ECONSTOR
Make Your Publications Visible.

A Service of
ZBW
Leibniz-Informationszentrum Wirtschaft
Leibniz Information Centre for Economics

Offick, Sven; Winkler, Roland C.

Working Paper

Endogenous firm entry in an estimated model of the U.S. business cycle

Economics Working Paper, No. 2014-01

Provided in Cooperation with:
Christian-Albrechts-University of Kiel, Department of Economics

Suggested Citation: Offick, Sven; Winkler, Roland C. (2014) : Endogenous firm entry in an estimated model of the U.S. business cycle, Economics Working Paper, No. 2014-01, Kiel University, Department of Economics, Kiel

This Version is available at:
https://hdl.handle.net/10419/90813

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

WWW.ECONSTOR.EU

Mitglied der Leibniz-Gemeinschaft

C | A | U

Christian-Albrechts-Universität zu Kiel

Department of Economics

Economics Working Paper
No 2014-01

endogenous firm entry in an estimated model of the U.S. business cycle

by Sven Offick and Roland C. Winkler

issn 2193-2476

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

Sven Offick†, *Christian-Albrechts-University Kiel*

Roland C. Winkler§, *TU Dortmund University*

January 18, 2014

Abstract

A recent theoretical literature highlights the role of endogenous firm entry as an internal amplification mechanism of business cycle fluctuations. The amplification mechanism works through the competition and the variety effect. This paper tests the significance of this amplification mechanism, quantifies its importance, and disentangles the competition and the variety effect. To this end, we estimate a medium-scale real business cycle model with firm entry for the U.S. economy. The parameter governing the competition and variety effect is estimated to be statistically significant. We find that firm entry substantially amplifies output by 8.5 percent. The competition effect accounts for most amplification, whereas the variety effect only plays a minor role.

JEL classification: E20, E32

Keywords: Bayesian estimation, Business Cycles, Competition Effect, Entry, Mark-ups, Variety Effect

*We thank for comments Christian Bredemeier, Hans-Werner Wohltmann and seminar participants at Aarhus University, Kiel University, University Duisburg-Essen, the 8th Dynare Conference, the 17th Spring Meeting of Young Economists, the 2013 Annual Conference of the Royal Economic Society, the 67th European Meeting of the Econometric Society, the 2013 Annual Conference of the German Economic Society, and the 10th Euroasia Business and Economic Society Conference.

‡Department of Economics, Christian-Albrechts-University Kiel, Olshausenstr. 40, 24098 Kiel, Germany. Phone: ++49-431-880-1472, E-mail: offick@economics.uni-kiel.de

§ *Correspondence to*: Faculty of Business, Economics and Social Sciences, TU Dortmund University, Vogelpothsweg 87, 44227 Dortmund, Germany. Phone: ++49-231-755-5403, E-mail: roland.winkler@tu-dortmund.de

1 Introduction

Standard dynamic stochastic general equilibrium (DSGE) models used for forecasting and policy analysis have a fixed range of products and firms and neglect the effect of firm entry on business cycle fluctuations.[1] Empirical evidence on firm and product entry, however, suggests otherwise. First, the number of firms varies substantially over the business cycle and is strongly procyclical. Second, the opening of establishments explains around 20 percent of quarterly job gains. Third, product creation (at new and existing firms) accounts for almost 50 percent of output in a 5 year interval.[2]

In light of these findings, a recent theoretical branch of the literature has started to study the role of endogenous firm (or product) entry in business cycle fluctuations.[3] This literature identifies endogenous entry as an important amplification mechanism for business cycle fluctuations.

This amplification mechanism works through two channels. The variety effect describes the productivity gains from additional varieties. An increase in the number of firms, equivalent to an increase in the number of varieties, increases output more than proportional due to increasing returns to specialization.[4] The so-called competition effect captures the inverse relation between the number of producers and price mark-ups. An increase in the number of producers erodes market power. Price mark-ups fall which in turn boosts aggregate demand.

This paper aims to test the significance of this amplification mechanism, to quantify its importance, and to disentangle the competition and the variety effect in a medium-scale business cycle model. To this end, we use the firm entry model by Bilbiie, Ghironi, and Melitz (2012), extend it with several real frictions, and estimate the model on U.S. data with Bayesian methods. We investigate the capacity of the model in fitting the data, study how firm entry affects the estimates of structural model parameters, and explore the amplification mechanism embedded in the firm entry model for transitory supply and demand shocks.

The entry model by Bilbiie, Ghironi, and Melitz (2012) is able to explain three empirical findings simultaneously: procyclical entry, countercyclical price mark-ups, and procyclical profits. It is characterized by sunk entry costs and a translog final goods production technology as proposed

[1] See e.g. Smets and Wouters (2007) and Christiano, Eichenbaum, and Evans (2005).

[2] The empirical evidence is based on US data. The procyclicality of firm entry is demonstrated by Chatterjee and Cooper (1993), Devereux, Head, and Lapham (1996), or Etro and Colcagio (2010). Davis, Haltiwanger, and Schuh (1998) investigate the role of firm turnover for job flows. Bernard, Redding, and Schott (2010) compute the contribution of product creation for aggregate output.

[3] For a detailed overview on the existing literature, see Section 5 in Bilbiie, Ghironi, and Melitz (2012).

[4] Note that this effect is equivalent to the well-known love of variety effect, where households 'love' varieties and gain utility from an increasing set of consumption goods.

by Feenstra (2003).[5] The number of firms is endogenously determined by a free entry condition, that equates expected future profits with entry costs. Under the translog technology both the competition and the variety effect are present. The competition effect is demand-side driven and stems from the fact that the substitutability between different varieties, and hence the price elasticity of demand, is increasing in the number of varieties.

To estimate the model, we use U.S. data on output, consumption, investment, hours, wages, profits, and firm entry. The estimate of the key parameter that governs the competition and the variety effect is found to be statistically significant.

To quantify the strength of the amplification mechanism and to disentangle the competition and the variety effect, we specify two counterfactual model frameworks with a constant elasticity of substitution (CES) production technology, where either the competition effect or both the competition and the variety effect are switched off. By conducting counterfactual simulations, we find that firm entry substantially amplifies fluctuations in output and consumption, but dampens fluctuations in investment. For output, the total increase in volatility is given by 8.5 percent. The competition effect accounts for most of the amplification, amplifying output by 7 percent, whereas the increase through the variety effect only amounts to 1.5 percent. If we consider each structural shock in isolation, the results are mixed. On the one hand, the firm entry mechanism amplifies the impacts of labor productivity and wage mark-up shocks on output. On the other hand, it dampens the impacts of aggregate demand and investment-specific technology shocks on output.

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 (2013) 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 amplification mechanism embedded in the endogenous entry model.

Closely related to our paper is the work of Jaimovich and Floetotto (2008). Based on a calibrated and – apart from firm entry – standard real business cycle model, they show that firm entry amplifies the impacts of technology shocks on output by 64 to 158 percent, depending on

[5] Note that Bilbiie, Ghironi, and Melitz (2012) aggregate products through the consumers' intratemporal optimization and therefore refer to a translog expenditure function instead. However, both concepts are equivalent.

the exact specification of their model. This paper confirms the qualitative results in Jaimovich and Floetotto (2008) but finds the quantitative impact of firm entry to be less dominant. Our paper extends their work in a number of ways. First, we carry out a full-fledged estimation of a medium-scale real business cycle model, that already accounts for a large fraction of economic fluctuations. This approach enables us to extract the net amplification effect associated with firm entry. Moreover, we provide an estimate of the key parameter governing the strength of the amplification mechanism. Second, we consider several shocks and demonstrate that the role of firm entry in aggregate fluctuations depends on the nature of the shock. Third, in the model of Jaimovich and Floetotto (2008), the variety effect is turned off, and the sole focus lies on the competition effect. The latter is supply-side driven and stems from the strategic interaction between oligopolistic firms.[6] We, in contrast, consider a demand-side driven competition effect. Lewis and Poilly (2012) compare both alternatives and find the supply-side driven competition effect to be insignificant.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 describes the data and the estimation procedure. Section 4 discusses the estimation results. Section 5 quantifies the amplification mechanism. Section 6 tests the robustness of our quantification results and Section 7 concludes.

2 The model

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-Grohé and Uribe (2012). The model is characterized by monopolistic competition on product and labor markets, habit formation in consumption, investment 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 entry model proposed by Bilbiie, Ghironi, and Melitz (2012).

The model economy consists of a government, a fixed mass of final goods producers, labor bundlers, households, and a time-varying and endogenously determined mass of intermediate goods producers. Households consume, invest in physical capital and in start-ups (or new firms), hold government bonds and equity of intermediate goods producers, and supply differentiated labor types

[6] Other studies that consider a supply-side driven competition effect in business cycle models are, for example, Colcagio and Etro (2010) and Etro and Colcagio (2010). In contrast to Jaimovich and Floetotto (2008), however, these studies do not provide a quantitative evaluation of the amplification mechanism.

to a labor bundler under monopolistically competitive conditions. Competitive labor bundlers aggregate the differentiated labor types into a homogeneous labor input. A time-varying mass of monopolistic firms employ labor and capital to produce differentiated intermediate goods. The creation of a new product variety – equivalent to the establishment of a new firm – requires labor input. The entry of firms into the intermediate goods market is endogenously determined by a free entry condition, that equates expected future profits with entry costs. Final goods producers bundle the intermediate goods to a homogenous final good used for private and government consumption and for investment in physical capital. We specify two alternative ways in which intermediate goods are combined to produce final goods: a constant elasticity of substitution (CES) production function as in Benassy (1996) and a translog production function as in Feenstra (2003). The latter specification gives rise to countercyclical price mark-ups and increasing returns to specialization (or love of variety). The first specification brings about constant price mark-ups and allows us to disentangle the degree of increasing returns to specialization from the degree of monopoly power.

2.1 Final goods producers

There is a mass N_t of monopolistically competitive firms, each producing a different variety of an intermediate good, indexed by $i \in [0, N_t]$. Final goods producers buy the differentiated intermediate goods or varieties $y_{i,t}$ at a price $p_{i,t}$, bundle them to a homogenous final good Y_t^C, and sell it to the households and to the government under perfectly competitive conditions at a price P_t. A final goods producer maximizes its profits $Y_t^C P_t - \int_0^{N_t} p_{i,t} y_{i,t} di$ subject to a final goods production function. We specify two alternative final goods production technologies.

