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# Endogenous Firm Entry in an Estimated Model of the U.S. Business Cycle

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Preliminary and incomplete

## Abstract

This paper explores and quantifies the role of endogenous firm entry in amplifying and propagating shocks to the economy. To this end, we estimate two DSGE models on US data with Bayesian methods: one model with endogenous firm entry and translog preferences and one model without. Both models perform equally well in fitting the data but in doing so the endogenous entry model does not rely on a fairly flexible supply of labor. The presence of firm entry amplifies the effects of productivity and wage mark-up shocks, but it dampens those of aggregate demand and investment-specific technology shocks.

*JEL classification:* E20, E32

*Keywords:* Bayesian estimation, Business Cycles, Firm Entry, Markups

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# 1 Introduction

This paper estimates a dynamic stochastic general equilibrium model with firm entry to quantify the role of endogenous firm entry in amplifying and propagating business cycle fluctuations, to explore the importance of firm entry in fitting the data, and to investigate how firm entry affects the estimates of structural model parameters.

Our paper is related to a growing body of literature that highlights the role of endogenous firm entry in business cycle fluctuations. Bilbiie, Ghironi and Melitz (2010) and Colcagio and Etro (2010) investigate the effects of technology shocks in business cycle models in which endogenous firm entry – by changing the number of products or competitors – leads to a countercyclical price mark-up. Bergin and Corsetti (2008) and Bilbiie, Ghironi and Melitz (2007) explore the role of firm entry for the monetary transmission mechanism. These studies rely on simulations within calibrated business cycle models. Lewis (2009) compare VAR-generated impulse responses to shocks to productivity, aggregate demand, monetary policy, and entry costs to those obtained from a calibrated endogenous entry model. Closely related to our paper is the work of Jaimovich and Floetotto (2008). They show that firm entry magnifies significantly the impacts of technology shocks by comparing two real business cycle models, one with and one without endogenous firm entry. In both models, they derive model-consistent expressions for total factor productivity and estimate the processes of technology. To quantify the internal amplification mechanism embedded in the entry model, the model economies are simulated using the estimated time series of technology. Our study goes beyond this exercise by carrying out a full-fledged estimation of an endogenous entry model.

This article is among the first attempts to bring a business cycle model with firm entry to the data. Lewis and Poilly (2012) study the role of firm entry for the monetary transmission mechanism by minimizing the distance between the impulse responses to a monetary policy shock generated by a sticky price entry model and those obtained from a VAR. Lewis and Stevens (2012) estimate – as we do – a business cycle with firm entry using Bayesian methods. However, they consider a monetary DSGE model and focus mainly on the role of firm entry for inflation dynamics. Our primary focus is on output dynamics and on the internal magnification mechanism.

We lay out, estimate and compare two dynamic stochastic general equilibrium models, one model with and one without firm entry. The no-entry model is a real business cycle model enriched by the following empirically motivated real frictions which is similar to the model outlined in Schmitt-Grohe and Uribe (2010): monopolistic competition on product and labor markets, habit formation in consumption, capital adjustment costs, variable capital utilization, and Jaimovich and Rebelo (2009) preferences which allow for a parametric wealth elasticity of labor supply. When analyzing firm entry we augment this model by the entry mechanism proposed by Bilbiie, Ghironi and Melitz (2007). In this model, the numbers of firms (which is identical to the number of products due to a one to one mapping between a firm and a product) is endogenously determined by a free entry condition that equates expected future profits with entry costs. Due to the assumption of translog preferences as proposed by Feenstra (2003), firm entry and thus the availability of new product variants increases the degree of substitutability between the differentiated goods which gives rise to a countercyclical price mark-up.

We estimate the entry model on U.S. quarterly data for GDP, consumption, investment, hours worked, real wages, firm entry, and profits ranging. The data set ranges from 1964:Q1 to 2009:Q4. For the model without firm entry we exclude the real wage and the firm entry series from the list of observables. We estimate the models by including a labor-augmenting technology shock, which – in the entry model – also affects the productivity of firm creation, a capital investment specific technology shock, a government spending shock, a wage mark-up shock, a preference shock, and – in the entry model – a shock to entry costs.

Our main results are as follows: First, both estimated models perform equally well in fitting data on GDP, consumption, investment, and hours worked. The entry model, although able to explain a positive co-movement of entry and profits with GFP, has difficulties to fit the empirical moments of profits and entry. In particular, it overestimates the volatility and autocorrelation of firm entry entry and it underestimates dramatically the volatility of profits. Second, the no-entry model needs a much more flexible labor supply to fit the data. This indicates the ability of firm dynamics to amplify and propagate shocks to the economy. Third, introducing firm entry indeed magnifies the effects of shocks to labor-augmenting productivity and wage mark-ups, while it dampens those of investment-specific technology

and aggregate demand shocks. The rationale behind this result is that for the latter shocks, the conditional correlation of firm entry with GDP is negative. This implies that the change in the number of firms/products is inversely related to GDP movements. It also implies that for those shocks, mark-ups which are in turn inversely related to the number of firms due to translog preferences co-move with GDP. Hence, the amplifying effect of a countercyclical mark-up is not at work. For labor-augmenting productivity and wage mark-up shocks, though, the strength of the magnification mechanism can be quantified by comparing the relative volatilities of output and shock processes which increase by 20 percent and 19 percent, relative to a model in which firm entry is turned off. Finally, we seek to measure the strength of internal amplification taking into account all shock processes simultaneously. We find that introducing firm entry generates 16 percent more output volatility.

The remainder of the paper is organized as follows. Section 2 presents the models. Section 3 describes the data and the estimation procedure. Section 4 discusses the estimation results and Section 5 concludes.

## **2 A DSGE model with firm entry**

This section outlines our business cycle model for the U.S. economy. The core is a medium scale real business cycle model close to that of Schmitt-Grohe and Uribe (2010) which is characterized by monopolistic competition on product and labor markets, habit formation in consumption, capital adjustment costs, variable capital utilization, and Jaimovich and Rebelo (2009) preferences which allow for a parametric wealth elasticity of labor supply. To this we add the endogenous entry mechanism proposed by Bilbiie, Gironi and Melitz (2010) which is based on sunk entry costs.

The economy consists of final goods producers, labor bundlers, intermediate goods producers, the government, and households. Households consume, invest in physical capital and in startups (or new firms), hold government bonds and equity of intermediate goods producers, and supply differentiated labor types to a labor bundler under monopolistically competitive conditions. Competitive labor bundlers aggregate the differentiated labor types into homogeneous labor input. A time-varying mass of monopolistic firms employ labor and capital to produce differentiated intermediate goods. Final goods producers bundle the in-

intermediate goods to a homogenous final good used for private and government consumption and for investment in physical capital. Creation of a new product variety – equivalent to the establishment of a new firm – requires labor input. Firm entry is endogenously determined by a free entry condition that equates expected future profits with entry costs.

## 2.1 Monopolistic firms

There is a mass  $N_t$  of monopolistically competitive firms, each producing a single variety of an intermediated good, indexed by  $i \in [0, N_t]$ . Firm  $i$  uses the amount  $l_{i,t}$  of labor, the amount  $k_{i,t}^s$  of capital services and the constant returns to scale technology

$$y_{i,t} = (z_t l_{i,t})^\alpha (k_{i,t}^s)^{1-\alpha} \quad (1)$$

to produce its output  $y_{i,t}$ .  $z_t$  is a labor productivity shifter which follows the exogenous AR(1) process  $\log z_t = (1 - \rho_z) \log z + \rho_z \log z_{t-1} + \varepsilon_t^z$ , where  $\varepsilon_t^z$  is *i.i.d.*  $N(0, \sigma_{\varepsilon^z}^2)$ .  $\alpha \in (0, 1)$  denotes the share of labor in production. The firm takes the factor prices  $w_t$  and  $r_t^K$  as given. Firm  $i$  chooses prices,  $p_{i,t}$ , and factor inputs to maximize real profits  $d_{i,t} = \frac{p_{i,t}}{P_t} y_{i,t} - w_t l_{i,t} - r_t^K k_{i,t}^s$ , subject to the production technology and the demand function  $y_{i,t} = f(p_{i,t}/P_t) Y_t^C$ , where  $\partial f / \partial (p_{i,t}/P_t) < 0$ ,  $Y_t^C$  is aggregate output of final goods, and  $P_t$  is the price of the final good. Under translog preference as proposed by Feenstra (2003), the elasticity of substitution between varieties is increasing in the number of varieties:  $-\frac{\partial y_{i,t}}{\partial p_{i,t}} \frac{p_{i,t}}{y_{i,t}} = 1 + \tilde{\sigma} N_t$  with  $\tilde{\sigma} > 0$ . As a result, the monopolistic price mark-up,  $\mu_t^p$ , is decreasing in  $N_t$ :  $\mu_t^p = 1 + \frac{1}{\tilde{\sigma} N_t}$ .

The first order conditions read as follows:

$$\frac{p_{i,t}}{P_t} = \mu_t^p m c_t, \quad (2)$$

$$w_t = \alpha m c_t \frac{y_{i,t}}{l_{i,t}}, \quad (3)$$

$$r_t^K = (1 - \alpha) m c_t \frac{y_{i,t}}{k_{i,t}^s}, \quad (4)$$

where  $m c_t$  are real marginal costs.

Since all firms will choose in equilibrium the same price and allocation we can as-

sume symmetry and drop the index  $i$ . Under translog preferences and a symmetric firm equilibrium, the price index is given by  $P_t = \exp\left(\frac{\tilde{N} - N_t}{2\tilde{\sigma}\tilde{N}N_t}\right) p_t$ , where  $\tilde{N}$  is the mass of potential entrants. Aggregate production of intermediated goods is  $N_t y_t = (z_t L_t^C)^\alpha (K_t^s)^{1-\alpha}$ , where  $L_t^C = N_t l_t$  and  $K_t^s = N_t k_t^s$ . Aggregate production of final goods is given by  $Y_t^C = \rho_t N_t y_t$ , where  $\rho_t = p_t/P_t$  is the relative price. Total profits can be expressed as  $N_t d_t = (1 - 1/\mu_t^p) Y_t^C$ .

## 2.2 Households

The economy is made up by a continuum of households, indexed by  $j \in [0, 1]$ . Each household is a monopolistic supplier of a differentiated labor type  $L_{j,t}$ . Labor bundlers combine the differentiated labor types to a homogenous labor input  $L_t$ , according to  $L_t = \left(\int_0^1 L_{j,t}^{1/\mu_t^w} dj\right)^{\mu_t^w}$ . The wage mark-up,  $\mu_t^w$ , follows the exogenous AR(1) process  $\log \mu_t^w = (1 - \rho_\mu) \log \mu^w + \rho_\mu \log \mu_{t-1}^w + \varepsilon_t^\mu + \nu \varepsilon_{t-1}^\mu$ , where  $\varepsilon_t^\mu$  is *i.i.d.*  $N(0, \sigma_{\varepsilon^\mu}^2)$ . Profit maximization by the perfectly competitive labor bundlers yields the labor demand function

$$L_{j,t} = \left(\frac{w_{j,t}}{w_t}\right)^{-\mu_t^w/(\mu_t^w-1)} L_t, \quad (5)$$

where  $w_t = \left(\int_0^1 w_{j,t}^{-1/(\mu_t^w-1)} dj\right)^{-(\mu_t^w-1)}$  is the real wage paid for the homogenous labor input and  $w_{j,t}$  is the (real) price of labor type  $j$ .

