters γ, φ, for the interest rate rule coefficients Π_0, Π_1, λ, for the AR(1) shock coefficients ϕ_g, ϕ_κ, ϕ_b, ϕ_{zc}, ϕ_{ze}, and for the wage stickiness α, we follow Peersman and Straub (2006). The steady state share of government consumption in total consumption Γ is fixed to 0.2, as in Gertler and Comin (2003). Regarding the remaining parameters, the firm exit rate, the elasticity of substitution between goods and labour types, respectively, and the firm startup adjustment cost, we use ranges from standard DSGE models with capital. We vary the firm exit rate δ in a symmetric range around the value 0.025, which is commonly used for the capital depreciation rate. The elasticity of substitution between goods and between labour types, θ and ϕ, can take any value between 3 and 20. The parameter range for firm startup adjustment costs S'' is lower than the values assumed in models with physical capital. However, those models typically have another adjustment margin through variable capital utilisation, which is absent here. For the love of variety parameter ξ, we set a range of 0.05-0.5, which corresponds to the widely-used Dixit-Stiglitz benchmark $1/(\theta - 1)$, where θ can vary between 3 and 20.

Table 6: **Parameter ranges for theoretical impulse responses**

β	0.99	discount factor
γ	1-4	inverse elasticity of intertemporal substitution
φ	1-3	inverse labour supply elasticity
ξ	0.05-0.5	love of variety
θ	3-20	elasticity of substitution (goods)
δ	0.01-0.04	firm exit rate
S''	0.5-1	firm startup adjustment costs
ϕ	3-20	elasticity of substitution (labour)
α	0.4-0.95	Calvo wage stickiness
Π_0	1-4	interest rate rule coefficient on inflation
Π_1	0-0.8	interest rate rule coefficient on output gap
λ	0.6-0.99	interest rate smoothing
Γ	0.2	steady state share of government consumption
ϕ_{shock}	0.6-0.99	AR(1) shock parameters