First, intermediate goods are combined using the constant elasticity of substitution (CES) production function $Y_t^C = N_t^{\zeta - \frac{1}{\varepsilon-1}} \left(\int_0^{N_t} y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$, where $\varepsilon > 1$ is the elasticity of substitution between the intermediate inputs, and the parameter $\zeta \geq 0$ captures the degree of increasing returns to specialization. The first-order condition for profit maximization yields the demand function for variety i, which is given by $y_{i,t} = \rho_{i,t}^{-\varepsilon} N_t^{\zeta(\varepsilon-1)-1} Y_t^C$, where $\rho_{i,t} \equiv p_{i,t}/P_t$ is the relative price of variety i and $P_t = N_t^{\frac{1}{\varepsilon-1}-\zeta} \left(\int_0^{N_t} p_{i,t}^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}$.

In a symmetric equilibrium, all firms make identical choices: $y_{i,t} = y_t$, $p_{i,t} = p_t$ and $\rho_{i,t} = \rho_t$. The aggregate production of final goods (or: aggregate demand) is then given by $Y_t^C = \rho_t N_t y_t$, and the price index can be written as $P_t = N_t^{-\zeta} p_t$, implying $\rho_t = N_t^{\zeta}$.

The second specification of the final goods production technology uses the translog cost function

as proposed by Feenstra (2003). Under this specification, the elasticity of substitution between varieties is increasing in the number of varieties: $\varepsilon_t = 1 + \tilde{\sigma} N_t$ with $\tilde{\sigma} > 0$. In a symmetric equilibrium, the price index is given by $P_t = \exp\left((\tilde{N} - N_t)/(2\tilde{\sigma}\tilde{N}N_t)\right) p_t$, where $\tilde{N}$ is the mass of potential entrants.[7] The aggregate production of final goods is again given by $Y_t^C = \rho_t N_t y_t$.

Denote by ω_t the elasticity of the relative price with respect to the number of firms[8], which captures the degree of increasing returns to specialization, $\omega_t = \frac{\partial \rho_t}{\partial N_t} \frac{N_t}{\rho_t}$. Under the CES technology, the degree of returns to specialization is equal to ζ, i.e. $\omega_t = \zeta$. Under the translog specification, ω_t is equal to $(2\tilde{\sigma} N_t)^{-1}$.

2.2 Intermediate goods producers

Each intermediate good is produced by a monopolist $i \in [0, N_t]$ that uses the amount $l_{i,t}$ of labor, the amount $k^s_{i,t}$ of capital services, and the constant returns to scale technology

$$y_{i,t} = (z_t l_{i,t})^{\alpha} (k^s_{i,t})^{1-\alpha} \tag{1}$$

to produce its output $y_{i,t}$. z_t is a labor productivity shifter, which follows the exogenous AR(1) process $\log z_t = (1 - \rho_z) \log z + \rho_z \log z_{t-1} + \varepsilon^z_t$, where z is the steady state of z_t, and ε^z_t is $i.i.d.N(0, \sigma^2_{\varepsilon^z})$. $\alpha \in (0, 1)$ denotes the share of labor in production. The firm takes the real factor prices w_t and r^k_t as given. Firm i chooses prices $p_{i,t}$ and factor inputs to maximize real profits $d_{i,t} = \frac{p_{i,t}}{P_t} y_{i,t} - w_t l_{i,t} - r^k_t k^s_{i,t}$ subject to the production technology and the demand for its variety.

At the optimum, the firm sets its real price as a mark-up over real marginal costs.

$$\frac{p_{i,t}}{P_t} = \mu^p_t mc_t \,, \tag{2}$$

where $\mu^p_t = \frac{\varepsilon_t}{\varepsilon_t - 1}$ is the mark-up and mc_t are real marginal costs. The demands of firm i for hours and capital are given by

$$w_t = \alpha mc_t \frac{y_{i,t}}{l_{i,t}} \,, \tag{3}$$

$$r^k_t = (1 - \alpha) mc_t \frac{y_{i,t}}{k^s_{i,t}} \,. \tag{4}$$

In a symmetric equilibrium, the aggregate production of intermediated goods is given by $N_t y_t =$

[7] See Appendix A for the derivation of the price index P_t and the price elasticity ε_t.

[8] For convenience, we denote N_t in the following as the number of firms. Note, however, that $N_t \in \mathbb{R}$ is strictly speaking the mass of firms.

$(z_t L_t^C)^\alpha (K_t^s)^{1-\alpha}$, where $L_t^C = N_t l_t$ and $K_t^s = N_t k_t^s$. Total profits can be expressed as $N_t d_t = (1 - 1/\mu_t^p)\, Y_t^C$.

Denote by ξ_t the (negative) elasticity of the mark-up with respect to the number of goods (or firms), which captures the competition effect, $\xi_t = -\frac{\partial \mu_t^p}{\partial N_t} \frac{N_t}{\mu_t^p}$. Under the CES final goods production technology, the mark-up is constant and equal to $\frac{\varepsilon}{\varepsilon - 1}$. Thus, the competition effect is zero. Under the translog specification, the mark-up is decreasing in the number of goods, i.e. $\mu_t^p = 1 + \frac{1}{\tilde{\sigma} N_t}$. The competition effect is equal to $\xi_t = (1 + \tilde{\sigma} N_t)^{-1}$.

2.3 Labor bundlers

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 $L_{j,t}$. Analogously to final goods producers, 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 μ_t^w is assumed to follow the ARMA(1,1) 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 μ^w is the steady state of μ_t^w, and ε_t^μ is $i.i.d. N(0, \sigma_{\varepsilon^\mu}^2)$.[9] Profit maximization by the perfectly competitive labor bundlers yields the labor demand function

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

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.

2.4 Households

Each household j maximizes the following lifetime utility function proposed by Jaimovich and Rebelo (2009):

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \chi_t \log \left(C_{j,t} - b C_{j,t-1} - \psi L_{j,t}^\eta S_{j,t} \right) \,, \tag{6}$$

where $C_{j,t}$ and $L_{j,t}$ denote consumption and hours worked, respectively. $\beta \in (0, 1)$ is the discount factor, $\psi > 0$ is a scale parameter, and $b \in [0, 1)$ measures the degree of (internal) habit formation. $\chi_t > 0$ is a preference shock and follows $\log \chi_t = \log \chi + \varepsilon_t^\chi$, where χ is the steady state of χ_t,

[9] The moving average term allows the wage mark-up shock to capture high frequency movements in the wage series, see Smets and Wouters (2007).

and ε_t^{χ} is $i.i.d.N(0, \sigma^2_{\varepsilon^{\chi}})$. S_t is a habit-adjusted weighted average of current and past consumption, which evolves over time according to

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

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 (in units of final goods) is given by

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

The household purchases the amount $C_{j,t}$ of final goods, pays lump-sum taxes T_t, buys risk-less government bonds $B_{j,t}$ at a price $1/R_t$, and buys equity of firms operating in the intermediate goods market $x_{j,t}$ 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 $N_{E,j,t}$. Setting up a new firm (or inventing a new product) 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 f_E is the steady state of $f_{E,t}$, and $\varepsilon_t^{f_E}$ is $i.i.d.N(0, \sigma^2_{\varepsilon^{f_E}})$. 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.[10] During this period, new firms are hit by the exogenous exit shock δ. In addition, we follow Lewis (2009) and 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 κ_E serves as the counterpart of the investment adjustment cost parameter κ_I, introduced below, at the firm entry margin.

Finally, the household invests the amount $I_{j,t}$ into physical capital $K_{j,t}$, which is assumed to

[10] Empirically, firm entry lags GDP. See, for example, Devereux, Head, and Lapham (1996).

be owned by households. Capital evolves according to the following law of motion

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

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

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

where δ_0 is the capital deprecation rate in a deterministic steady state in which capital utilization is set to unity. The elasticity of capital utilization with respect to the rental rate of capital is given by δ_1/δ_2. Capital services $K^s_{j,t}$ are rented to intermediate goods firms at a rental rate r_t^k.

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 λ_t^C, $\lambda_t^C Q_t$, λ_t^S denote Lagrange multipliers for the budget constraint, the capital accumulation equation, and the definition of S_t, respectively. The first-order conditions read as follows:

$$\lambda_t^C = \beta R_t \,\mathrm{E}_t\left\{\lambda_{t+1}^C\right\}\,, \tag{11}$$

$$\lambda_t^C Q_t = \beta\,\mathrm{E}_t\left\{\lambda_{t+1}^C\big(r_{t+1}^K u_{t+1} + Q_{t+1}(1-\delta^K(u_{t+1}))\big)\right\}\,, \tag{12}$$

$$\lambda_t^C v_t = (1-\delta)\beta\,\mathrm{E}_t\left\{\lambda_{t+1}^C\big(v_{t+1}+d_{t+1}\big)\right\}\,, \tag{13}$$

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

$$\lambda_t^S = \chi_t V_t \psi L_t^\eta + \beta(1-\gamma)\,\mathrm{E}_t\left\{\lambda_{t+1}^S\frac{S_{t+1}}{S_t}\right\}\,, \tag{15}$$

$$\begin{aligned} 1 = {} & Q_t u_t^I\left(1 - \frac{\kappa_I}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2 - \kappa_I\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}}\right) \\ & + \beta\,\mathrm{E}_t\left\{\frac{\lambda_{t+1}^C}{\lambda_t^C}Q_{t+1}u_{t+1}^I\kappa\left(\frac{I_{t+1}}{I_t}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\}\,, \end{aligned} \tag{16}$$

$$\frac{w_t}{z_t} f_{E,t} = v_t \left(1 - \frac{\kappa_E}{2} \left(\frac{N_{E,t}}{N_{E,t-1}} - 1 \right)^2 - \kappa_E \left(\frac{N_{E,t}}{N_{E,t-1}} - 1 \right) \frac{N_{E,t}}{N_{E,t-1}} \right)$$
$$+ \beta \, \mathrm{E}_t \left\{ \frac{\lambda^C_{t+1}}{\lambda^C_t} v_{t+1} \kappa_E \left(\frac{N_{E,t+1}}{N_{E,t}} - 1 \right) \left(\frac{N_{E,t+1}}{N_{E,t}} \right)^2 \right\} , \tag{17}$$

$$r^k_t = Q_t(\delta_1 + \delta_2(u_t - 1)) , \tag{18}$$

$$\lambda^C_t w_t = \mu^w_t \chi_t V_t \psi \eta L^{\eta-1}_t S_t , \tag{19}$$

where $V_t = (C_t - bC_{t-1} - \psi L^\eta_t S_t)^{-1}$.