Each household seeks to maximize the following lifetime utility function proposed by Jamovich and Rebelo (2009):

$$E_0 \sum_{t=0}^{\infty} \beta^t \chi_t \log \left( C_{j,t} - b C_{j,t-1} - \psi L_{j,t}^\eta S_{j,t} \right), \quad (6)$$

where  $C_{j,t}$  and  $L_{j,t}$  denote consumption and hours worked, respectively.  $\beta \in (0, 1)$  is the discount factor,  $\psi$  is a scale parameter, and  $b \in [0, 1)$  measures the degree of internal habit formation.  $\chi_t > 0$  is a preference shock that follows the exogenous AR(1) process  $\log \chi_t = (1 - \rho_\chi) \log \chi + \rho_\chi \log \chi_{t-1} + \varepsilon_t^\chi$ , where  $\varepsilon_t^\chi$  is *i.i.d.*  $N(0, \sigma_{\varepsilon^\chi}^2)$ .  $S_t$  is a habit-adjusted weighted average of current and past consumption, which evolves over time according to

$$S_{j,t} = (C_{j,t} - b C_{j,t-1})^\gamma S_{j,t-1}^{1-\gamma}, \quad (7)$$

where  $\gamma \in (0, 1]$  governs the wealth elasticity of labor supply. Finally,  $\theta = \eta - 1$  is the Frisch elasticity of labor supply in the limiting case  $\gamma = b = 0$ .

The household's period-by-period budget constraint is given by

$$C_{j,t} + I_{j,t} + \frac{B_{j,t}}{R_t} + v_t x_{j,t} + \frac{f_{E,t}}{z_t} w_t N_{E,j,t} + T_{j,t} = w_{j,t} L_{j,t} + r_t^K K_t^s + B_{j,t-1} + (1 - \delta)(v_t + d_t) \left[ x_{j,t-1} + \left( 1 - \frac{\kappa_E}{2} \left( \frac{N_{E,j,t-1}}{N_{E,j,t-2}} - 1 \right)^2 \right) N_{E,j,t-1} \right]. \quad (8)$$

The household consumes, pays lump-sum taxes,  $T_t$ , buys risk-less government bonds,  $B_{j,t}$ , at a price  $1/R_t$ , and equity of operating firms,  $x_{j,t}$ , at a price  $v_t$ . Each bond pays one unit of the final good one period later. Each unit of equity bought at period  $t - 1$  pays a (real) profit equal to  $(1 - \delta)d_t$  and is worth  $(1 - \delta)v_t$ , where  $\delta \in (0, 1)$  denotes the exogenous exit rate of firms.

The household invests into new firms,  $N_{E,j,t}$ , and invests into physical capital,  $K_{j,t}$ , which is assumed to be owned by households. Capital evolves according to the following law of motion

$$K_{j,t} = (1 - \delta^K(u_{j,t}))K_{j,t-1} + u_t^I \left[ 1 - \frac{\kappa_I}{2} \left( \frac{I_{j,t}}{I_{j,t-1}} - 1 \right)^2 \right] I_{j,t}, \quad (9)$$

where  $\frac{\kappa_I}{2} (I_{j,t}/I_{j,t-1} - 1)^2$  represents investment adjustment costs and  $u_t^I > 0$  is an investment specific technology shock that follows the exogenous AR(1) process  $\log u_t^I = (1 - \rho_\chi) \log u^I + \rho_I \log u_{t-1}^I + \varepsilon_t^I$ , where  $\varepsilon_t^I$  is *i.i.d.N*(0,  $\sigma_{\varepsilon^I}^2$ ). The household chooses the capital utilization rate,  $u_{j,t}$  which transforms physical capital into capital services,  $K_{j,t}^s$ , according to  $K_{j,t}^s = u_{j,t} K_{j,t-1}$ . We assume that an increasing utilization of capital implies a higher depreciation rate,  $\delta^K(u_t)$ , specified as

$$\delta^K(u_{j,t}) = \delta_0 + \delta_1(u_{j,t} - 1) + \frac{\delta_2}{2}(u_{j,t} - 1)^2, \quad (10)$$

where  $\delta_0$  is the capital depreciation rate in a deterministic steady state in which  $\delta_1 = u$  is set to unity. The elasticity of capital utilization with respect to the rental rate of capital is given by  $\delta_1/\delta_2$ . Capital services  $K_{j,t}^s$  are rented to intermediate goods firms at a rental rate  $r_t^K$ .



Inventing a new product (or setting up a new firm) requires  $f_{E,t}/z_t$  units of the composite labor input, where  $f_{E,t}$  represents an entry cost shock that follows the exogenous AR(1) process  $\log f_{E,t} = (1 - \rho_{f_E}) \log f_E + \rho_{f_E} \log f_{E,t-1} + \varepsilon_t^{f_E}$ , where  $\varepsilon_t^{f_E}$  is *i.i.d.*  $N(0, \sigma_{\varepsilon^{f_E}}^2)$ . Consequently, household  $j$  spends  $f_{E,t}/z_t \cdot w_t N_{E,j,t}$  on investment in new firms. We assume that it takes one period before newly established firms become operational.<sup>1</sup> During this period, new firms are hit by the exogenous exit shock  $\delta$ . Furthermore, we model an endogenous failure rate that is an increasing function of the change in firm entry. The payoff in period  $t$  from investing in new firms in period  $t - 1$  is thus given by  $(1 - \delta)(v_t + d_t) \left(1 - \frac{\kappa_E}{2} \left(\frac{N_{E,j,t-1}}{N_{E,j,t-2}} - 1\right)^2\right) N_{E,j,t-1}$ , where the parameter  $\kappa_E$  serves as the counterpart of the capital adjustment cost parameter,  $\kappa_I$ , at the firm entry margin.

Household  $j$  chooses  $\{C_{j,t}, w_{j,t}, S_{j,t}, I_{j,t}, N_{E,j,t}, u_{j,t}, K_{j,t}, x_{j,t}, B_{j,t}\}_{t=0}^{\infty}$  taking as given  $\{w_t, r_t^K, R_t, v_t, d_t, L_t, T_t, z_t, f_{E,t}, u_t^I, \chi_t, \mu_t^w\}_{t=0}^{\infty}$  and the initial conditions  $B_{-1}, K_{-1}, C_{-1}, I_{-1}, N_{E-1}, S_{-1}$  so as to maximize (6) subject to (7), (8), (9), (10), and (5). Since all households will choose in equilibrium the same wage and quantities we can now assume symmetry and drop the index  $j$ . Let  $\lambda_t^C, \lambda_t^C Q_t, \lambda_t^S$  denote Lagrange multipliers for the budget constraint, the capital accumulation equation, and the definition of  $S_t$ , respectively. The first-order

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<sup>1</sup>Empirically, firm entry lags GDP. See, for example, Devereux, Head, and Lapham (1996).

conditions read as follows:

$$\lambda_t^C = \beta R_t \mathbf{E}_t \{ \lambda_{t+1}^C \} , \quad (11)$$

$$\lambda_t^C Q_t = \beta \mathbf{E}_t \{ \lambda_{t+1}^C (r_{t+1}^K u_{t+1} + Q_{t+1} (1 - \delta^K (u_{t+1}))) \} , \quad (12)$$

$$\lambda_t^C v_t = (1 - \delta) \beta \mathbf{E}_t \{ \lambda_{t+1}^C (v_{t+1} + d_{t+1}) \} , \quad (13)$$

$$\lambda_t^C = \left( \chi_t V_t - \gamma \lambda_t^S \frac{S_t}{C_t - b C_{t-1}} \right) - \beta b \mathbf{E}_t \left\{ \chi_{t+1} V_{t+1} - \gamma \lambda_{t+1}^S \frac{S_{t+1}}{C_{t+1} - b C_t} \right\} , \quad (14)$$

$$V_t = (C_t - b C_{t-1} - \psi L_t^\eta S_t)^{-1} , \quad (15)$$

$$\lambda_t^S = \chi_t V_t \psi L_t^\eta + \beta (1 - \gamma) \mathbf{E}_t \left\{ \lambda_{t+1}^S \frac{S_{t+1}}{S_t} \right\} , \quad (16)$$

$$1 = Q_t u_t^I \left( 1 - \frac{\kappa_I}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2 - \kappa_I \left( \frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right) + \beta \mathbf{E}_t \left\{ \frac{\lambda_{t+1}^C}{\lambda_t^C} Q_{t+1} u_{t+1}^I \kappa \left( \frac{I_{t+1}}{I_t} - 1 \right) \left( \frac{I_{t+1}}{I_t} \right)^2 \right\} , \quad (17)$$

$$\frac{w_t}{z_t} f_{E,t} = v_t \left( 1 - \frac{\kappa_E}{2} \left( \frac{N_{E,t}}{N_{E,t-1}} - 1 \right)^2 - \kappa_E \left( \frac{N_{E,t}}{N_{E,t-1}} - 1 \right) \frac{N_{E,t}}{N_{E,t-1}} \right) + \beta \mathbf{E}_t \left\{ \frac{\lambda_{t+1}^C}{\lambda_t^C} v_{t+1} \kappa_E \left( \frac{N_{E,t+1}}{N_{E,t}} - 1 \right) \left( \frac{N_{E,t+1}}{N_{E,t}} \right)^2 \right\} , \quad (18)$$

$$r_t^K = Q_t (\delta_1 + \delta_2 (u_t - 1)) , \quad (19)$$

$$\lambda_t^C w_t = \mu_t^w \chi_t V_t \psi \eta L_t^{\eta-1} S_t . \quad (20)$$

The law of motion of the total mass of firms is given by

$$N_t = (1 - \delta) N_{t-1} + (1 - \delta) \left[ 1 - \frac{\kappa_E}{2} \left( \frac{N_{E,t-1}}{N_{E,t-2}} - 1 \right)^2 \right] N_{E,t-1} . \quad (21)$$

### 2.3 Aggregate resource constraint

The aggregate resource constraint

$$Y_t^C + \frac{w_t}{z_t} f_{E,t} N_{E,t} = w_t L_t + N_t d_t + r_t^K u_t K_{t-1} , \quad (22)$$

can be obtained by combining the aggregate budget constraint of households (using  $x_t = N_t$ ) with the government budget constraint,  $G_t + B_{t-1} = T_t + \frac{B_t}{R_t}$ . The goods market clearing condition requires aggregate output of final goods,  $Y_t^C$ , to be equal to private

and government consumption plus investment in physical capital,  $Y_t^C = C_t + G_t + I_t$ . The gross domestic product,  $Y_t$ , is equal to  $Y_t^C$  plus investment in new firms,  $\frac{w_t}{z_t} f_{E,t} N_{E,t}$ . Total investment is the sum of investment in physical capital and investment in new firms,  $TI_t = I_t + \frac{w_t}{z_t} f_{E,t} N_{E,t}$ . Government consumption,  $G_t$ , is described by the exogenous AR(1) process  $\log G_t = (1 - \rho_g) \log G + \rho_g \log G_{t-1} + \varepsilon_t^G$ , where  $\varepsilon_t^G$  is *i.i.d.*  $N(0, \sigma_{\varepsilon_G}^2)$ .

## 2.4 The no-entry model

The no-entry model can be obtained by setting  $N_{E,t} = 0$  and normalizing the mass of firms to  $N_t = N = 1$ . This implies  $L_t^E = 0$ ,  $L_t = L_t^C$ ,  $\rho_t = 1$ ,  $Y_t = Y_t^C$ , and  $TI_t = I_t$ .