Figure 1: **Cyclical component of net business formation**

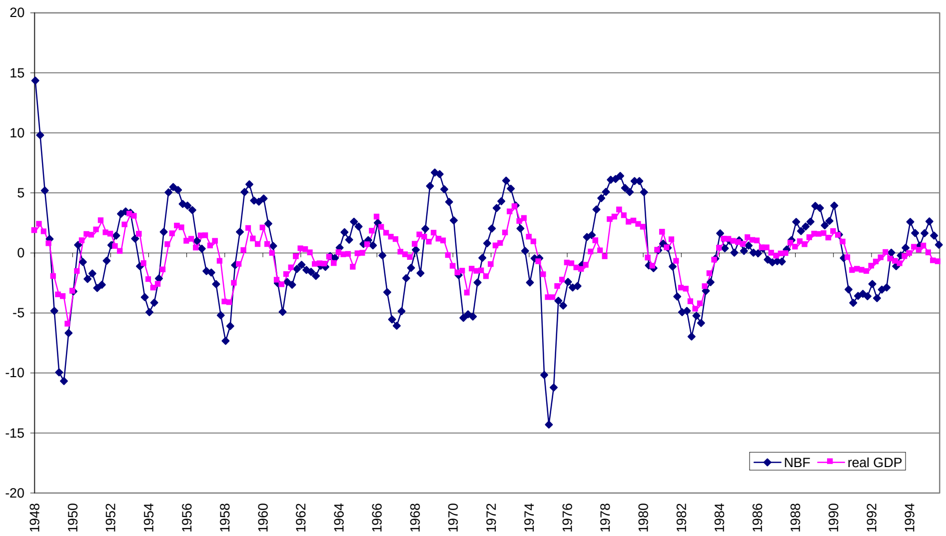
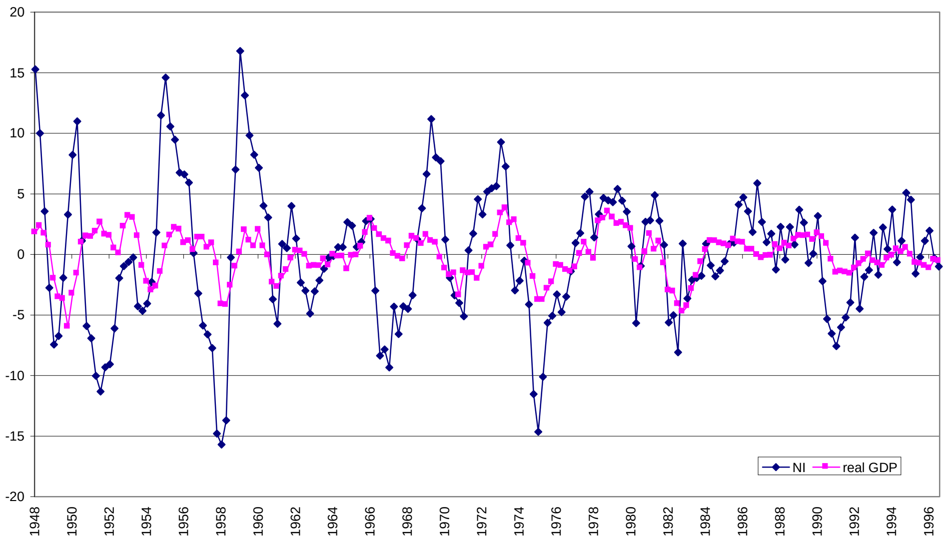
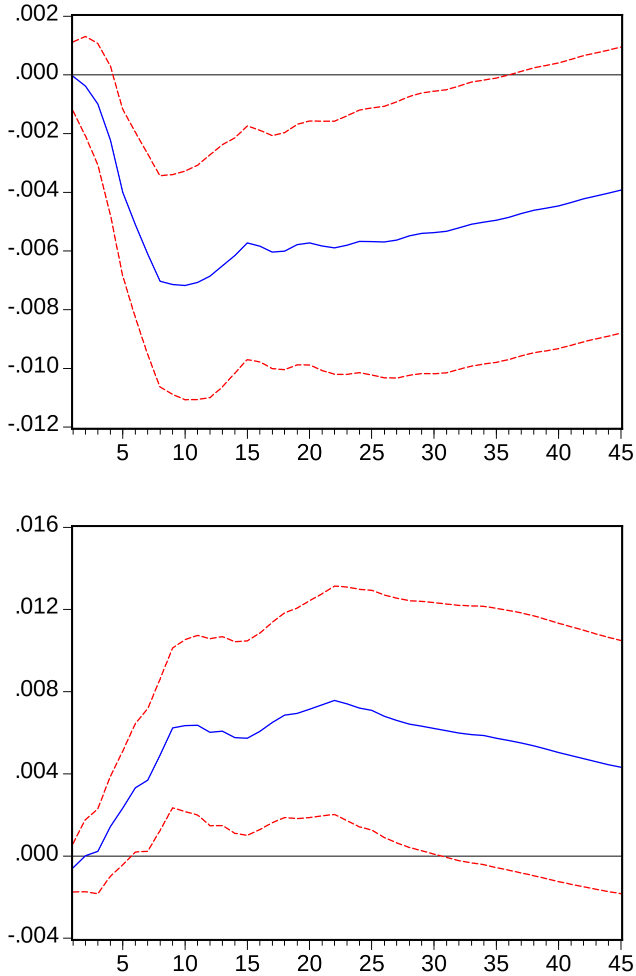


Figure 2: **Cyclical component of new incorporations**



These graphs show the cyclical components of firm entry and real GDP in the US over the sample period 1948q1-1995q3. Entry is measured as net business formation (top panel) and new incorporations (bottom panel). The two series have been HP-filtered with a smoothing parameter of 1600.

Figure 3: **Response of net business formation to innovation in federal funds rate (top panel) and in the nonborrowed reserves ratio (bottom panel)**