2.5 Aggregate accounting

The aggregate resource constraint

$$Y^C_t + \frac{w_t}{z_t} f_{E,t} N_{E,t} = w_t L_t + N_t d_t + r^k_t u_t K_{t-1} \tag{20}$$

can be obtained by combining the aggregate budget constraint of households (using $x_t = N_t$) with the government budget constraint $G_t + B_{t-1} = T_t + \frac{B_t}{R_t}$. Government consumption G_t is described by the exogenous AR(1) process $\log G_t = (1 - \rho_g) \log G + \rho_g \log G_{t-1} + \varepsilon^G_t$, where G is the steady state of G_t, and ε^G_t is $i.i.d.N(0, \sigma^2_{\varepsilon^G})$.

The goods market clearing condition requires aggregate output of final goods Y^C_t to be equal to private and government consumption plus investment in physical capital, i.e. $Y^C_t = C_t + G_t + I_t$. Total investment TI_t is the sum of investment in physical capital and investment in new firms, i.e. $TI_t = I_t + \frac{w_t}{z_t} f_{E,t} N_{E,t}$. The gross domestic product Y_t is equal to Y^C_t plus investment in new firms $\frac{w_t}{z_t} f_{E,t} N_{E,t}$.

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

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

Every period, a fraction of incumbent firms exit the market, where the exit rate δ is assumed to be constant and exogenous. In contrast, the exit rate of newly established firms consists of the exogenous component δ and the endogenous component $\frac{\kappa_E}{2} \left(\frac{N_{E,t-1}}{N_{E,t-2}} - 1 \right)^2$.

2.6 Model variants

We consider three model variants that differ with respect to the final goods production technology: one model with a translog technology and two models with a CES technology. The model variants have different implications for the competition and variety effect. In order to estimate the competition and variety effect and to quantify their importance in amplifying business cycle fluctuations, we log-linearize the three model variants around their deterministic steady states and bring the log-linearized translog model to the data.[11] The two CES model variants will enable us to disentangle competition and variety effect with the help of counterfactual simulations.

Table 1 summarizes the elasticities governing the competition and variety effect in the three (log-linearized) model variants.[12]

Table 1: Model variants

	Competition effect	Variety effect
Translog	$\xi = 1 - \frac{1}{\mu^p}$	$\omega = \frac{1}{2}(\mu^p - 1)$
CES-TrVE	$\xi = 0$	$\omega = \frac{1}{2}(\mu^p - 1)$
CES-NoVE	$\xi = 0$	$\omega = 0$

Under the translog final goods production function, the competition effect ξ and the variety effect ω can be expressed in terms of the steady-state price mark-up: $\xi = 1 - \frac{1}{\mu^p}$ and $\omega = \frac{1}{2}(\mu^p - 1)$.[13] We call this model variant the translog model. In both CES model variants, the competition effect is absent, i.e. $\xi = 0$. In the first CES specification, the variety effect is set equal to the value under the translog specification, i.e. $\omega = \frac{1}{2}(\mu^p - 1)$. We call this the CES-TrVE model. In the second CES specification, the variety effect is set equal to zero, i.e. $\omega = 0$. We call this the CES-NoVE model.

3 Data and estimation procedure

This section describes the data set and the estimation procedure we used to estimate the translog model. Following An and Schorfheide (2007) and Smets and Wouters (2007), we estimate a subset of the model parameters using Bayesian techniques. For the estimation, we use eight time series of U.S. quarterly data: the growth rates of real per capita GDP, consumption, investment, and

[11] The log-linearized model equations are summarized in Appendix B.

[12] Note that the elasticities in the log-linearized models are evaluated at the deterministic steady state and thus time-invariant.

[13] Recall that, in the steady state of the translog model, $\xi = \frac{1}{1+\tilde{\sigma}N}$, $\omega = \frac{1}{2\tilde{\sigma}N}$, and the price mark-up is given by $\mu^p = 1 + \frac{1}{\tilde{\sigma}N}$.

profits, the logarithm of per capita hours worked, the growth rates of two measures of real wages, and the growth rate of per capita new firms.

As empirical measure for firm entry, we use the data series of new business incorporations (NBI) from the Survey of Current Businesses published by the Bureau of Economic Analysis.[14] We define consumption as consumption expenditures on non-durables and services and investment as the sum of consumption expenditures on durables, fixed private investments, and changes in private inventories. Following Justiniano, Primiceri, and Tambalotti (2013) and Gali, Smets, and Wouters (2012), we use two empirical wage measures: hourly compensation in the non-farm business sector and average hourly earnings of production and non-supervisory employees. Both measures are taken from the Bureau of Labor Statistics. A full description of the data sources and the construction of the data series can be found in Appendix C. The estimation sample starts in 1964:Q1 and ends in 2012:Q2. Due to limited data availability, the new firm series ends in 1998:Q3.[15]

As pointed out by Ghironi and Melitz (2005), empirical measures for the price index are closer to the product price p_t than to the price index P_t for the following two reasons: First, these empirical measures do not update their product space frequently enough to fully account for changes in the number of available products. Second, the construction of these measures is certainly not of the functional form present in the translog model. In order to obtain data-consistent model variables X_t^r, we divide the real model variables $X_t \in \{Y_t, C_t, TI_t, w_t, d_t\}$ by the relative price $\rho_t = p_t/P_t$. The measurement equations for GDP, consumption, investment, hours worked, profits, and entry then read as follows:

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

[14] Alternatively, one can use the data series net business formation (NBF) published in the same survey as measure for net firm entry. We decided to use the NBI measure for two reasons: First, data on NBF is only available until 1995:Q3, whereas NBI is published until 1998:Q3. Second, we do not model firm exit endogenously. We, therefore, believe that NBI is a closer measure for firm entry than NBF for net firm entry.

[15] Note that the missing observations of the new firm series are treated as an unobserved state during the Kalman filter routine. We show in a robustness exercise in Section 6 that our estimation results do not change substantially if we limit our data sample to 1998:Q3.

Table 2: Calibrated parameters

Parameter	Value	Definition
β	0.99	Discount factor
δ_0	0.025	Steady-state capital depreciation rate
δ	0.025	Steady-state firm exit rate
u	1	Steady-state capacity utilization rate
μ^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	Potential mass of firms

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 Δ is the time-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 $i.i.d.N(0, \sigma^2_{\varepsilon^{d,me}})$.

To include the information of both wage measures, we set up the following measurement equation:

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

where λ denotes the loading coefficient for the second wage series. Since both loadings are not separately identified, we set the first loading coefficient to unity. $\varepsilon_t^{w1,me}$ and $\varepsilon_t^{w2,me}$ are two measurement errors, which are $i.i.d.N(0, \sigma^2_{\varepsilon^{w1,me}})$ and $i.i.d.N(0, \sigma^2_{\varepsilon^{w2,me}})$, respectively. $\Delta\hat{w}_t^r$ can be interpreted as latent factor, which captures the common movement in both wage series. The two error terms capture the idiosyncratic fluctuations in the wage series.[16]

The application of eight data series requires at least eight exogenous disturbances. In total, the model is governed by nine disturbances, including innovations to government consumption ε_t^g, to labor productivity ε_t^z, to investment-specific technology ε_t^I, to entry costs $\varepsilon_t^{f_E}$, to preferences ε_t^χ, and to the wage mark-up $\varepsilon_t^{\mu^w}$, plus the three measurement errors ε_t^d, $\varepsilon_t^{w1,me}$, and $\varepsilon_t^{w2,me}$.

A subset of parameters is calibrated as summarized in Table 2. The discount rate β is set to 0.99, implying an annual steady-state interest rate of approximately 4 percent. The steady-state value for the utilization rate u is set to unity, implying the steady-state value of the depreciation rate δ^K to be equal to δ_0. For the latter, we choose a standard value of 0.025. Following Chugh and

[16] The concept to capture the common movement of multiple time series in a few latent variables originally comes from the factor analysis. For a general discussion of estimating DSGE models in a date-rich environment, see Boivin and Giannoni (2006).

Ghironi (2012), the potential mass of firms in the economy $\tilde{N}$ is assumed to be 10^9. The exogenous firm exit rate δ is set to 0.025, as in Bilbiie, Ghironi, and Melitz (2012). The steady-state values G/Y and L are set to 0.18 and 0.25, respectively. Following Gali, Smets, and Wouters (2012), we set the steady-state wage mark-up μ^w at 20 percent.

The remaining parameters are estimated. Table 3 summarizes the prior distributions. Our choice of distributions is in line with the literature and mainly results from different distributional supports. The probability mass of the inverse gamma distribution is distributed over the interval $(0, \infty)$, the gamma distribution over the interval $[0, \infty)$, the beta distribution over the interval $[0, 1]$, and the normal distribution over the interval $(-\infty, \infty)$.

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 of the exogenous shock processes, 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.

The prior distributions for the structural parameters related to firm entry are given as follows. For the steady-state price mark-up μ^p, we use a truncated gamma distribution, where we only allow for values greater than 1.01. It has mean 1.3 and standard deviation 0.2. The 90 percent confidence interval of this distribution then ranges from 1.04 to 1.68. For the entry adjustment cost parameter κ_E, we use the same prior distribution as for the investment adjustment cost parameter, i.e. a gamma distribution with mean 4.0 and standard deviation 1.0. For the prior distribution of the remaining structural parameters, we broadly follow the existing literature.

4 Estimation results

In this section, we first present the parameter estimates. Next, we discuss the model's predictions regarding volatility, autocorrelations, and cross-correlations of the time series included as observables. Then we discuss the contribution of each of the structural shocks to the forecast error variance of the endogenous variables at business cycle frequency. Finally, we analyze the model-implied impulse responses to the structural shocks.