## 3 Data and Estimation Procedure

In this section we describe the data set and the conducted estimation procedure. Following the methodology of An and Schorfheide (2007) and Smets and Wouters (2007), we estimate both the entry and the no-entry model using Bayesian techniques. For the entry model we use eight time series of U.S. quarterly data ranging from 1964:Q1 to 2009:Q4: the growth rate of real per capita GDP, consumption, investment and profits, the logarithm of per capita hours worked, the growth rate of two measures of real wages, and the growth rate of per capita new firms. For the no-entry model, we exclude profits, wages and entry from the list of observables.

Table 6 reports the data source of the raw data which is used to construct the vector of observables. The construction is described in table 7. To the best of our knowledge there exists no time series for entry that covers the full sample period. Therefore, our measure for entry is the composite of two time series. From 1964:Q1 to 1998:Q3 the entry series is based on new incorporations from the Survey of Current Business and from 1998:Q4 till 2009:Q4 we use private sector establishment births from the Bureau of Labor Statistics.<sup>2</sup>

In order to generate data-consistent model variables, we divide the real model variables  $X_t \in \{Y_t, C_t, TI_t, w_t, d_t\}$  by the relative price  $\rho_t$  which is indicated by the superscript  $r$ .<sup>3</sup> Real data-consistent variables are therefore defined as  $X_t^r = X_t / \rho_t$ . The corresponding

<sup>2</sup>New incorporations is only available till 1998:Q3 and private sector establishment births starts in 1993:Q2.

<sup>3</sup>Bilbiie, Ghironi, and Melitz (2010) point out that for data-consistency real model variables should be deflated by  $p_t$  instead of  $P_t$ .

measurement equations for GDP, consumption, investment, hours worked, profits and entry then read as follows:

$$\begin{pmatrix} dl(\text{GDP}_t) \\ dl(\text{CONS}_t) \\ dl(\text{INV}_t) \\ l(\text{HOURS}_t) \\ dl(\text{PROFITS}_t) \\ dl(\text{ENTRY}_t) \end{pmatrix} = \begin{pmatrix} \Delta \hat{Y}_t^r \\ \Delta \hat{C}_t^r \\ \Delta \hat{T}I_t^r \\ \hat{L}_t \\ \Delta \hat{d}_t^r + \Delta \hat{N}_t \\ \Delta \hat{N}_{E,t} \end{pmatrix} \times 100 + \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ \varepsilon_t^{d,me} \\ 0 \end{pmatrix}$$

where the functions  $l$  and  $dl$  stand for 100 times the demeaned logarithm and the demeaned log-difference, respectively. A hat denotes log-deviations from the steady state and  $\Delta$  is a difference operator. Overall profits in the economy are defined by the number of firms,  $N_t$ , times the average profits per firm,  $d_t$ . Since the entry model is not able to capture the whole dynamics of profits, we add the measurement error,  $\varepsilon_t^{d,me}$ , which is assumed to be  $i.i.d.N(0, \sigma_{\varepsilon^{d,me}}^2)$ .

Following Justiniano, Primiceri, and Tambalotti (2010) and Gali Smets and Wouters (2011) we use two real wage measures in order to match the theoretical counterpart  $\Delta \hat{w}_t^r$ :

$$\begin{pmatrix} dl\text{WAGE1}_t \\ dl\text{WAGE2}_t \end{pmatrix} = \begin{pmatrix} 1 \\ \lambda \end{pmatrix} \Delta \hat{w}_t^r + \begin{pmatrix} \varepsilon_t^{w1,me} \\ \varepsilon_t^{w2,me} \end{pmatrix}$$

where  $\lambda$  denotes the loading coefficient for the second wage series and  $\varepsilon_t^{w1,me}$  and  $\varepsilon_t^{w2,me}$  are two measurement errors which are  $i.i.d.N(0, \sigma_{\varepsilon^{w1,me}}^2)$  and  $i.i.d.N(0, \sigma_{\varepsilon^{w2,me}}^2)$ , respectively. Since both loadings are not separately identified, we set one element of the loading vector to unity.

The application of eight data series requires at least eight exogenous disturbances. In total the model is governed by nine disturbances, including shocks to government consumption,  $\varepsilon_t^g$ , to labor productivity,  $\varepsilon_t^z$ , to investment-specific technology,  $\varepsilon_t^I$ , to entry costs,  $\varepsilon_t^{fE}$ , to preferences,  $\varepsilon_t^\chi$ , and to the wage mark-up,  $\varepsilon_t^{\mu^w}$ , and three measurement errors.

Table 1 displays the calibrated parameters. The discount rate,  $\beta$ , is set to 0.99, implying an annual steady state interest rate of approximately 4 percent. The steady-state value for

**Table 1:** Calibrated Parameters

Parameter	Value	Definition
$\beta$	0.99	Discount factor
$\delta_0$	0.025	Steady-state capital depreciation rate
$u$	1	Steady-state capacity utilization rate
$\mu^w$	1.2	Steady-state wage mark-up
$G/Y$	0.18	Steady-state ratio of government consumption to GDP
$L$	0.25	Steady-state of hours worked
$\tilde{N}$	$10^9$	Mass of firms

the utilization rate,  $u$ , is set to unity, implying the steady-state value of the depreciation rate,  $\delta^K$ , to be equal to  $\delta_0 = 0.025$ . The steady-state values  $G/Y$  and  $L$  are set to 0.18 and 0.25, respectively. Following Bilbiie, Ghironi, and Melitz (2010) the overall mass of firms in the economy,  $\tilde{N}$ , is assumed to be  $10^9$ .

The remaining parameters are estimated for which we choose the following prior distributions as summarized in Table 2. The standard deviation of the innovations are assumed to follow an inverse gamma distribution with mean 0.02 and standard deviation 1. For the autocorrelation parameters we choose a beta distribution with mean 0.5 and standard deviation 0.2. The moving average coefficient of the wage mark-up shock is assumed to follow a normal distribution with mean zero and standard deviation 0.2. For the prior distribution of the structural parameters we broadly follow the existing literature.

## 4 Estimation results

### 4.1 Parameter estimates

Table 2 compares the estimation results of the entry and the no-entry model by showing the estimated parameters as means of the posterior distribution and the 90 percent confidence intervals obtained by the Metropolis-Hastings algorithm.

To start with, we focus on the parameters related to the entry mechanism. The point estimate of the price mark-up,  $\mu^p$ , is 1.42 with a confidence interval ranging from 1.24 to 1.58. This point estimate implies that a one percent increase in the mass of firms lowers the price mark-up by around 0.3 percent and raises the relative price by 0.21 percent. Notice that the former elasticity captures the competition effect and the latter captures the degree of love of variety. These estimates are smaller than those estimated in Lewis and Poilly

**Table 2:** Results from the Bayesian estimation including prior distribution and confidence intervals

Parameters	Prior distribution				Posterior distribution			
	T	Mean	STD	Entry model		NoEntry model		
				Mean	[5% – 95%]	Mean	[5% – 95%]	
<i>Structural parameters</i>								
Labor share in production	$\alpha$	$B$	0.7	0.2	0.85	[0.79 – 0.92]	0.63	[0.60 – 0.65]
Labor utility	$\theta$	$G$	2.0	1.0	4.23	[2.04 – 6.39]	1.20	[0.50 – 1.87]
Wealth elast. labor supply	$\gamma$	$B$	0.5	0.2	0.79	[0.65 – 0.95]	0.11	[0.02 – 0.19]
Consumption habit	$b$	$B$	0.5	0.2	0.77	[0.71 – 0.82]	0.68	[0.60 – 0.76]
Investment adj. cost	$\kappa_I$	$G$	4.0	1.0	4.69	[3.21 – 6.13]	4.00	[2.59 – 5.41]
Inv. elast. of capital util.	$\frac{\delta_2}{\delta_1}$	$IG$	1.0	1.0	0.43	[0.26 – 0.59]	0.52	[0.30 – 0.74]
Price mark-up	$\mu_p$	$G$	1.3	0.2	1.42	[1.24 – 1.58]	–	–
Firm exit rate	$\delta$	$B$	.03	.02	0.01	[0.01 – 0.02]	–	–
Entry adj. cost	$\kappa_E$	$G$	4.0	1.0	1.31	[0.89 – 1.72]	–	–
<i>Autocorrelation of shocks</i>								
Labor productivity	$\rho_z$	$B$	0.5	0.2	0.96	[0.93 – 0.99]	0.95	[0.91 – 0.98]
Wage mark-up	$\rho_\mu$	$B$	0.5	0.2	0.97	[0.94 – 0.99]	0.98	[0.96 – 0.99]
Invest. spec. tech.	$\rho_I$	$B$	0.5	0.2	0.22	[0.07 – 0.35]	0.43	[0.27 – 0.59]
Preference	$\rho_\chi$	$B$	0.5	0.2	0.24	[0.07 – 0.39]	0.37	[0.04 – 0.77]
Gov. spending	$\rho_G$	$B$	0.5	0.2	0.95	[0.92 – 0.97]	0.94	[0.92 – 0.96]
Entry cost	$\rho_{fE}$	$B$	0.5	0.2	0.96	[0.91 – 0.99]	–	–
<i>Standard deviation of innovations</i>								
Labor prod.	$\sigma_{\varepsilon z}$	$IG$	2.0	1	0.81	[0.69 – 0.93]	1.24	[1.07 – 1.41]
Wage mark-up	$\sigma_{\varepsilon \mu}$	$IG$	2.0	1	4.73	[2.97 – 6.47]	1.44	[0.86 – 1.99]
Invest. spec. tech.	$\sigma_{\varepsilon I}$	$IG$	2.0	1	48.3	[18.1 – 80.4]	42.9	[27.4 – 59.2]
Preference	$\sigma_{\varepsilon \chi}$	$IG$	2.0	1	1.82	[1.28 – 2.35]	1.07	[0.60 – 1.52]
Gov. spending	$\sigma_{\varepsilon G}$	$IG$	2.0	1	2.18	[1.96 – 2.39]	1.87	[1.71 – 2.03]
Entry cost	$\sigma_{\varepsilon fE}$	$IG$	2.0	1	2.08	[1.40 – 2.76]	–	–
<i>Moving average parameter and loading coefficient</i>								
Wage mark-up shock	$\nu$	$N$	0.0	0.2	0.41	[0.26 – 0.56]	0.54	[0.34 – 0.73]
Loading coefficient	$\lambda$	$N$	1.0	2.0	0.14	[0.06 – 0.21]	–	–

(2012) who find a mark-up of 66 percent implying 0.33 for consumer’s love of variety and 0.4 for the competition effect. However, they estimate a New Keynesian model with firm entry by minimizing the distance between the impulse responses to a monetary policy shock generated by the model and those obtained from a VAR.

The estimated firm exit rate is around 1.4 percent with a confidence interval ranging from 0.5 to 2.3 percent. This value is therefore significantly lower than the calibrated 2.5 percent used by Bilbiie, Ghironi, and Melitz (2007) who point out that a lower value of  $\delta$  generates more persistent dynamics. Entry adjustment costs,  $\kappa_E$ , are estimated to be around 1.31 with a confidence interval ranging from 0.89 to 1.72. This is significantly lower than the 4.69 point estimate for the capital adjustment cost parameter,  $\kappa_I$ . As discussed below, the model overestimates the volatility of firm entry and its first order

autocorrelation. Higher entry adjustment costs would help to bring the model closer to the empirical standard deviation of firm entry but only at the cost of an even higher autocorrelation.