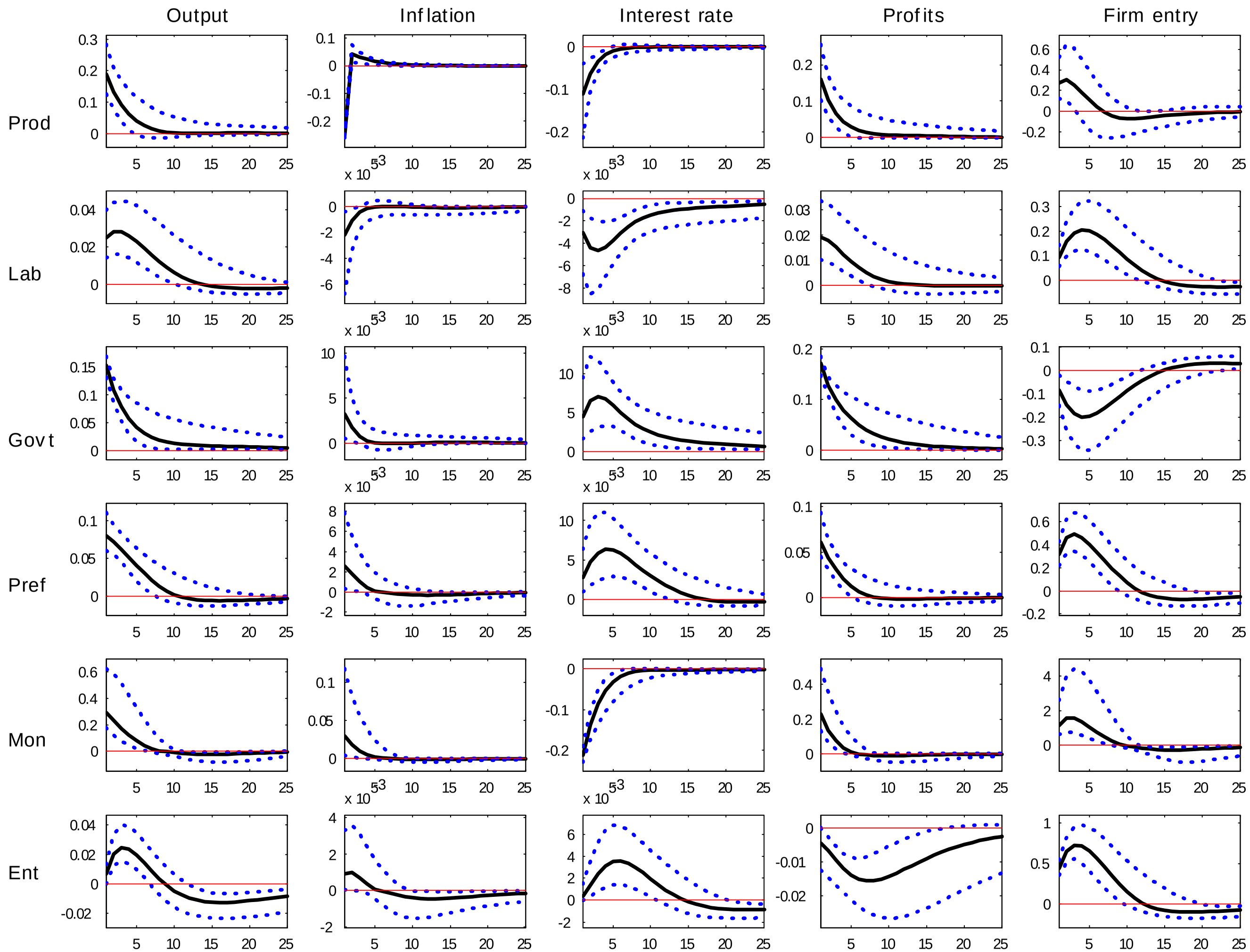
These graphs replicate the recursive VAR exercise in Bergin and Corsetti (2005). The variables in order are as follows: log industrial production, log CPI, commodity prices, ratio of non-borrowed reserves to total reserves or federal funds rate, log net business formation. Replacing net business formation by new incorporations in the VAR results in an insignificant response of the entry variable to monetary policy shocks (not shown). The identification scheme supposes a contemporaneous reaction of the monetary policy instrument to industrial production, the CPI and commodity prices, but not to entry. Further, the monetary policy shock does not affect industrial production, the CPI and commodity prices on impact. Data is monthly. The sample period is January 1959 to June 1995. The graphs should be interpreted as follows. A one-standard-deviation rise in the federal funds rate leads to a drop in the net business formation index of 7% after 10 months.

Table 7: **Estimated variance decomposition (VAR model)**

		Supply			Demand			Monetary			Entry cost		
		lower	median	upper	lower	median	upper	lower	median	upper	lower	median	upper
Output	0	9%	31%	67%	12%	43%	74%	1%	10%	33%	1%	7%	23%
	4	5%	17%	40%	21%	53%	78%	4%	14%	35%	2%	6%	15%
	8	6%	20%	44%	16%	46%	74%	4%	16%	40%	2%	5%	13%
	20	10%	27%	52%	15%	38%	64%	5%	16%	38%	3%	7%	18%
Entry	0	0%	4%	21%	6%	45%	91%	0%	3%	16%	0%	7%	31%
	4	1%	5%	22%	5%	40%	84%	1%	6%	27%	1%	5%	18%
	8	1%	7%	23%	6%	33%	76%	2%	10%	35%	2%	6%	18%
	20	3%	12%	28%	7%	28%	64%	4%	16%	40%	3%	8%	20%