Table 3: Results from the Bayesian estimation including prior distribution and confidence intervals

		Prior distribution			Posterior distribution	
Parameter		Type	Mean	Std	Mean	[5% – 95%]
Structural parameters						
Labor share in production	α	Beta	0.7	0.2	0.85	[0.80 – 0.90]
Labor utility	θ	Gamma	2.0	1.0	3.62	[1.70 – 5.48]
Wealth elast. labor supply	γ	Beta	0.5	0.2	0.80	[0.66 – 0.95]
Consumption habit	b	Beta	0.5	0.2	0.75	[0.71 – 0.80]
Investment adj. cost	κ_I	Gamma	4.0	1.0	3.83	[2.48 – 5.15]
Inv. elast. of capital util.	$\frac{\delta_2}{\delta_1}$	Igamma	1.0	1.0	0.55	[0.29 – 0.80]
Price mark-up	μ^p	Gamma	1.3	0.2	1.26	[1.16 – 1.36]
Entry adj. cost	κ_E	Gamma	4.0	1.0	1.49	[1.05 – 1.94]
Autocorrelation of shock processes						
Labor productivity	ρ_z	Beta	0.5	0.2	0.96	[0.94 – 0.98]
Wage mark-up	ρ_μ	Beta	0.5	0.2	0.97	[0.95 – 0.98]
Invest. spec. tech.	ρ_I	Beta	0.5	0.2	0.25	[0.11 – 0.38]
Gov. spending	ρ_G	Beta	0.5	0.2	0.91	[0.88 – 0.95]
Entry cost	ρ_{f_E}	Beta	0.5	0.2	0.95	[0.92 – 0.98]
Standard deviation of innovations						
Labor prod.	σ_{ε^z}	Igamma	2.0	1	0.79	[0.69 – 0.89]
Wage mark-up	σ_{ε^μ}	Igamma	2.0	1	4.28	[2.83 – 5.70]
Invest. spec. tech.	σ_{ε^I}	Igamma	2.0	1	4.02	[2.06 – 5.94]
Preference	$\sigma_{\varepsilon^\chi}$	Igamma	2.0	1	1.45	[1.03 – 1.85]
Gov. spending	σ_{ε^G}	Igamma	2.0	1	1.87	[1.71 – 2.02]
Entry cost	$\sigma_{\varepsilon^{f_E}}$	Igamma	2.0	1	2.44	[1.92 – 2.93]
Moving average parameter and loading coefficient						
Wage mark-up shock	ν	Normal	0.0	0.2	0.41	[0.26 – 0.56]
Loading coefficient	λ	Normal	1.0	2.0	0.13	[0.06 – 0.19]

4.1 Parameter estimates

Table 3 displays 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 gross price mark-up μ^p is estimated to be significantly different from one. The point estimate implies a steady-state mark-up of 26 percent with a confidence band ranging from 16 percent to 36 percent. Regarding the competition and the variety effect, the point estimate implies that a one percent increase in the mass of firms lowers the price mark-up by 0.21 percent (the competition effect) and raises the relative price by 0.13 percent (the variety effect). The point estimate of μ^p is close to the value of 1.22 reported in Lewis and Stevens (2013). However, it is significantly smaller than the value of 1.66 reported in Lewis and Poilly (2012).

Entry adjustment costs κ_E are estimated to be around 1.5 with a confidence interval ranging from 1.05 to 1.94. This is significantly lower than the 3.83 point estimate for the investment

adjustment cost parameter κ_I. As discussed below, the model overestimates both 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.

Turning to the other structural parameters, θ, which determines the labor supply elasticity, is estimated at 3.62 with a relatively wide confidence interval ranging from 1.70 to 5.48. The point estimate of the wealth elasticity of labor supply γ is 0.80 with a confidence interval ranging from 0.66 to 0.95, implying that preferences are close to those in King, Plosser, and Rebelo (1988). Notice that this is in contrast to the results of Schmitt-Grohé and Uribe (2012), who estimate a near-zero wealth elasticity of labor supply in a model similar to ours but without endogenous firm entry. The labor share in production α is estimated at 0.85 with a confidence interval ranging from 0.80 to 0.90. Notice that this estimate is not comparable to the estimates of standard DSGE models without firm entry since in our model, in which labor is utilized in the manufacturing sector and in the creation of new products, α is not equal to the labor share in GDP. For the latter, our point estimate implies a standard value of 72 percent.

Regarding the exogenous shock processes, we find that shocks to labor productivity, to wage mark-ups, to government spending, and to entry costs are estimated to be highly persistent with AR(1) coefficients all above 0.9. In contrast, the persistence parameter of the investment-specific technology shock is relatively low with a value of 0.25, implying that the investment-specific technology shock explains less forecast-error variance at higher forecast-horizons.

4.2 Second moments

In order to assess the performance of the model in fitting the data, we compare the model-implied second moments to the corresponding empirical moments of the data. Table 4 reports standard deviations, relative standard deviations, first-order autocorrelations, and contemporaneous correlations with the growth rate of GDP. The model-implied moments are derived from simulated data, where the measurement errors are turned off during the simulation.

The empirical moments of GDP, consumption, total investment, and hours worked are matched quite well. The estimated model captures the observed procyclicality of profits and firm entry. We find notable discrepancies between the model predictions and the data with respect to volatility and autocorrelation of profits and firm entry. Concerning firm entry growth, the model overstates its volatility and its serial correlation. This is attributable to the fact that we model an endogenous

Table 4: Second moments

	X	σ_X		$\sigma_X/\sigma_{\Delta\hat{Y}^r}$		1st autocorr.		$corr(X, \Delta\hat{Y}^r)$	
		Data	Model	Data	Model	Data	Model	Data	Model
GDP growth	$\Delta\hat{Y}^r$	0.86	0.85	1.00	1.00	0.31	0.31	1.00	1.00
Consumption growth	$\Delta\hat{C}^r$	0.55	0.59	0.63	0.69	0.42	0.39	0.59	0.53
Investment growth	$\Delta\widehat{TI}^r$	3.27	3.43	3.80	4.01	0.31	0.26	0.86	0.84
Hours	$\hat{L}$	5.05	4.16	5.87	4.87	0.98	0.98	0.14	0.11
Profit growth	$\Delta\hat{D}^r$	6.35	0.91	7.38	1.07	0.05	0.27	0.42	0.79
Firm Entry growth	$\Delta\hat{N}_E$	3.10	4.30	3.43	5.03	-0.02	0.53	0.20	0.27

Note: To compute the empirical moments of the entry series, we only use the limited data sample until 1998:Q3.

failure rate of firms as an increasing function of the change in firm entry. This mechanism is introduced to dampen the volatility of firm entry. However, it also generates substantial persistence in firm entry. As mentioned above, this trade-off between volatility and autocorrelation explains the small point estimate of the entry adjustment cost parameter κ_E, compared to the capital adjustment cost parameter κ_I. Concerning profits, the model explains only a small fraction of the observed volatility in profit growth. Most of the variability is captured by the measurement error, which is absent during the computation of the second moments. In a robustness exercise in Section 6, we demonstrate that we obtain similar estimation results when we exclude profits from the set of observables.

4.3 Variance decomposition

Table 5 shows the mean forecast-error variance decomposition of GDP, consumption, total investment, hours worked, wages, profits, and firm entry at business cycle frequencies ranging from 6 to 32 quarters. Most variations are explained by the labor productivity and the wage mark-up shock. Together they account for 69 percent to 91 percent of the variations in GDP, consumption, total investment, hours worked, and wages. The investment-specific technology shock explains 21 percent of the variations in total investment and profits, respectively. The firm entry cost shock accounts for most variations in firm entry and profits. The government spending and the preference shock are only of minor importance for the variables under consideration.

To summarize, wage mark-up and labor productivity shocks are the two most important drivers of business cycle fluctuations, whereas investment-specific technology shocks are of minor importance. This is consistent with the findings in Smets and Wouters (2007) but stands in contrast to Justiniano, Primiceri, and Tambalotti (2010), who find that most of the variations in GDP is due to shocks to investment-specific technology. The discrepancy between Smets and Wouters (2007) and

Table 5: Variance decomposition at business cycle frequency

		Labor productivity	Wage mark-up	Invest. spec. technology	Preference	Government spending	Entry cost
GDP	Y^r	31	60	7	0	1	0
Consumption	C^r	28	58	3	4	3	4
Total invest.	TI^r	24	45	21	1	2	7
Hours	L	1	96	1	0	1	1
Wages	w^r	88	2	3	0	0	6
Profits	D^r	2	3	21	1	3	70
Firm Entry	N_E	11	19	6	1	1	63

Note: Shares may not add up to 100 due to rounding.

Justiniano, Primiceri, and Tambalotti (2010) stems from different definitions of investment and consumption. The latter define purchases of consumer durables and changes in inventories as part of investment, whereas the former define purchases of consumer durables as part of consumption and exclude changes in inventories from investment. Interestingly, we find that investment-specific technology shocks are minor contributors to business cycle fluctuations although we adopt the same definition of consumption and investment as Justiniano, Primiceri, and Tambalotti (2010). The difference is due to the endogenous firm entry mechanism which is absent in the above mentioned papers. In our framework, shocks to the efficiency with which final goods can be transformed into physical capital – in contrast to wage mark-up and labor productivity shocks – are not able to replicate the positive comovement between firm entry and other key variables in the data. On the contrary, a positive investment-specific technology shock induces a drop in investments into new firms, as discussed below.

4.4 Impulse responses

In this section, we analyze the model-implied impulse responses to the various structural shocks. The aim of this section is to illustrate the amplification mechanism and to visualize the impact of the competition and variety effect on the model dynamics. To this end, we present the impulse responses for three models, the estimated translog model and two counterfactuals: the CES-TrVE model with the competition effect switched off and the CES-NoVE model with competition and variety effect switched off. For both CES models, we keep the parameter estimates from the translog model.