The estimates for the other structural parameters are in line with previous DSGE studies. The estimates are not statistically different across the two models with three notable exceptions. First, the labor share in production,  $\alpha$ , is estimated at 0.85 in the entry model and at 0.63 in the no-entry model, with a confidence interval ranging from 0.79 to 0.92 and 0.60 to 0.65, respectively. Notice, however, that the estimates are not directly comparable because in the entry-model labor is not only utilized for producing manufactured goods but also for creating new products. Second, the parameter  $\theta$  which determines the labor supply elasticity is estimated at 4.23 in the entry model and at 1.2 in the no-entry model with relatively wide confidence intervals ranging from 2.04 to 6.39 in the entry model and from 0.5 to 1.87 in the no-entry model. Thus, labor supply is estimated to be considerably more elastic when firm dynamics are ignored. Finally, the estimate of the wealth elasticity of labor supply,  $\gamma$ , is 0.79 in the entry model and decreases to 0.11 in the no-entry model. The confidence intervals are 0.65 – 0.95 and 0.02 – 0.19, respectively. These estimates imply that preferences in the entry-model are close to those in King, Plosser, and Rebelo (1988), whereas preferences in the no-entry model are characterized by a low wealth elasticity of labor supply and are thus closer to those in Greenwood, Hercowitz, and Huffmann (1988). The latter echoes results from Schmitt-Grohe and Uribe (2010) who estimate a near-zero wealth elasticity of labor supply within a framework similar to our no-entry model.

It is well known that standard business cycle models need a highly flexible labor supply to generate macroeconomic fluctuations of the magnitude that is observed in the data. The estimation results for the labor supply coefficients  $\theta$  and  $\gamma$  imply that in the entry model labor supply is significantly less flexible than in the no-entry model. This suggests that firm dynamics play an important role as an amplification mechanism for macroeconomic fluctuations and thus help to reconcile macro models with micro evidence of an inelastic supply of labor.

The estimated autoregressive coefficients are not significantly different across the models. Shocks to labor productivity, to wage mark-ups, to government spending, and in model

with firm entry also shocks to entry costs are estimated to be highly persistent, whereas preference shocks and investment-specific technology shocks are much less persistent.

Finally, we examine the estimates of the standard deviations of innovations. For all shocks, except for labor productivity shocks, the estimates of  $\sigma$  are larger in the model with firm entry than in the model without. This may partly be driven by the fact that the estimation of the firm entry model requires additional time series for firm entry, profits, and wages. However, and as discussed below, it might also point to the fact that the entry mechanism does amplify the effects of labor productivity shocks but dampens the effects of the other shocks. Notice that the size of the shock to investment-specific technology is roughly in line with other studies such as Smets and Wouters (2007) who report a smaller value but normalize the shock process so that it enters the linearized model equation for investment in physical capital with a unit coefficient.

## 4.2 Second moments

In order to assess the model fit of the estimated entry and no-entry model to the data, we compare the model-implied second moments with the corresponding empirical moments of the data and across the models. Table 3 reports the standard deviations, the relative standard deviations, the autocorrelation, and the contemporaneous correlation with output of six time series used as observables in the estimation, excluding the two wage series. In order to gain some more meaningful insights into the properties of the model, we also compute the moments for the corresponding HP-filtered level series. The model-implied second moments are derived from simulated data of the corresponding models, where the measurement errors is muted during the simulation.

In both models the empirical moments of output, consumption, total investment and hours worked are matched quite well, whereas the entry model has some difficulties to fit the moments of profits and entry. The structural entry model can only explain a small fraction of the actual volatility in profits. Most of the variability is captured by the measurement error which is absent in the computation of the second moments.

The entry model overstates the volatility in firm entry and is not able to replicate the negative serial correlation of the growth rate of firm entry. The model-implied serial



**Table 3:** Second moments

$X$	$\sigma_X$			$\sigma_X/\sigma_{\Delta\hat{Y}^r}$			1st autocorr.			$corr(X, \Delta\hat{Y}^r)$		
	Data	Ent	ENoEnt	Data	Ent	ENoEnt	Data	Ent	ENoEnt	Data	Ent	ENoEnt
<i>Data series used for estimation</i>												
$\Delta\hat{Y}^r$	0.87	0.88	0.88	1.00	1.00	1.00	0.31	0.28	0.42	1.00	1.00	1.00
$\Delta\hat{C}^r$	0.53	0.58	0.59	0.61	0.66	0.67	0.41	0.41	0.47	0.59	0.44	0.55
$\Delta\hat{T}\hat{I}^r$	3.30	3.60	3.48	3.79	4.08	3.94	0.30	0.25	0.40	0.87	0.85	0.85
$\hat{L}$	4.47	4.23	4.12	5.14	4.79	4.68	0.96	0.98	0.98	0.14	0.12	0.11
$\Delta\hat{D}^r$	6.12	1.00	–	7.03	1.14	–	0.11	0.23	–	0.43	0.79	–
$\Delta\hat{N}_E$	3.30	4.43	–	3.79	5.02	–	–0.12	0.50	–	0.17	0.24	–
<i>HP filtered data</i>												
$\hat{Y}^r$	1.56	1.42	1.61	1.00	1.00	1.00	0.86	0.83	0.87	1.00	1.00	1.00
$\hat{C}^r$	0.95	1.01	1.07	0.61	0.71	0.67	0.86	0.87	0.87	0.30	0.52	0.67
$\hat{T}\hat{I}^r$	5.79	5.71	6.24	3.72	4.01	3.87	0.86	0.82	0.86	0.93	0.86	0.90
$\hat{L}$	1.89	1.39	1.31	1.21	0.98	0.81	0.91	0.84	0.85	0.87	0.74	0.75
$\hat{D}^r$	9.49	1.61	–	6.10	1.33	–	0.80	0.83	–	0.49	0.68	–
$\hat{N}_E$	4.27	8.66	–	2.75	6.09	–	0.72	0.89	–	0.52	0.36	–

*Note:* Ent and ENoEnt refer to the estimated entry and the estimated no-entry model, respectively.

correlation is 0.50, whereas in the data we find a value of  $-0.12$ . Nevertheless, the entry model confirms the procyclical nature of profits and firm entry with GDP in the data.

### 4.3 Variance decomposition

Table 4 shows the forecast-error variance decomposition of GDP, consumption, total investment, employment and firm entry from the entry and the no-entry model at a one-quarter, a four-quarter and a forty-quarter forecast horizon, respectively. In the entry model labor productivity and wage mark-up shocks are the important drivers of variations in GDP, consumption and total investment at all forecast horizons. In total, both shocks account for 79% and 91% at a four-quarter and a forty-quarter horizon, respectively. At a one-quarter horizon most fluctuations in GDP and investment are explained by the investment-specific technology shock. Contrarily, we find that consumption is mainly driven by the preference shock in the short run.

For all considered time series, except for firm entry, we find that the wage mark-up shock is the dominant driver of long-run fluctuations and almost exclusively drives employment at all horizons. Firm entry is mainly driven by entry cost shocks which account for 37% to 62% of its fluctuations. For all other time series, shocks to firm entry play only a minor role.

**Table 4:** Variance Decomposition

Variance decomposition	GDP			Consumption			Investment			Employment		Entry
	$Y_{Ent}$	$Y_{Ent}^r$	$Y_{ENoEnt}$	$C_{Ent}$	$C_{Ent}^r$	$C_{ENoEnt}$	$TI_{Ent}$	$TI_{Ent}^r$	$I_{ENoEnt}$	$L_{Ent}$	$L_{ENoEnt}$	$N_E$
<i>1 quarter horizon</i>												
Labor productivity	23	23	30	16	16	42	15	15	13	6	6	21
Wage mark-up	29	29	11	22	22	16	18	18	4	84	64	24
Invest. spec. tech.	39	39	44	1	1	2	62	62	82	7	19	11
Preference	2	2	4	55	55	38	4	4	0	1	4	5
Gov. spending	7	7	11	3	3	3	1	1	1	3	7	2
Entry cost	1	1	–	4	4	–	0	0	–	0	–	37
<i>4 quarter horizon</i>												
Labor productivity	29	29	45	22	20	51	22	22	26	1	2	16
Wage mark-up	50	49	23	40	38	33	35	35	11	96	81	26
Invest. spec. tech.	18	19	29	0	0	1	33	33	62	1	15	10
Preference	0	0	1	22	23	12	3	3	1	0	1	2
Gov. spending	2	2	3	4	4	3	2	2	1	0	2	1
Entry cost	0	0	–	13	15	–	6	5	–	1	–	45
<i>40 quarter horizon</i>												
Labor productivity	30	30	48	26	25	42	24	24	45	0	2	11
Wage mark-up	61	63	42	56	55	47	46	46	28	98	92	20
Invest. spec. tech.	4	5	9	5	8	7	16	17	26	1	5	6
Preference	0	0	0	2	2	1	1	1	0	0	0	1
Gov. spending	0	0	1	3	3	3	1	1	1	0	1	1
Entry cost	5	1	–	8	8	–	13	11	–	1	–	62

As for the entry model, we find that labor productivity and wage mark-up shocks in the no-entry model account for a large fraction of fluctuations for all variables and across all forecast horizons. Contrarily to the entry model, the importance of wage mark-up shocks is mitigated, whereas investment specific technology shocks play a more dominant role.

#### 4.4 Shock specific and overall amplification

In this section we evaluate the qualitative and quantitative importance of endogenous firm entry as internal amplification and propagation mechanism in business cycle fluctuations. Following Jaimovich and Floetotto (2008) table 5 summarizes our amplification measures for overall amplification and for shock specific amplification of five structural shocks, including shocks to labor productivity, to wage mark-up, to investment specific technology, to preferences, and to government spending.

For each shock we compute five relative standard deviations. The first three columns in table 5 give the standard deviation of output,  $\sigma_Y$ , relative to the standard deviation of the underlying shock process,  $\sigma_X$ . These ratios are computed from simulated data where only the shock under consideration is active. The three columns corresponds to three different model frameworks. Ent refers to the estimated entry model, and NoEnt and ENoEnt refer to the no-entry model framework with parameter estimates from the entry and the no-entry model, respectively. The fourth column show the ratios of the estimated standard deviation of the shock process between the Ent and the ENoEnt model. Analogously, the fifth column states the corresponding ratios for the estimated innovation volatilities.

**Table 5:** Relative standard deviations and amplification indicators

<i>Shock specific amplification</i>					
Shock X	$\frac{\sigma_{Y,Ent}}{\sigma_{X,Ent}}$	$\frac{\sigma_{Y,NoEnt}}{\sigma_{X,NoEnt}}$	$\frac{\sigma_{Y,ENoEnt}}{\sigma_{X,ENoEnt}}$	$\frac{\sigma_{X,Ent}}{\sigma_{X,ENoEnt}}$	$\frac{\sigma_{\varepsilon^X,Ent}}{\sigma_{\varepsilon^X,ENoEnt}}$
Labor prod.	1.11	0.92	0.95	0.73	0.65
Wage mark-up	0.19	0.16	0.37	2.48	3.28
Invest. spec. tech.	0.02	0.03	0.15	4.84	5.23
Preference	0.09	0.13	0.23	1.63	1.70
Gov. spending	0.05	0.06	0.07	1.21	1.17
<i>Overall amplification</i>					
	$\frac{\sigma_{Y,Ent}}{\sigma_{Y,NoEnt}}$	$\frac{\sigma_{Y^r,Ent}}{\sigma_{Y,NoEnt}}$			
All shocks	1.21	1.06			
No entry cost shock	1.16	1.04			

In order to quantify the marginal amplification effect of firm entry, we compare the relative standard deviations of output from the Ent model with the relative standard deviation from the NoEnt model. For the labor productivity shock we obtain a value of 1.11 compared to 0.92 in the NoEnt model. This implies that variations in output increase by 20% when the firm entry mechanism is active. Similarly, for wage mark-up shocks the increase is given by 19%. For the remaining three shocks firm entry has a dampening effect. With firm entry the relative output volatility of investment specific technology, preference and government spending shocks reduces by 33%, 31% and 17%, respectively.<sup>4</sup>

Except for wage mark-up shocks these results continue to hold qualitatively if we compare the entry model with the estimated no-entry model. Contrarily to the NoEnt model, the ENoEnt model also accounts for the different parameter estimates. Recall that the ENoEnt model features a significantly more flexible labor supply. Taking the different parameter estimates into account, wage mark-up shocks cause higher output variations in the no-entry model than in the entry model. Labor productivity shocks remain more effective in the entry model.