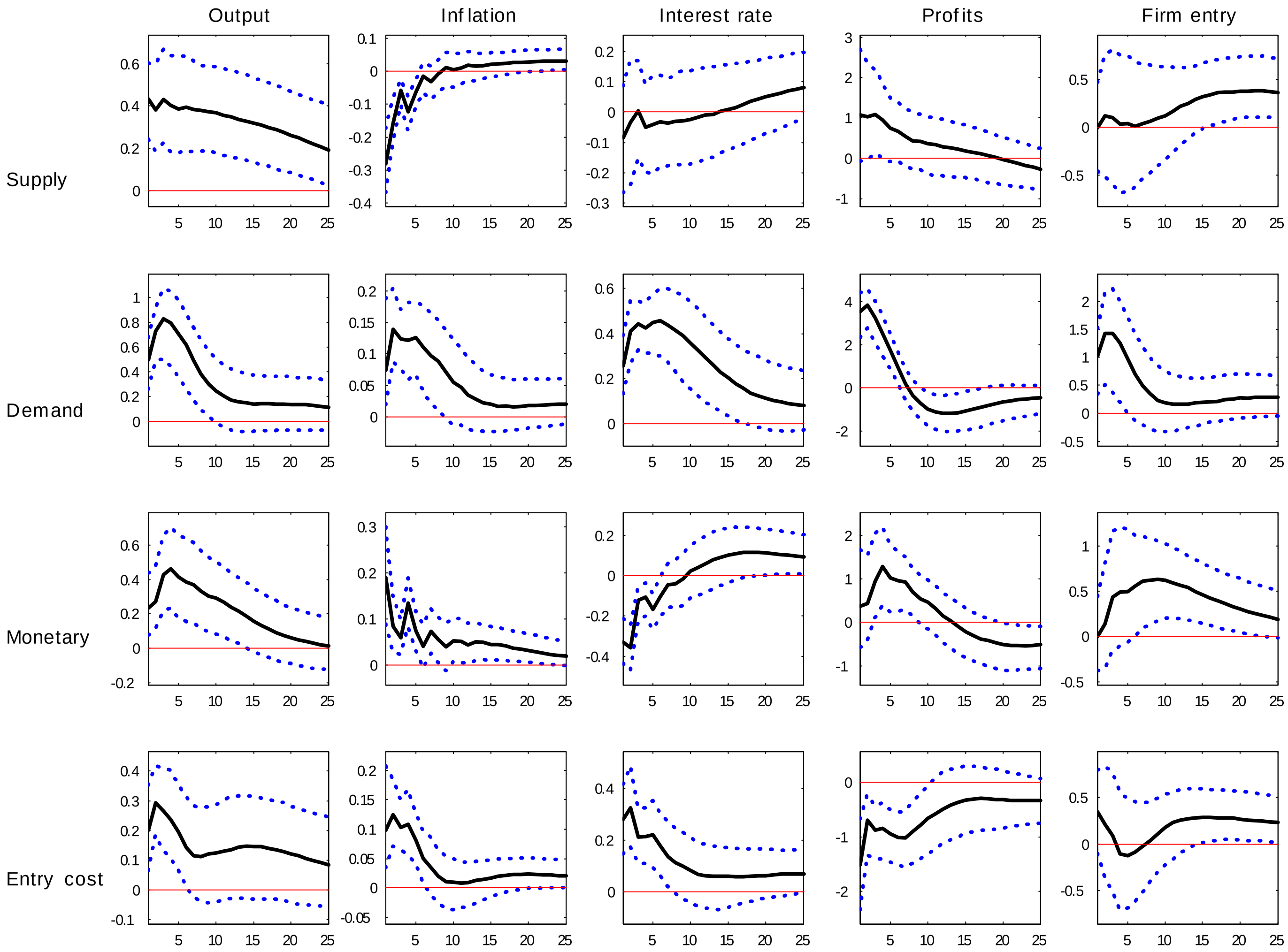
This table shows median variance decompositions, together with 16th and 84th percentile error bands for different time horizons expressed in quarters.

Figure 4: **Theoretical impulse responses (DSGE model)**



This graph shows median impulse responses to a one-standard deviation shock, together with 16th and 84th percentile error bands. On the x-axis the horizon is given in quarters.

Figure 5: **Estimated impulse responses (VAR model)**



This graph shows median impulse responses to a one-standard deviation shock, together with 16th and 84th percentile error bands. On the x-axis the horizon is given in quarters.

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