Figure 1 to 6 show the impulse responses of GDP, consumption, total investment, entry costs, the price mark-up, firm entry, profits per firm, and average output of an individual firm to the six structural shocks. All real variables are shown using the data-consistent deflator p_t. Impulse

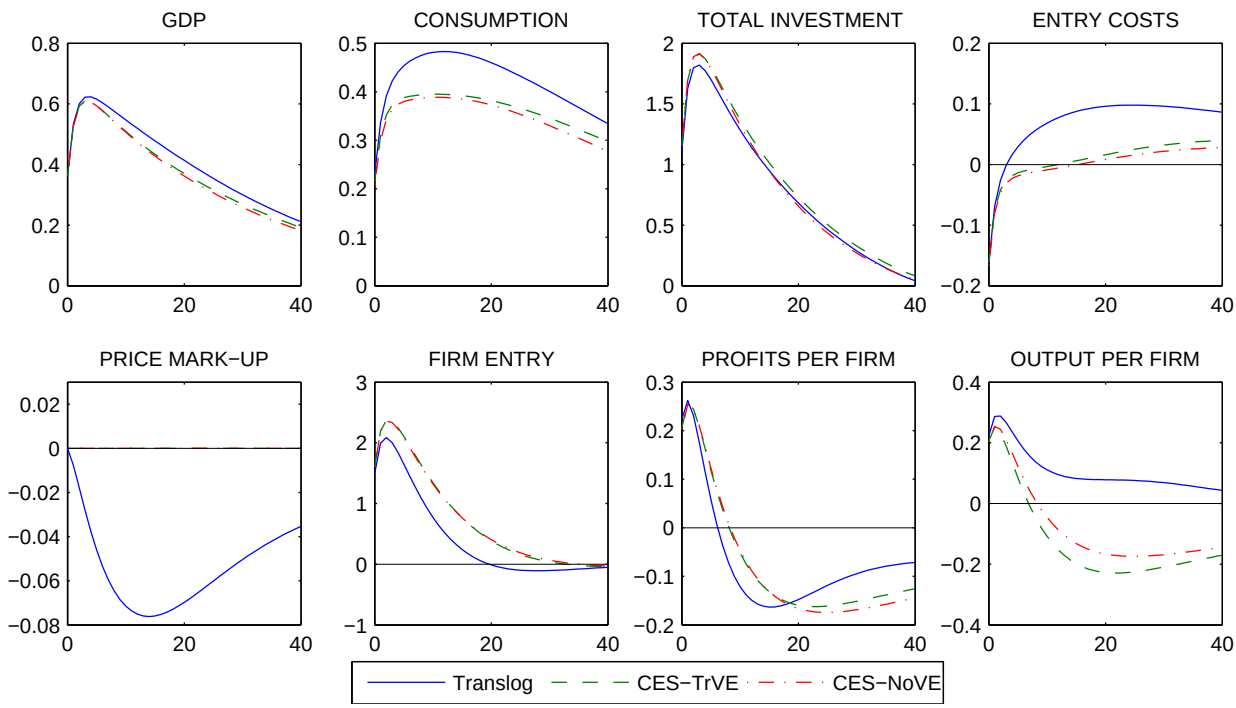

Figure 1: Impulse responses to a labor productivity shock

responses are measured as percentage deviations from steady states.

To start with, Figure 1 plots the responses to a positive labor-augmenting technology shock z_t. This boosts GDP, consumption, as well as both components of total investment, investment in physical capital (not shown here), and in firm entry. Firm entry is fueled by rising profit opportunities of monopolistic firms due to the increase in aggregate demand as well as by the drop in entry costs. The latter decreases since the increase in z_t outweighs the rise in real wages. Hence, the mass of firms (or products) starts to increase. In the presence of the competition effect, this makes products closer substitutes and thus deteriorates 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 if the variety effect is present.

The magnification effect is evident in the impulse response functions. The competition effect and to a much lesser extent the variety effect magnify the effects of productivity shocks on GDP and, in particular, on consumption. Total investment, however, is dampened. Since investment in physical capital is also amplified, this can only be explained by a dampening of firm entry. The latter is caused by the substantial rise in entry costs due to rising real wages and by the fall in price mark-ups, which, in isolation, deteriorates profit opportunities of monopolistic firms.

Figure 2 shows the responses to an increase in wage mark-ups μ_t^w. The increase in wage

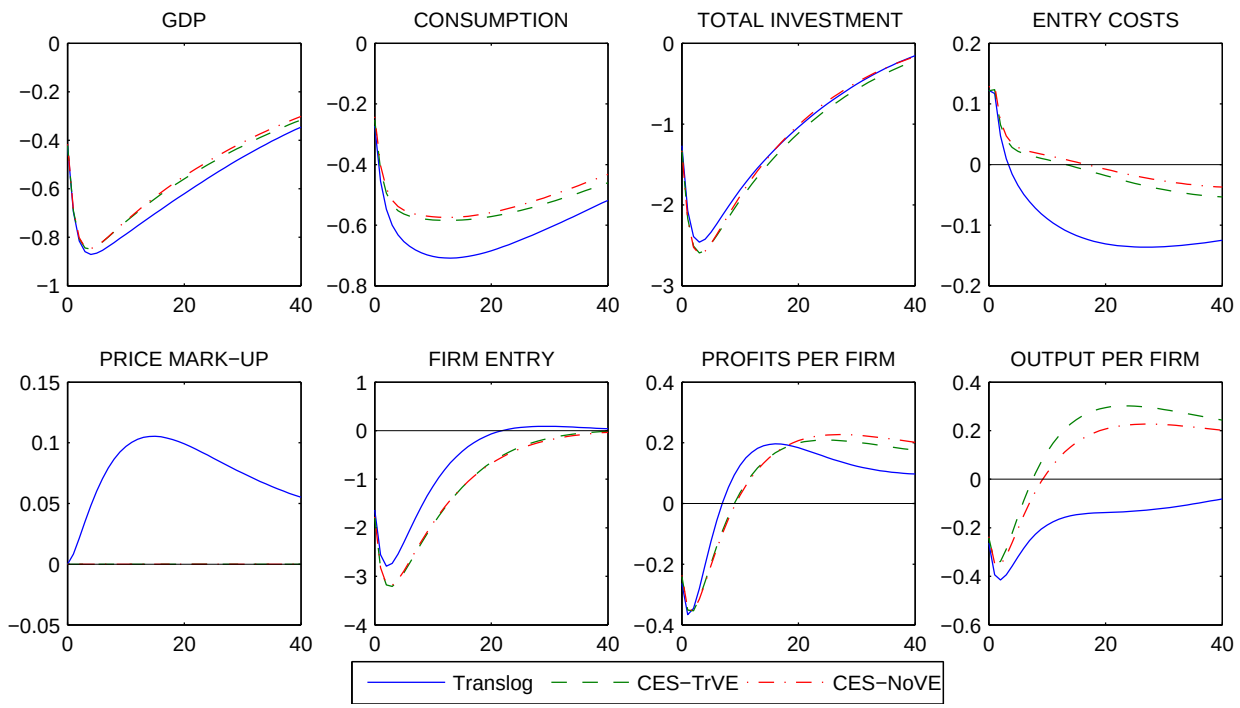

Figure 2: Impulse responses to a wage mark-up shock

mark-ups leads to a decline of GDP, consumption, and total investment. The drop in GDP and consumption is amplified when the competition and variety effect are at work. 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. The competition effect is in turn slightly enforced by the rise in the welfare-relevant price index via the variety effect. As in the case of labor productivity shocks, there is a dampening of the response of total investment when competition and variety effect are present.

To sum up, it is mainly the competition effect that amplifies, via countercyclical price mark-ups, the impact of labor-augmenting technology and wage mark-up shocks on GDP and consumption. However, countercyclical price mark-ups dampen the responses of firm entry, which translates into a dampening of total investment.

The results are different when we consider shocks to investment-specific technology, to preferences, and to government spending. The reason is that the estimated conditional correlation between GDP and firm entry is negative for those shocks. Hence, competition and variety effect dampen the rise in GDP following positive shocks to investment-specific technology, preferences, and government spending.

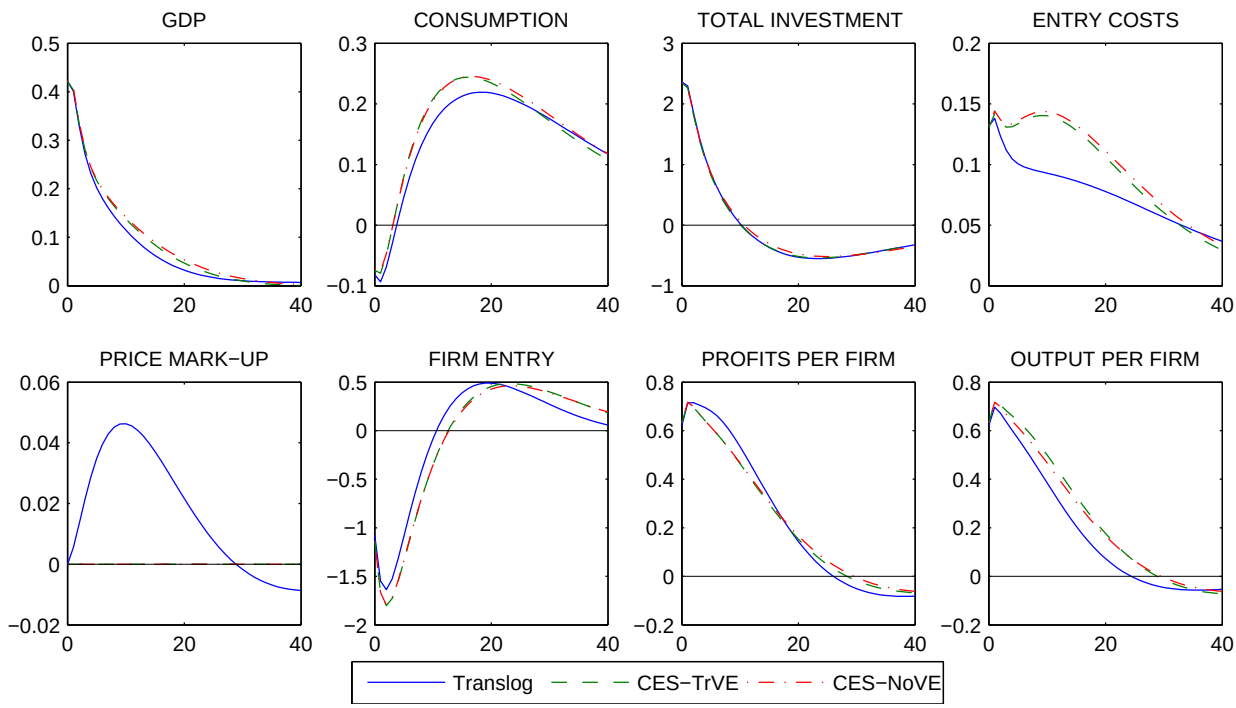

Figure 3: Impulse responses to an investment-specific technology shock

Figure 3 shows the responses to the investment-specific technology shock u_t^I. 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. Consumption falls on impact but turns positive during the course of adjustment. 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. The procyclical response of firm's market power abates the impacts of investment-specific technology shocks on GDP and consumption. The response of total investment is almost identical across the models.

Figures 4 and 5 show the responses to a preference shock χ_t that induces households to consume more and to a rise in government spending G_t, respectively. Both shocks raise 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, under translog preferences price mark-ups and the welfare-relevant price index rise, which both dampens the impacts of these aggregate demand disturbances on GDP.