So far, we measure amplification only in terms of relative output variation. In order to account for amplification in consumption, total investment and hours worked as well, we compare the estimated standard deviations of the shock process and of the innovations between the estimated entry and the estimated no-entry model. A value smaller than unity means that the entry model needs less exogenous volatility in order to match the standard deviations in GDP, consumption, total investment and hours worked, indicating that additional volatility is generated through the endogenous firm entry mechanism. The converse holds for values larger than unity. Notice that we use four additional time series to estimate the entry model. Consequently, higher exogenous volatility might result from variations in firm entry, profits or wages that are not explained by intrinsic dynamics of the entry model.

We measure overall amplification as the output volatility in the estimated entry model relative to the output volatility in the NoEnt model. In contrast to the shock specific amplification, we compute the standard deviations from simulated data of the corresponding models where all structural shocks are active. Given the same underlying shock processes

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<sup>4</sup>Note that these results also hold for data-consistent variables.

in both models, we find that the entry model generates 21% more volatility in output than the NoEst model. If we exclude the entry cost shock, the overall amplification reduces to 16%. On the other hand, we only find a marginal amplification of four to six percent when we use data-consistent variables.

#### 4.5 Impulse responses

Figure 1 to 6 show the impulse responses of GDP, consumption, total investment, the real wage, firm entry, the price mark-up, profits per firm,  $d_t$ , and output of a representative intermediate good firm,  $y_t$ , to the six structural shocks. In order to illustrate the impact of firm entry on the dynamics we present impulse responses for two models: the estimated entry model and the no-entry model where firm dynamics are switched off but where we keep the parameter estimates from the entry model.<sup>5</sup> For the model with firm entry the dynamics of welfare-relevant and data-consistent variables are shown.

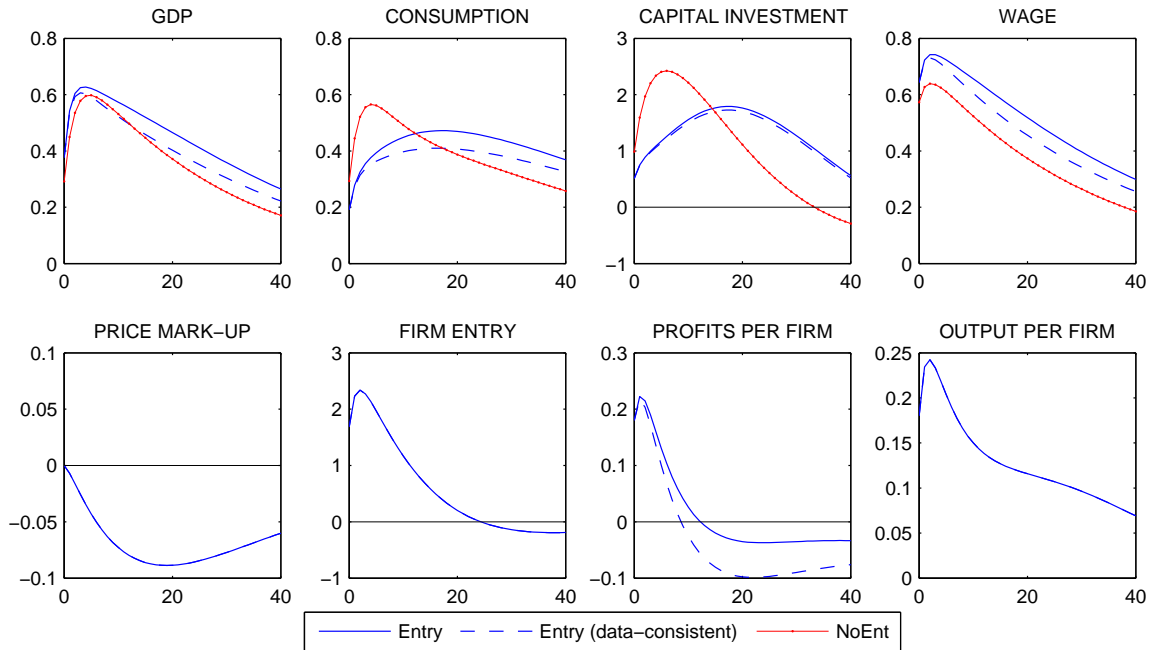


Figure 1: Impulse responses to a labor productivity shock

To start with, Figure 1 plots the responses to a positive labor-augmenting technology shock. This boosts GDP, consumption, as well as investment in physical capital and firm entry. Firm entry is fueled by rising profit opportunities of monopolistic firms due to the

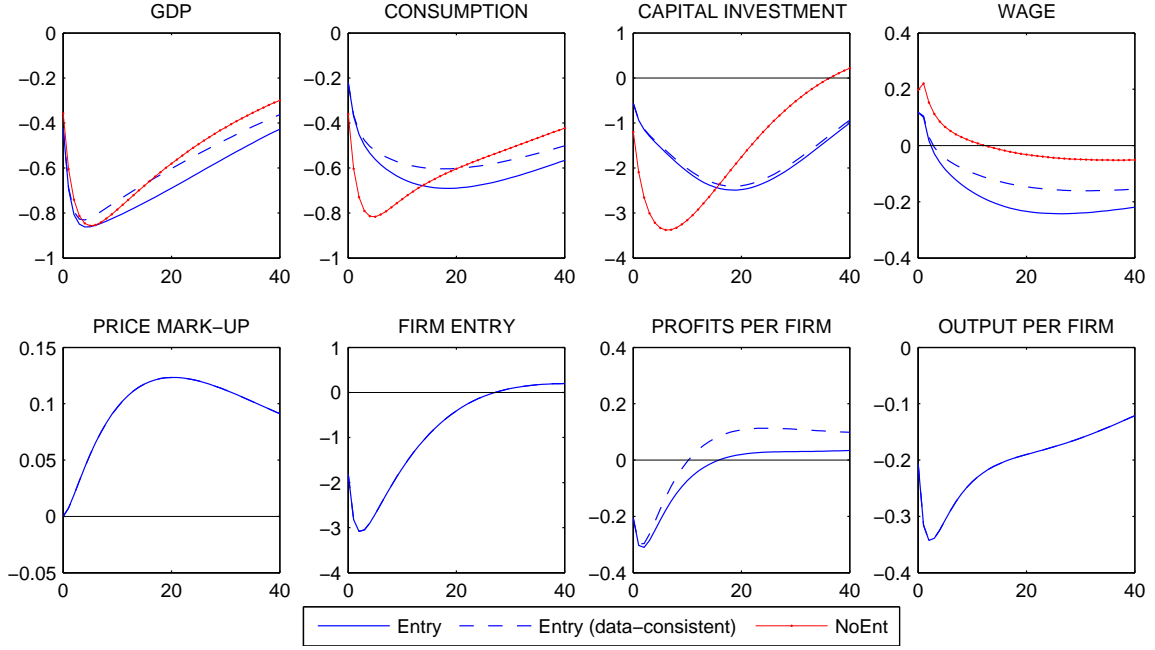
<sup>5</sup>The estimated impulse responses in the entry model including the 90 percent confidence bands can be found in the appendix.

increase in aggregate demand as well as by the drop in entry costs. The latter decreases since the increase in  $z$  outweighs the rise in real wages. Hence, the mass of firms (or products) starts to increase making products closer substitutes and thus deteriorating market power in the monopolistic sector. This leads to a decrease in price mark-ups which boosts aggregate demand and induces individual firms to increase their production. The increase in aggregate demand is enforced by the drop in the welfare-relevant price index through the love of variety effect. The drop in mark-ups in conjunction with the love of variety effect is at the heart of why firm entry magnifies the impacts of productivity shocks. This magnification effect can be seen in the impulse response functions. There is an amplification of GDP, in particular in the medium run, when firm entry is present. In the entry model, the response of consumption and capital investment is muted on impact but persists for longer.

Figure 2 shows the responses to an increase in wage mark-ups. In both models, this leads to a decline of GDP, consumption, and capital investment. The drop in GDP is amplified when firm entry is taken into account. The reason is that firm entry is depressed by the increase in entry costs and the drop in firm profits triggered by the initial increase in real wages. Since the mass of firms declines, the product space becomes less crowded and the elasticity of substitution declines. Consequently, the price mark-up rises which causes aggregate demand and individual firm's production to fall. As in the case of labor productivity shocks, the responses of consumption and capital investment are initially dampened in the firm entry model. However, over the course of adjustment this pattern is reversed due to higher persistence.

To sum up, the interaction between procyclical changes in the mass of products and countercyclical mark-up movements acts as an internal amplification mechanism for labor-augmenting technology and wage mark-up shocks. The question remains to be answered why shocks to aggregate demand (government spending and preference shocks) and to investment-specific technology are dampened when firm entry is present.

From inspecting the impulse responses in Figure 3, 4, and 5 it is evident that the conditional correlation of firm entry and GDP is negative for those shocks. Consequently, the price mark-up reacts procyclically to firm's output and GDP and the internal amplification mechanism is turned off. Quite the contrary, the countercyclical response of firm entry and

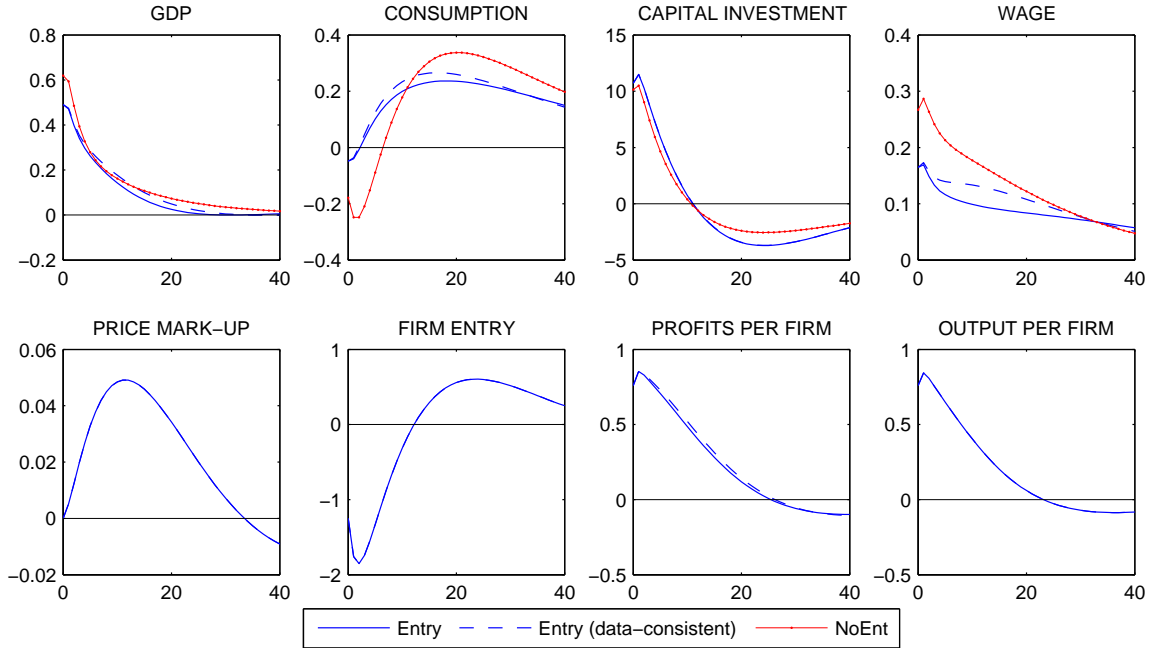


**Figure 2:** Impulse responses to a wage mark-up shock

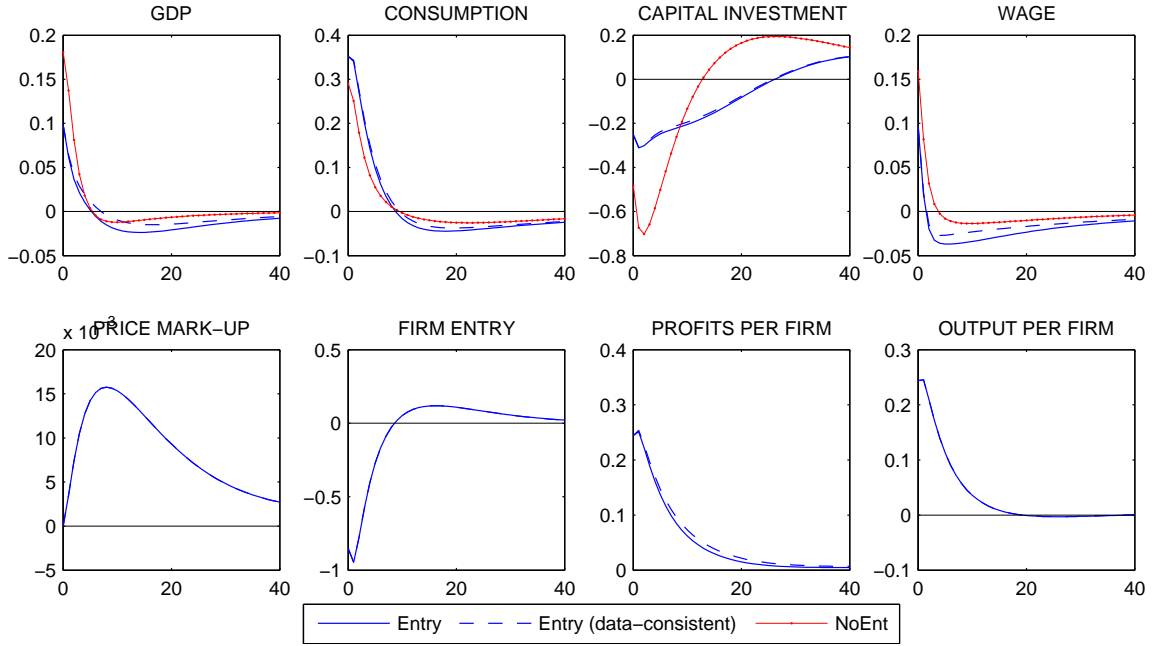
the procyclical response of firm's market power abate the impacts of those shocks on GDP when compared to the no-entry model.

Figure 3 shows the response to the investment-specific technology shock. The increase in the efficiency with which final goods can be transformed into physical capital produces a boom in capital investment and a hike in GDP. In both models, consumption falls on impact but turns positive during the course of adjustment. This consumption path is much more pronounced in the no-entry model. Real wages and thus entry costs increase. The value of a firm,  $v_t$ , decreases due to the increase in the real interest rate which outweighs the increase in individual firm's profits. Consequently, firm entry falls inducing an increases in price mark-ups. This, in turn, depresses aggregate demand and individual firm's production.

Figure 4 and 5 show the responses to the preference shock and the government spending shock, respectively. Both, the positive time-impatience shock and the increase in government spending increase aggregate demand and the real interest rate. The latter lowers firm values which induces, in conjunction with the rise in entry costs, a decline in firm entry. Consequently, price mark-up falls which dampens the impacts of aggregate demand shocks compared to the no-entry model. The impulse responses show a dampening effect in particular for the components of aggregate demand,  $C_t$  and  $I_t$ . The initial drop in capital



**Figure 3:** Impulse responses to an investment specific technology shock



**Figure 4:** Impulse responses to a preference shock

investment triggered by the preference shock is almost doubled in the no-entry model. In the case of an increase in government spending, both consumption and capital investment are much stronger affected when firm entry is present.

Finally, Figure 6 shows that an exogenous increase in entry costs generates a strong de-



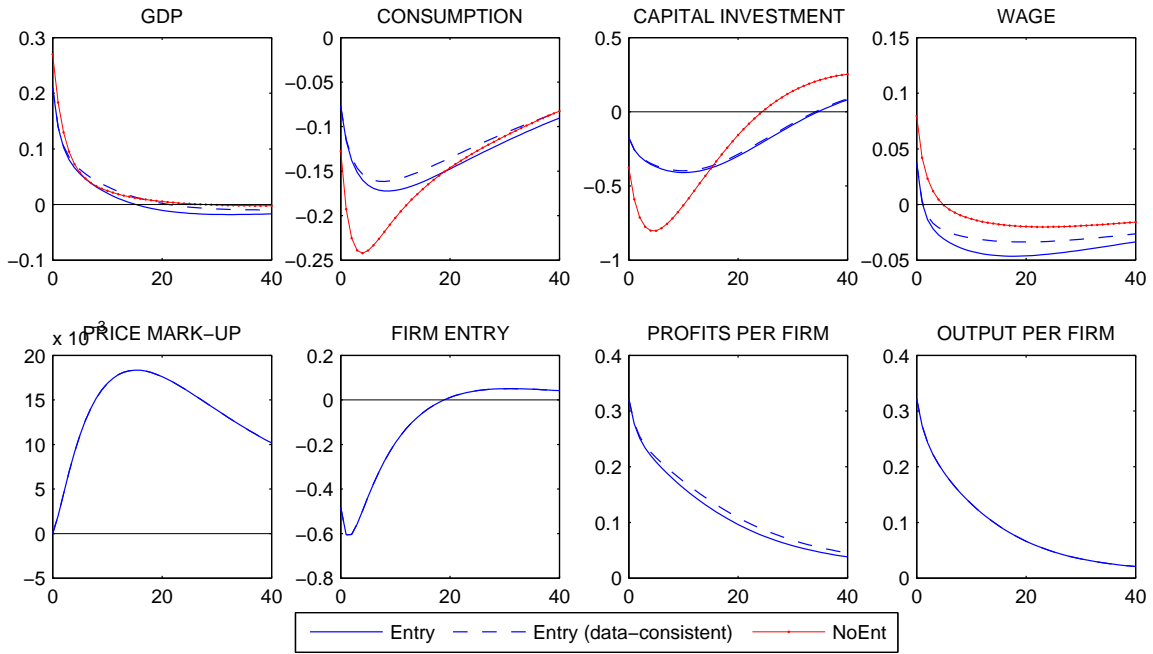


Figure 5: Impulse responses to a government spending shock

cline in firm entry. On impact, consumption and capital investment are boosted. However, the decrease in the number of products leads to an increase in the market power of firms. The increase in price mark-ups induces a fall in capital investment and consumption. GDP, after a temporary rise on impact, declines significantly.

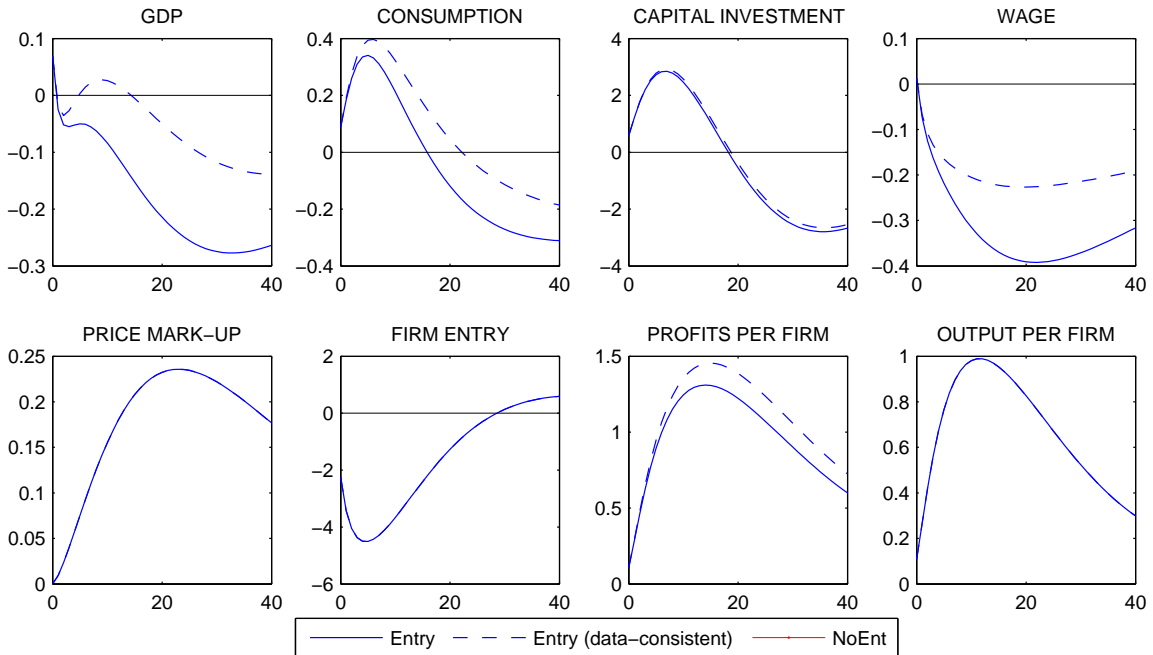


Figure 6: Impulse responses to an entry cost shock

## 5 Conclusion

– to be added –

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## Appendix

### The log-linear model

- Consumption Euler equation:

$$\hat{\lambda}_t^C = E_t \hat{\lambda}_{t+1}^C + \hat{R}_t$$

where  $\lambda_t^C$  denotes the Lagrange multiplier for the budget constraint.

- Shares Euler equation:

$$\hat{v}_t = E_t \left\{ \hat{\lambda}_{t+t}^C - \hat{\lambda}_t^C + \beta(1 - \delta)\hat{v}_{t+1} + (1 - \beta(1 - \delta))\hat{d}_{t+1} \right\}$$

- Capital Euler equation:

$$\hat{Q}_t = E_t \left\{ \hat{\lambda}_{t+t}^C - \hat{\lambda}_t^C + \beta(1 - \delta^K)\hat{Q}_{t+1} + (1 - \beta(1 - \delta^K))\hat{r}_{t+1}^K \right\}$$

where  $Q_t$  is marginal Tobin's Q.