Following a time-impatience shock, the responses of GDP, investment, and consumption are, however, not very different across the models. This is because the mark-up is only marginally affected by this type of shock. In contrast, the competition and variety effect visibly amplify the crowding-out of private consumption after a fiscal expansion, as can be seen from Figure 5. Private

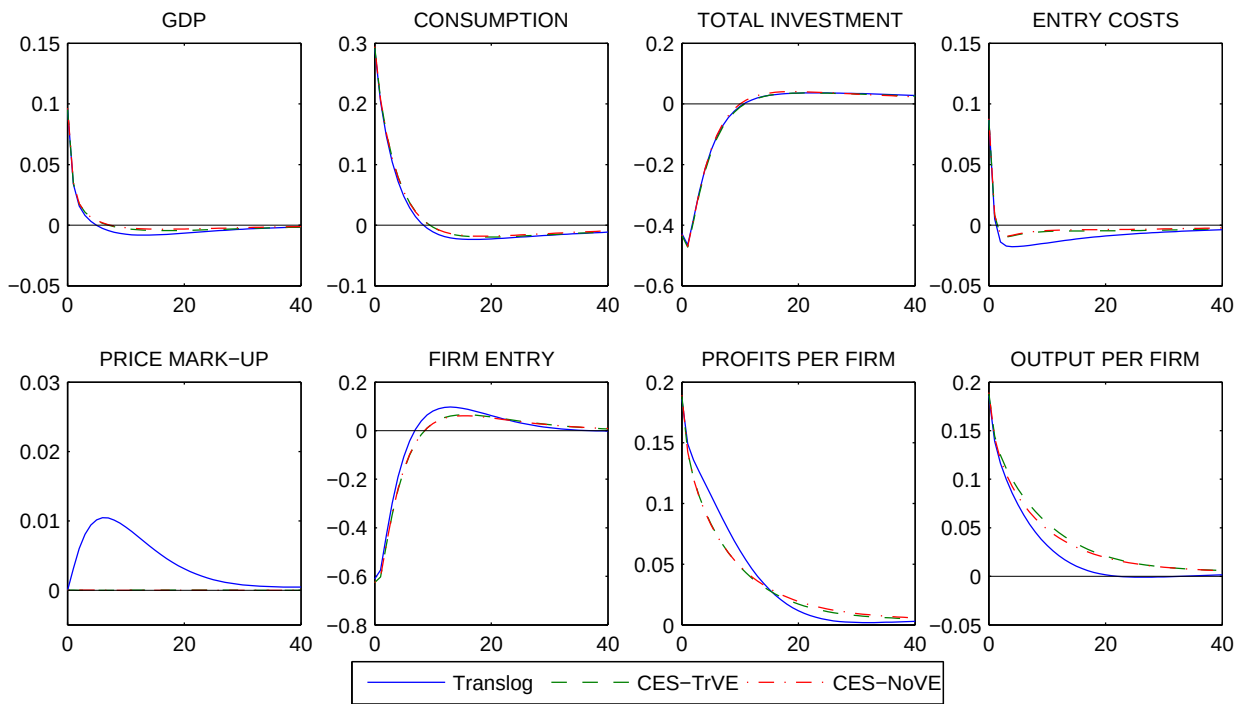

Figure 4: Impulse responses to a preference shock

consumption falls due to the negative wealth effect of higher taxes and the rise in real interest rates. Investment is again only marginally affected by these mechanisms.

Finally, Figure 6 shows that an exogenous increase in entry costs $f_{E,t}$ generates a strong decline 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 when the competition effect is present. The increase in price mark-ups induces a fall in capital investment and consumption. GDP, after a temporary rise on impact, declines significantly. In the absence of the competition effect, the decline in GDP is only short-lived and followed by a hump-shaped rise. This can be explained by the significant increase of consumption, which is otherwise depressed by the sharp increase in price mark-ups.

As in the case of shocks to investment-specific technology, to preferences, and to government spending, the increase in firm's market power lowers GDP. In the case of these disturbances the increase in GDP is dampened. In the case of entry cost shocks, though, the competition effect changes the GDP response qualitatively.

Overall, the presence of the competition and variety effect substantially amplifies the impact of labor productivity and wage mark-up shocks on GDP and consumption. On the other hand, the competition and variety effect dampen the impact of investment-specific technology shocks on GDP and consumption. In the case of shocks to government spending and preferences, the impact

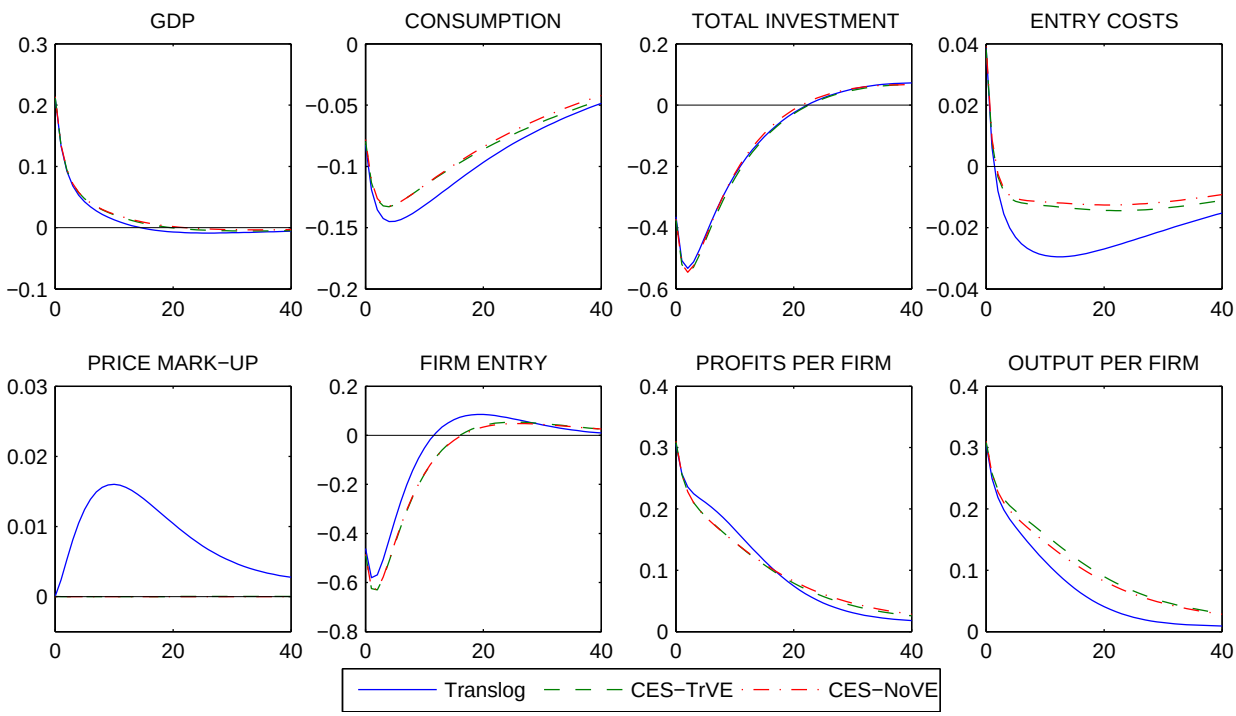

Figure 5: Impulse responses to a government spending shock

of these mechanisms is only marginal. Inspecting the impulse responses suggests also marginal effects for total investment. In the case of labor productivity and wage mark-up shocks, the responses of total investment are slightly dampened. For the other disturbances, the impacts are negligible. The next section aims to quantify the amplification mechanism by comparing simulated volatilities across the three model frameworks.

5 Quantifying the internal amplification mechanisms

In this section, we quantify the amplification mechanism embedded in the entry model and assess the contribution of the competition and the variety effect. Following Jaimovich and Floetotto (2008), we consider overall and shock-specific amplification measures, including shocks to labor productivity, to wage mark-ups, to investment-specific technology, to preferences, and to government spending. Recall from the previous section that shocks to entry costs generate qualitative different responses across the models. We therefore exclude this shock from our amplification analysis. Including this shock would only slightly change the overall amplification results.

In order to quantify the amplification mechanism, we proceed in two steps. In the first step, we simulate the three model frameworks (translog model, CES-TrVE model, CES-NoVE model) and compute shock-specific and overall volatility measures. As in the analysis of the impulse responses,

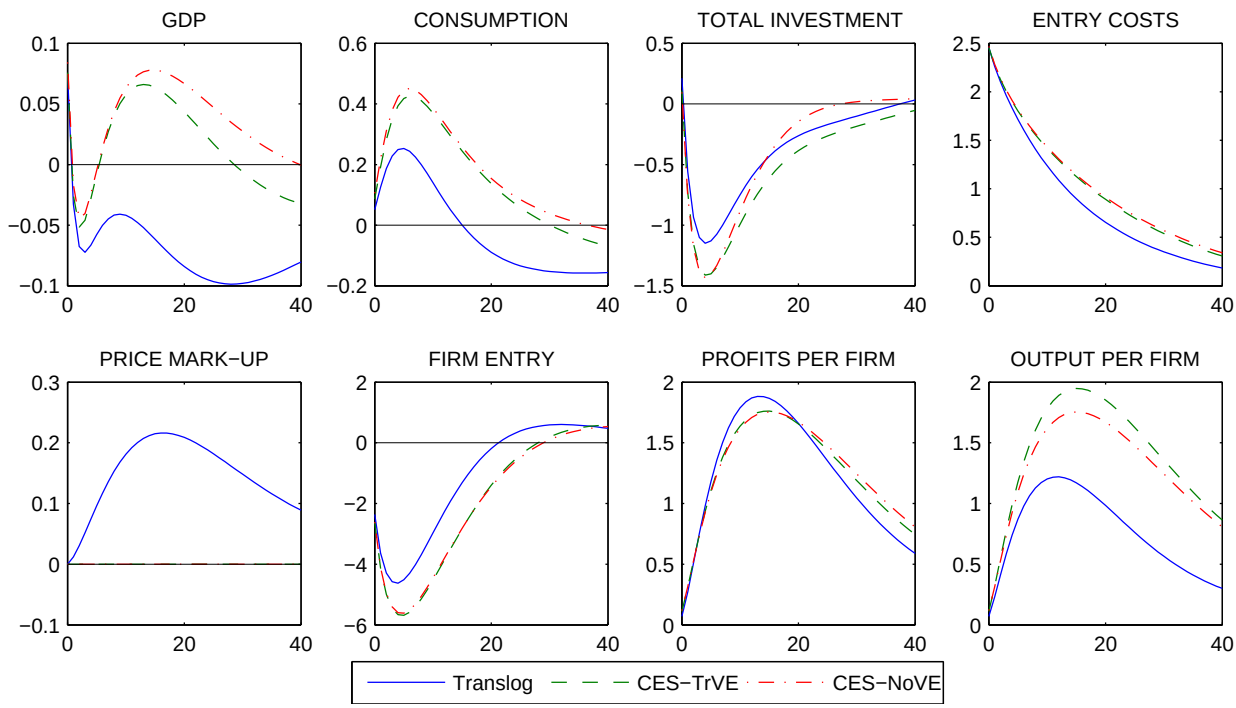

Figure 6: Impulse responses to an entry cost shock

we keep the parameter estimates from the translog model when simulating the CES models.[17] Based on the simulated volatility measures, we compute, in the second step, three amplification metrics. The overall amplification through both the competition and variety effect is measured as the volatility difference, in percentage terms, between the translog model and the CES-NoVE model. The contribution of the competition effect (CE) is measured by the volatility difference, in percentage terms, between the translog model and the CES-TrVE model. Analogously, the contribution of the variety effect (VE) is computed as the volatility difference, in percentage terms, between the CES-TrVE model and the CES-NoVE model. Note that the contributions of the competition and of the variety effect do not necessarily add up to the total amplification since they are computed on different bases. Table 6 shows our results.

To start with, we focus on GDP. The results are displayed in the upper panel of Table 6. The shock-specific and overall volatility measures are shown in columns one to three. Shock-specific volatilities are obtained by assuming that at each time only one of the above mentioned shocks is active. We then compute, for all three model frameworks and for all five shocks under consideration, the standard deviation of GDP relative to the standard deviation of the underlying

[17] This ensures that we extract the model-specific amplification effect that exclusively results from the different model setups. In a robustness exercise in Section 6, we estimate both CES models separately and obtain similar amplification results using the estimated CES models.

Table 6: Standard deviations, relative volatilities and amplification indicators

	Volatility			Amplification			
	Translog	CES-TrVE	CES-NoVE	Total	CE	VE	$Corr(X, N)$
Std of GDP relative to ... shock							$X = Y^r$
labor prod.	1.0036	0.9347	0.9187	9.2 %	7.4 %	1.7 %	0.92
wage mark-up	0.1823	0.1699	0.1670	9.2 %	7.3 %	1.7 %	0.93
invest. spec. tech.	0.2118	0.2233	0.2268	-6.6 %	-5.2 %	-1.5 %	-0.55
preference	0.0743	0.0729	0.0731	1.6 %	1.9 %	-0.3 %	0.14
gov. spending	0.0630	0.0643	0.0647	-2.6 %	-2.0 %	-0.6 %	-0.16
Absolute std of GDP							
All five shocks	0.0522	0.0488	0.0481	8.5 %	7.0 %	1.5 %	0.86
Std of consumption relative to ... shock							$X = C^r$
labor prod.	1.0815	0.9365	0.8915	21.3 %	15.5 %	5.0 %	0.97
wage mark-up	0.2015	0.1754	0.1671	20.6 %	14.9 %	5.0 %	0.98
invest. spec. tech.	0.2726	0.2885	0.2964	-8.0 %	-5.5 %	-2.7 %	-0.50
preference	0.2921	0.2968	0.2954	-1.1 %	-1.6 %	0.5 %	-0.15
gov. spending	0.1451	0.1315	0.1284	13.0 %	10.3 %	2.4 %	0.95
Absolute std of consumption							
All five shocks	0.0580	0.0509	0.0488	18.9 %	13.9 %	4.3 %	0.90
Std of total investment relative to ... shock							$X = TI^r$
labor prod.	2.1817	2.3126	2.2435	-2.8 %	-5.7 %	3.1 %	0.67
wage mark-up	0.3739	0.3984	0.3868	-3.3 %	-6.1 %	3.0 %	0.68
invest. spec. tech.	1.2272	1.2068	1.2147	1.0 %	1.7 %	-0.7 %	-0.12
preference	0.5996	0.6105	0.6015	-0.3 %	-1.8 %	1.5 %	0.34
gov. spending	0.3130	0.3224	0.3148	-0.6 %	-2.9 %	2.4 %	0.52
Absolute std of total investment							
All five shocks	0.1200	0.1259	0.1229	-2.4 %	-4.7 %	2.4 %	0.58

Note: The contemporaneous correlation in the last column is based on simulated data from the translog model.

shock process.[18] The overall volatility is measured by the absolute standard deviations of GDP when all five considered structural shocks are active. Columns four to six show the amplification ratios measured in percentage points. The last column reports the contemporaneous correlation between the number of firms and GDP.

When all five shocks are active, the volatility of GDP under translog preferences is substantially higher than under the two CES models. In total, GDP is amplified by 8.5 percent. The competition effect accounts for most amplification across all shocks. Overall, the competition effect increases the volatility of GDP by 7 percent, whereas the increase through the variety effect only amounts to 1.5 percent.

Turning to the shock-specific amplification ratios, we obtain the following results. Productivity and wage mark-up shocks are amplified by 9.2 percent, shocks to preferences by 1.6 percent. Contrarily, shocks to investment-specific technology are dampened by 6.6 percent, government spending shocks by 2.6 percent. For all shocks, except for shocks to preferences, the competition and the variety effect work in the same direction. Since the price mark-up μ_t^p decreases with the number of firms and the relative price ρ_t increases with the number of firms, the following rule applies: If GDP and the number of firms are positively correlated, both effects amplify GDP. If, on the other hand, the correlation is negative, both effects dampen GDP. Note that the variety effect on data-consistent variables, as considered here, is smaller than for welfare-consistent variables since $\partial \hat{Y}_t^r / \partial \hat{\rho}_t = \partial \hat{Y}_t / \partial \hat{\rho}_t - 1$ and $\partial \hat{Y}_t / \partial \hat{\rho}_t > 0$. Except for shocks to preferences, the effect through Y_t dominates the effect, which stems from deflating. The shock-specific amplification is mainly driven by the competition effect, as for total amplification.

Next, we investigate the components of GDP. The results for consumption and investment are shown in the middle and lower panel of Table 6, respectively. For consumption, the amplification results are qualitatively the same as for GDP, except for shocks to preferences and government spending. However, the volatility differences across the models are much more pronounced. Over all shocks, the volatility in consumption is amplified by 18.9 percent in total. For the two most important shocks to consumption, i.e. labor productivity and wage mark-ups, the total volatility increase is given by 21.3 percent and 20.6 percent, respectively. Contrarily to GDP, consumption is positively correlated with the number of firms in the presence of a government spending shock, amplifying the crowding out in consumption.

For total investment, the competition effects has two opposing effects. Recall that total invest-

[18] As in the previous section, GDP is deflated by the relative price ρ_t.

ment is defined as the sum of investment in physical capital and investments in new firms. On the one hand, a lower price mark-up boosts GDP and therefore increases investment in physical capital for existing firms. On the other hand, a lower price mark-up reduces the incentive to invest into new firms. We find that the latter effect dominates such that an increase in the number of firms reduces total investment through the competition effect and outweighs the positive variety effect. Over all shocks, the volatility in total investment is dampened by -2.4 percent.

6 Robustness

In this section, we apply three robustness exercises. In the first exercise, we use estimated, instead of counterfactual, CES models to quantify the amplification mechanism. In the remaining two exercises, we estimate the translog model with two different data samples. Details on the results of our robustness exercises can be found in Appendix D.

In the previous section, we have used the same estimated parameter set in all three model frameworks in order to isolate the model-specific competition and variety effect that exclusively result from the different model setups. In this first exercise, we estimate the two CES models and check whether these parameter estimates are significantly different from the parameter estimates of the translog model. Based on the estimated CES models, we then quantify the amplification mechanism.

For the estimation of the two CES models, we use the same data set as for the translog model. The constant price mark-up is fixed to the estimated steady-state value under the translog specification. The parameter estimates of the CES models are not significantly different from the parameter estimates of the translog model. All estimates lie within the 90 percent confidence interval of the translog estimation. Using the estimated CES models, we therefore obtain similar amplification measures. For the two most important shocks to GDP, i.e. labor productivity and wage mark-ups, the total amplification amounts to 9 percent and 13.7 percent, respectively. We find most notable discrepancies for the amplification of total investment. Contrarily to our previous analysis, total investment is now amplified for all shocks, except for shocks to labor productivity. This may result from higher entry adjustment costs, which lower the dampening effect of the competition effect through its effect on the number of firms. Note that we do not compute overall amplification measures. Differences in the absolute standard deviation of GDP, consumption, and total investment would rather reflect differences in the model fit.

In a second robustness exercise, we exclude profits from our set of observables and re-estimate the translog model which does not considerably change our estimation results. No parameter estimate is significantly different from parameter estimates of the baseline estimation. This mirrors our previous result that variations in profits are to a large extent captured by the measurement error.

In a third robustness exercise, we check whether the missing observations of firm entry in our data sample considerably affect our estimation and amplification results. We therefore re-estimate the model with translog preferences using only the limited sample period until 1998:Q2, which is the latest data point available for the new firm series. Hence, all missing observations are excluded from the data sample. Everything else remains the same.

Most parameter values are not significantly different from the parameter estimates of the full sample estimation. Two differences are worth mentioning. First, the estimate of the labor share in production is given by 0.92, which is even higher than the estimate of 0.85 in the full sample estimation. However, in both estimations the values correspond roughly to the same labor share in GDP of about 70 percent. Second, the steady-state price mark-up is estimated at 1.45, which is substantially higher than the full sample estimate of 1.26. The second moment analysis shows that the estimated model has difficulties to match the moments of the profit and the new firm time series as in the full sample estimation.

In a second step, we use the subsample estimates to compute the amplification measures for GDP, consumption, and total investment. Since the parameter estimates are not significantly different, we obtain qualitatively the same amplification measures as in the full sample estimation. However, due to the increased price mark-up, the size of positive and negative amplification is substantially higher for all shocks. The overall amplification on GDP, consumption, and total investment through the competition and the variety effect is given by 10.3, 24.3, and -4.5 percent, respectively.

7 Conclusion

This paper studies the empirical importance of endogenous firm entry as amplification mechanism for business cycle fluctuations. To this end, we use the firm entry model by Bilbiie, Ghironi, and Melitz (2012), extend it with several real frictions and estimate the model on U.S. data with Bayesian methods. In this model, the amplification mechanism of firm entry works through a

competition and a variety effect. Both effects are governed by the steady-state (net) price mark-up, which we find to be significantly different from zero.