- Lagrange multiplier associated with the household's budget constraint:

$$\begin{aligned} \hat{\lambda}_t^C = & \lambda_1 \left( \hat{V}_t + \hat{\chi}_t - b\beta E_t \{ \hat{V}_{t+1} + \hat{\chi}_{t+1} \} \right) - \lambda_2 \left( \hat{\lambda}_t^S + \hat{S}_t - b\beta E_t \{ \hat{S}_{t+1} + \hat{\lambda}_{t+1}^S \} \right) \\ & + \lambda_3 \left( \hat{C}_t - b\hat{C}_{t-1} - b\beta E_t \{ \hat{C}_{t+1} - b\hat{C}_t \} \right) \end{aligned}$$

where  $\lambda_1 = \frac{C(1-b)(1-\beta(1-\gamma))}{(1-b\beta)[(1-\beta(1-\gamma))C(1-b)-\gamma\psi SL^\eta]}$ ,  $\lambda_2 = \frac{\gamma\psi SL^\eta}{(1-b\beta)[(1-\beta(1-\gamma))C(1-b)-\gamma\psi SL^\eta]}$ ,  $\lambda_3 = \frac{\gamma\psi SL^\eta}{(1-b)(1-b\beta)[(1-\beta(1-\gamma))C(1-b)-\gamma\psi SL^\eta]}$ , and the auxiliary variable

$$\hat{V}_t = -\frac{C}{C(1-b) - \psi L^\eta S} \left( \hat{C}_t - b\hat{C}_{t-1} \right) + \frac{\psi L^\eta S}{C(1-b) - \psi L^\eta S} \left( \eta \hat{L}_t + \hat{S}_t \right)$$

- Dynamics of  $S_t$

$$\hat{S}_t = (1 - \gamma)\hat{S}_{t-1} + \frac{\gamma}{1-b}\hat{C}_t - \frac{\gamma b}{1-b}\hat{C}_{t-1}$$

- Lagrange multiplier associated with  $S_t$ :

$$\hat{\lambda}_t^S = \beta(1 - \gamma) \mathbf{E}_t \left\{ \hat{\lambda}_{t+1}^S + \hat{S}_{t+1} - \hat{S}_t \right\} + (1 - \beta(1 - \gamma)) \left( \eta \hat{L}_t + \hat{V}_t + \hat{\chi}_t \right)$$

- Labor supply:

$$\hat{w}_t = \hat{\mu}_t^w + \hat{V}_t + \theta \hat{L}_t + \hat{S}_t - \hat{\lambda}_t^C + \hat{\chi}_t$$

- Optimal pricing equation:

$$\hat{\rho}_t = \hat{\mu}_t^p + \hat{m}c_t$$

- Price mark-up:

$$\hat{\mu}_t^p = - \left( 1 - \frac{1}{\mu^p} \right) \hat{N}_t$$

- Relative price:

$$\hat{\rho}_t = \frac{1}{2} (\mu^p - 1) \hat{N}_t$$

- Factor demand equation:

$$\begin{aligned} \hat{w}_t &= \hat{Y}_t^C - \hat{L}_t^C - \hat{\mu}_t^p \\ \hat{r}_t^K &= \hat{Y}_t^C - (\hat{K}_{t-1} + \hat{u}_t) - \hat{\mu}_t^p \end{aligned}$$

- Total profit income:

$$\hat{D}_t \equiv \hat{N}_t + \hat{d}_t = \frac{1}{\mu^p - 1} \hat{\mu}_t^p + \hat{Y}_t^C$$

- Firm entry:

$$\hat{N}_{E,t} = \frac{\beta}{1 + \beta} \mathbf{E}_t \hat{N}_{E,t+1} + \frac{1}{1 + \beta} \hat{N}_{E,t-1} + \frac{1}{(1 + \beta)\kappa_E} (\hat{v}_t - (\hat{w}_t - \hat{z}_t + \hat{f}_{E,t}))$$

- Investment in new firms:

$$\hat{I}_{E,t} = \hat{w}_t - \hat{z}_t + \hat{f}_{E,t} + \hat{N}_{E,t}$$

- Firm dynamics:

$$\hat{N}_t = (1 - \delta)\hat{N}_{t-1} + \delta\hat{N}_{E,t-1}$$

- Investment in physical capital:

$$\hat{I}_t = \frac{\beta}{1 + \beta} \mathbf{E}_t \hat{I}_{t+1} + \frac{1}{1 + \beta} \hat{I}_{t-1} + \frac{1}{\kappa(1 + \beta)} (\hat{Q}_t + \hat{u}_t^I)$$

- Capital accumulation equation:

$$\hat{K}_t = (1 - \delta^K)\hat{K}_{t-1} + \delta^K \hat{I}_t - r^K \hat{u}_t + \delta^K \hat{u}_t^I$$

- Capital utilization:

$$\hat{u}_t = \frac{\delta_1}{\delta_2} (\hat{r}_t^K - \hat{Q}_t)$$

- Total investment:

$$\hat{T}I_t = \frac{I}{\hat{T}I} \hat{I}_t + \frac{vN_E}{\hat{T}I} \hat{I}_{E,t}$$

- Labor in entry:

$$\hat{L}_t^E = \hat{f}_{E,t} + \hat{N}_{E,t} - \hat{z}_t$$

- Aggregate production function:

$$\hat{Y}_t^C = \hat{\rho}_t + \alpha(\hat{z}_t + \hat{L}_t^C) + (1 - \alpha)(\hat{u}_t + \hat{K}_{t-1})$$

- Gross domestic product:

$$\hat{Y}_t = \frac{Y^C}{Y} \hat{Y}_t^C + \frac{vN_E}{Y} (\hat{w}_t - \hat{z}_t + \hat{f}_{E,t} + \hat{N}_{E,t})$$

- Goods market clearing:

$$\hat{Y}_t^C = \frac{C}{Y^C} \hat{C}_t + \frac{I}{Y^C} \hat{I}_t + \frac{G}{Y^C} \hat{G}_t$$

- Resource constraint:

$$\hat{Y}_t = \frac{wL}{Y} (\hat{w}_t + \hat{L}_t) + \frac{Nd}{Y} (\hat{N}_t + \hat{d}_t) + \frac{r^K K}{Y} (\hat{r}_t^K + \hat{K}_{t-1} + \hat{u}_t)$$

### Shock processes

- Labor productivity:

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_t^z$$

- Entry costs:

$$\hat{f}_{E,t} = \rho_{f_E} \hat{f}_{E,t-1} + \varepsilon_t^{f_E}$$

- Investment specific technology:

$$\hat{u}_t^I = \rho_I \hat{u}_{t-1}^I + \varepsilon_t^I$$

- Wage mark-up:

$$\hat{\mu}_t^w = \rho_\mu \hat{\mu}_{t-1}^w + \varepsilon_t^\mu + \nu \varepsilon_{t-1}^\mu$$

- Preferences:

$$\hat{\chi}_t = \rho_\chi \hat{\chi}_{t-1} + \varepsilon_t^\chi$$

- Government spending:

$$\hat{G}_t = \rho_G \hat{G}_{t-1} + \varepsilon_t^G$$



## Data

**Table 6:** Data

Series ID	Description	Source
GDP96	Real gross domestic product	BEA
PCND	Personal consumption expenditures: nondurable goods	BEA
PCESV	Personal consumption expenditures: services	BEA
FPI	Fixed private investment	BEA
PCDG	Personal consumption expenditures: durable goods	BEA
CBI	Change in private inventories	BEA
PRS85006033	Nonfarm business hours worked index (2005=100)	BLS
PRS85006103	Nonfarm Business hourly compensation index (2005=100)	BLS
CES0500000008	Average hourly earnings of production	BLS
CPATAX	Corporate profits after tax with IVA and CCAAdj	BEA
NBI	New business incorporations	SCB
ESTB	Private sector establishment births	BLS
CNP160V	Civilian noninstitutional population	BLS
GDPDEF	Gross domestic product: implicit price deflator	BEA

**Table 7:** Construction of Data Series

Time Series	Construction	Description
$dl(GDP_t)$	$= dl \left( \frac{GDP96_t}{CNP160V_t} \right)$	growth rate of real per capita GDP
$dl(CONS_t)$	$= dl \left( \frac{PCND_t + PCESV_t}{CNP160V_t \times GDPDEF_t} \right)$	growth rate of real per capita consumption
$dl(INV_t)$	$= dl \left( \frac{FPI_t + PCDG_t + CBI_t}{CNP160V_t \times GDPDEF_t} \right)$	growth rate of real per capita investment
$dl(WAGE1_t)$	$= dl \left( \frac{PRS85006033_t}{GDPDEF_t} \right)$	growth rate of first measure of real wage
$dl(WAGE2_t)$	$= dl \left( \frac{PRS85006103_t}{GDPDEF_t} \right)$	growth rate of second measure real wage
$l(HOURS_t)$	$= l \left( \frac{CES0500000008_t}{CNP160V_t} \right)$	logarithm of per capita hours worked
$dl(PROFITS_t)$	$= dl \left( \frac{CPATAX_t}{CNP160V_t \times GDPDEF_t} \right)$	growth rate of real per capita profits
$dl(ENTRY_t)$	$= \begin{cases} dl \left( \frac{NBI_t}{CNP160V_t} \right) & t \leq 1998Q3 \\ dl \left( \frac{ESTB_t}{CNP160V_t} \right) & t > 1998Q3 \end{cases}$	growth rate of per capita new firms

*Note:* The function  $l$  and  $dl$  stand for 100 times the demeaned logarithm and the demeaned log-difference, respectively.

## Estimated impulse responses with 90 percent confidence bands

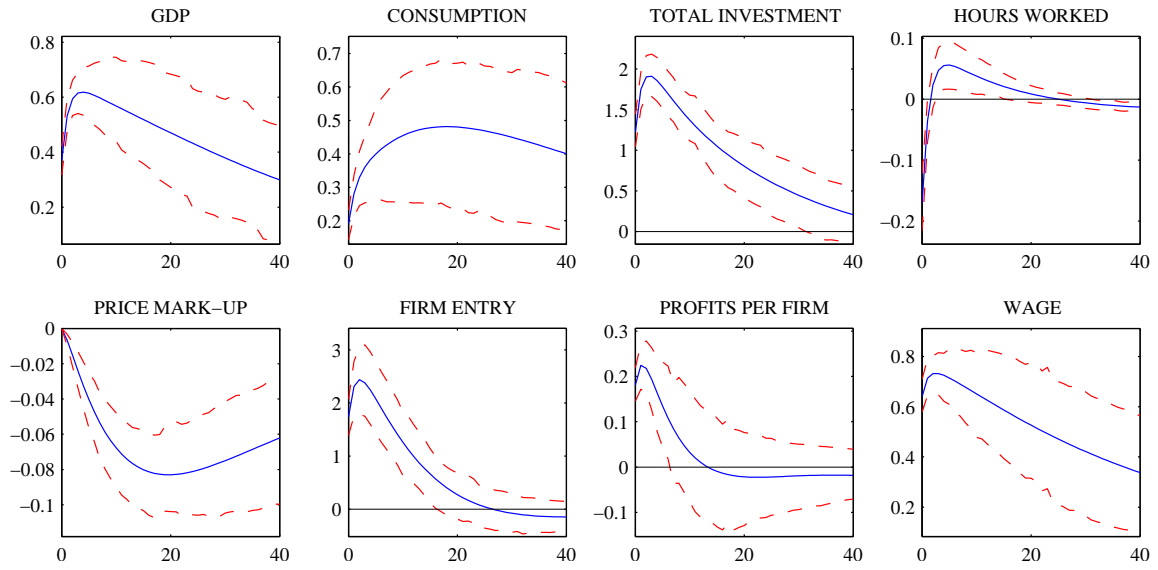


Figure 7: Impulse responses to a labor productivity shock

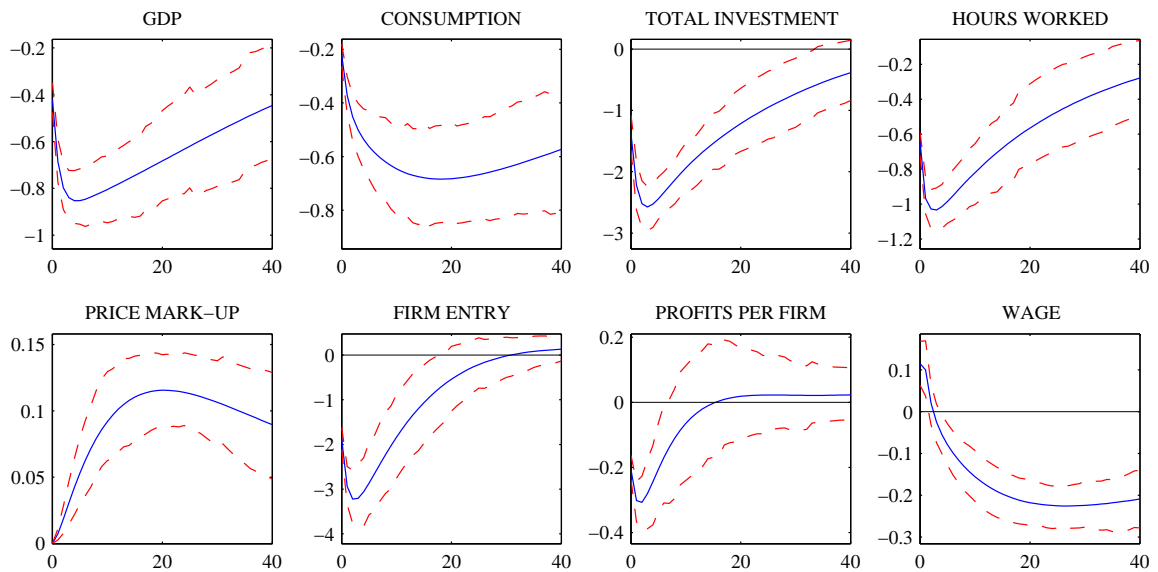


Figure 8: Impulse responses to a wage mark-up shock

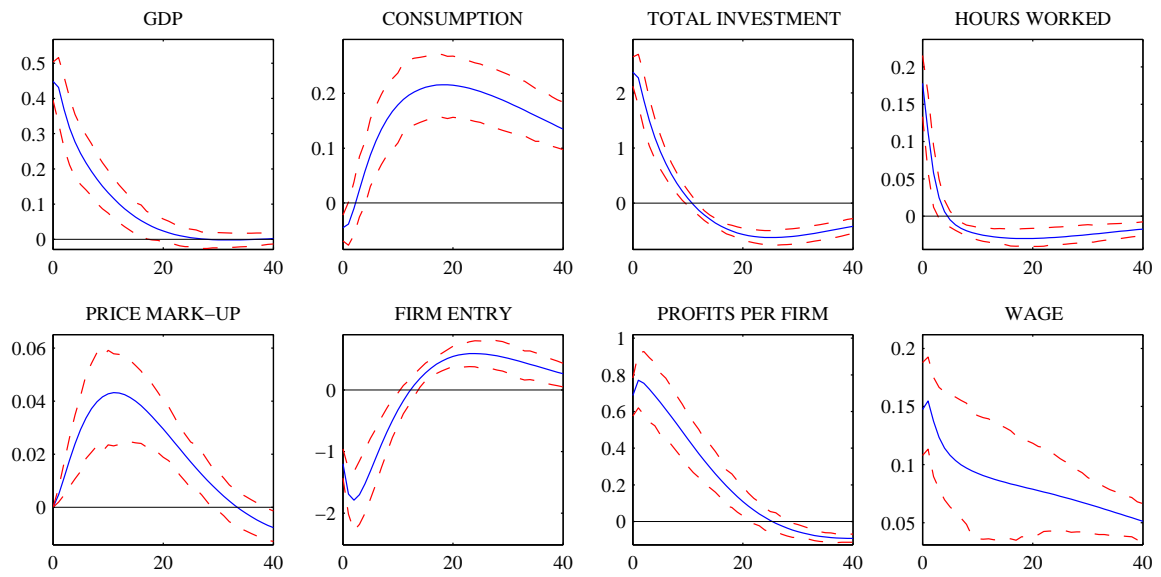


Figure 9: Impulse responses to an investment specific technology shock

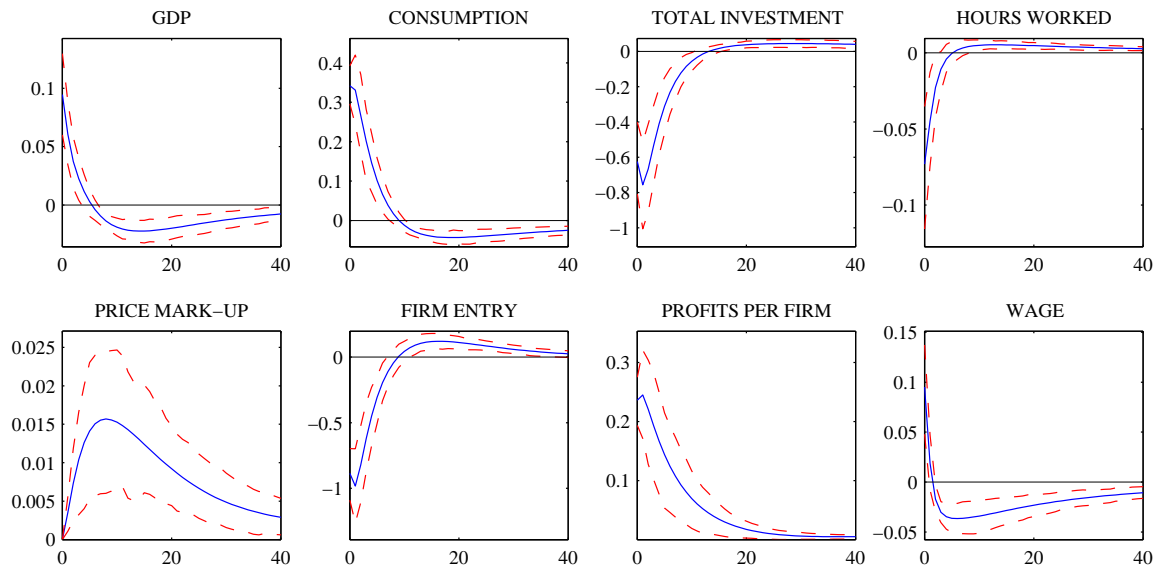


Figure 10: Impulse responses to a preference shock

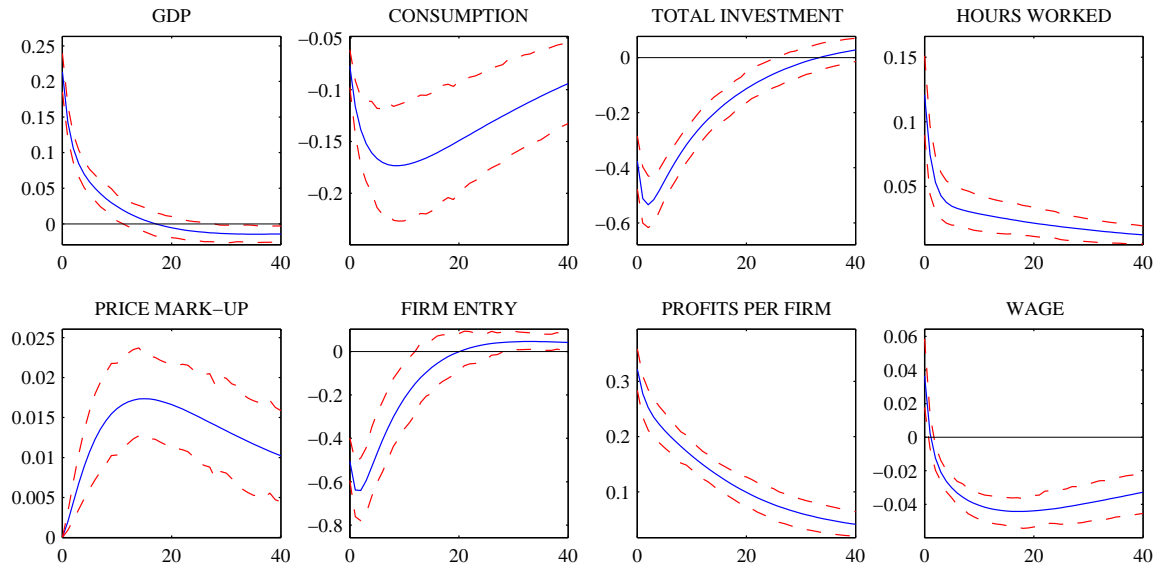


Figure 11: Impulse responses to a government spending shock

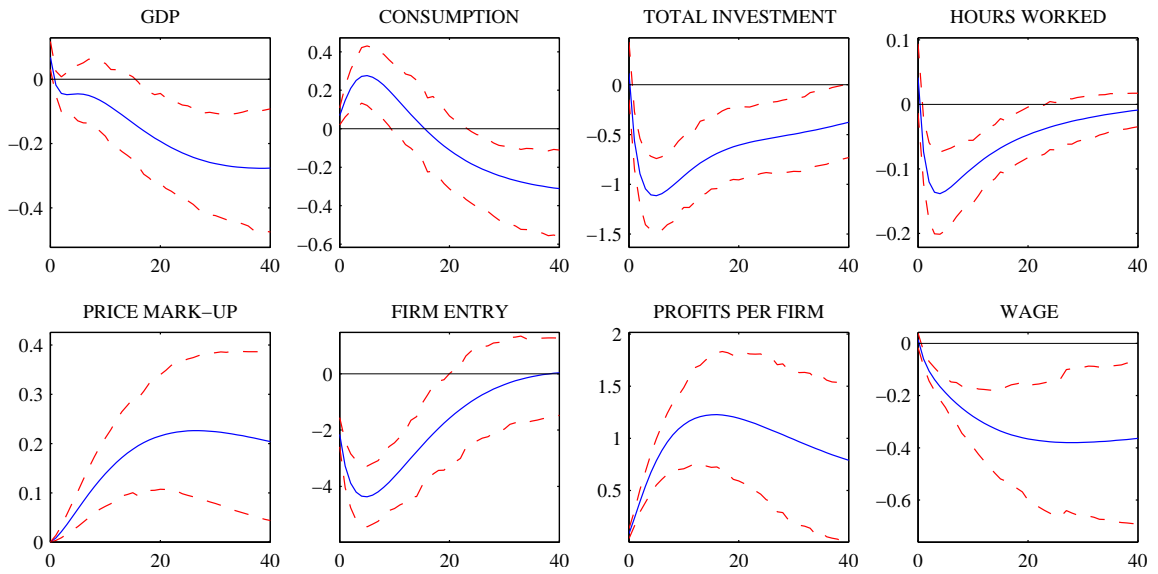


Figure 12: Impulse responses to an entry cost shock