To quantify the strength of this amplification mechanism and to disentangle the competition and the variety effect, we also specify two model frameworks, where either the competition or both effects are switched off. We measure the amplification as the percentage volatility difference in GDP, consumption, and investment across the three model variants.

Our results support the findings of Jaimovich and Floetotto (2008) that endogenous firm entry is an important amplification mechanism for business cycle fluctuations. However, in a medium-scale environment – as considered here – the quantitative impact of firm entry is less dominant. Over all shocks, firm entry substantially amplifies GDP by 8.5 percent. For the shock specific amplification, the results are mixed. For labor productivity and wage mark-up shocks firm entry amplifies GDP, but dampens shocks to aggregate demand and to investment-specific technology. The competition effect accounts for most amplification, whereas the variety effect only plays a minor role.

In the theoretical framework each firm produces one differentiated product, i.e. we have an identity between the number of firms and products. In our empirical exercise we exclusively focus on firm entry dynamics by using data on new business incorporations. However, this approach neglects the effect of product creation at existing firms. Bernard, Redding, and Schott (2010) and Broda and Weinstein (2010) highlight the empirical importance of product creation in business cycle fluctuations. We leave it to future research to identify the entry mechanism with data on product creation.

References

An, Sungbae and Frank Schorfheide (2007). Bayesian Analysis of DSGE Models. *Econometric Reviews* 26 (2), 113-172.

Benassy, Jean-Pascal (1996). Taste for variety and optimum production patterns in monopolistic competition. *Economics Letters* 52, 41-47.

Bergin, Paul R. and Giancarlo Corsetti (2008). The Extensive Margin and Monetary Policy. *Journal of Monetary Economics* 55 (7), 1222-1237.

Bernard, Andrew B., Stephen J. Redding, and Peter K. Schott (2010). Multi-Product Firms and Product Switching. *American Economic Review* 100, 70-97.

Bilbiie, Florin, Fabio Ghironi, and Marc J. Melitz (2012). Endogenous Entry, Product Variety, and Business Cycles. *Journal of Political Economy* 120, 304-345.

Boivin, Jean and Marc Giannoni (2006). DSGE Models in a Data-Rich Environment. NBER Technical Working Papers 0332, National Bureau of Economic Research.

Broda, Christian and David E. Weinstein (2010). Product Creation and Destruction: Evidence and Price Implications. *American Economic Review* 100, 691-723.

Chatterjee, Satyajit and Russell W. Cooper (1993). Entry and exit, product variety, and the business cycle. Working Papers 93-30, Federal Reserve Bank of Philadelphia.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy *Journal of Political Economy* 113(1), 1-45.

Chugh, Sanjay K. and Fabio Ghironi (2012). Optimal Fiscal Policy with Endogenous Product Variety. Boston College Working Papers in Economics 845, Boston College Department of Economics.

Colciago, Andrea and Federico Etro (2010). Real Business Cycles with Cournot Competition and Endogenous Entry. *Journal of Macroeconomics* 32, 1101-1117.

Davis, Steven, John C. Haltiwanger, and Scott Schuh (1998). Job Creation and Destruction, MIT Press, Cambridge.

Devereux, Michael B., Allen C. Head, and Beverly J. Lapham (1996). Aggregate Fluctuations with Increasing Return to Specialization and Scale. *Journal of Economic Dynamics and Control* 20, 627-656.

Etro, Federico and Andrea Colcagio (2010). Endogenous Market Structures and the Business Cycle. *Economic Journal* 120, 1201-1233.

Feenstra, Robert C. (2003). A Homothetic Utility Function for Monopolistic Competition Models, Without Constant Price Elasticity. *Economics Letters* 78, 79-86.

Gali, Jordi, Frank Smets, and Raf Wouters (2012). Unemployment in an Estimated New Keynesian Model. *NBER Macroeconomics Annual 2011*, 329-360.

Ghironi, Fabio and Marc J. Melitz (2005). International Trade and Macroeconomic Dynamics with Heterogeneous Firms. *Quarterly Journal of Economics* 120, 865-915.

Greenwood, Jeremy, Zvi Hercowitz, and Gregory Huffman (1988). Investment, Capacity Utilization, and the Real Business Cycle. *American Economic Review* 78, 402-417.

Jaimovich, Nir and Max Floetotto (2008). Firm dynamics, mark-up variations, and the business cycle. *Journal of Monetary Economics* 55, 1238-1252.

Jaimovich, Nir and Sergio Rebelo (2009). Can News about the Future Drive the Business Cycle?. *American Economic Review* 99, 1097-1118.

Justiniano, Alejandro, Giorgo Primiceri, and Andrea Tambalotti (2010). Investment Shocks and Business Cycles. *Journal of Monetary Economics* 57, 132-145.

Justiniano, Alejandro, Giorgo Primiceri, and Andrea Tambalotti (2013). Is There a Trade-Off Between Inflation and Output Stabilization? *American Economic Journal: Macroeconomics* 5, 1-31.

King, Robert, Charles Plosser, and Sergio Rebelo (1988). Production, Growth and Business Cycles: I. the Basic Neoclassical Model. *Journal of Monetary Economics* 21, 195-232.

Lewis, Vivien (2009). Business Cycle Evidence on Firm Entry. *Macroeconomic Dynamics* 13, 605-624.

Lewis, Vivien and Céline Poilly (2012). Firm Entry, Mark-ups, and the Monetary Transmission Mechanism. *Journal of Monetary Economics* 59, 670-685.

Lewis, Vivien and Arnoud Stevens (2013). Entry and mark-up dynamics in an estimated business cycle model. Center for Economic Studies - Discussion papers ces13.20, Katholieke Universiteit Leuven.

Schmitt-Grohé, Stephanie and Martín Uribe (2012). What's News In Business Cycles. *Econometrica* 80, 2733-2764.

Smets, Frank and Raf Wouters (2007). Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach. *American Economic Review* 97, 586-606.

Appendix

A The price index and the price elasticity of demand

This section derives the price index P_t and the price elasticity of demand ε_t for an individual intermediate good in the translog model. The final goods producers demand intermediate goods $y_{i,t}$ at price $p_{i,t}$ and bundle these intermediate goods to final goods Y_t^C. Under perfect competition and zero profits, total revenues equal total costs. The cost function of a final good producer then equals $P_t Y_t^C$, where P_t is the price and the cost of one final good. In the translog model, $\ln P_t$ is given by the following translog function as proposed by Feenstra (2003):

$$\begin{aligned}\ln P_t = \alpha_0 &+ \frac{1}{2}\frac{\tilde{N} - N_t}{\tilde{\sigma} N_t \tilde{N}} + \frac{1}{N_t}\int_0^{N_t} \ln p_{i,t} di \\ &+ \frac{1}{2}\frac{\tilde{\sigma}}{N_t}\int_0^{N_t}\int_0^{N_t} \ln p_{i,t} \ln p_{j,t} di dj - \frac{\tilde{\sigma}}{2}\int_0^{N_t} (\ln p_{i,t})^2 di \end{aligned} \tag{A.1}$$

In the following α_0 is normalized to zero.

Under symmetric intermediate goods producers, implying $p_{i,t} = p_{j,t} = p_t$, the translog function (A.1) simplifies to

$$\ln P_t = \frac{1}{2}\frac{\tilde{N} - N_t}{\tilde{\sigma} N_t \tilde{N}} + \ln p_t \tag{A.2}$$

and the relative price reads as

$$\rho_t = \frac{p_t}{P_t} = \exp\left(-\frac{1}{2}\frac{\tilde{N} - N_t}{\tilde{\sigma} N_t \tilde{N}}\right) \tag{A.3}$$

For the derivation of the price elasticity of demand for an individual good, we use the cost share $s_{i,t}$ of the ith production factor, which is defined as

$$s_{i,t} = \frac{p_{i,t} y_{i,t}}{P_t Y_t^C} \tag{A.4}$$

Taking logs of (A.4) and differentiating with respect to $\ln p_{i,t}$ gives

$$\frac{\partial \ln s_{i,t}}{\partial \ln p_{i,t}} = 1 + \frac{\partial \ln y_{i,t}}{\partial \ln p_{i,t}} \tag{A.5}$$

such that we can write the price elasticity as

$$\varepsilon_{i,t} = -\frac{\partial y_{i,t}}{\partial p_{i,t}} \frac{p_{i,t}}{y_{i,t}} = -\frac{\partial \ln y_{i,t}}{\partial \ln p_{i,t}} = 1 - \frac{\partial \ln s_{i,t}}{\partial \ln p_{i,t}} = 1 - \frac{\partial s_{i,t}}{\partial \ln p_{i,t}} \frac{1}{s_{i,t}} \tag{A.6}$$

According to Shepard's lemma, the demand for the ith production factor is given by

$$y_{i,t} = \frac{\partial P_t Y_t^C}{\partial p_{i,t}} = Y_t^C \frac{P_t}{p_{i,t}} \frac{\partial \ln P_t}{\partial \ln p_{i,t}} \tag{A.7}$$

Replacing $y_{i,t}$ in (A.4) and differentiating (A.1) with respect to $\ln p_{i,t}$, the cost share can be written as

$$s_{i,t} = \frac{\partial \ln P_t}{\partial \ln p_{i,t}} = \frac{1}{N_t} + \frac{1}{2}\frac{\tilde{\sigma}}{N_t}\int_0^{N_t} \ln p_{i,t} di + \frac{1}{2}\frac{\tilde{\sigma}}{N_t}\int_0^{N_t} \ln p_{i,t} di - \frac{1}{2}\tilde{\sigma} \ln p_{i,t} \tag{A.8}$$

$$= \frac{1}{N_t} + \frac{\tilde{\sigma}}{N_t}\int_0^{N_t} \ln p_{i,t} di - \tilde{\sigma} \ln p_{i,t} \tag{A.9}$$

Differentiating (A.9) with respect to $\ln p_{i,t}$ gives

$$\frac{\partial s_{i,t}}{\partial \ln p_{i,t}} = \frac{\tilde{\sigma}}{N_t} - \tilde{\sigma} \tag{A.10}$$

such that

$$\varepsilon_{i,t} = 1 - \left(\frac{\tilde{\sigma}}{N_t} - \tilde{\sigma}\right)\frac{1}{s_{i,t}} \tag{A.11}$$

which reduces for large N_t to

$$\varepsilon_{i,t} = 1 + \tilde{\sigma}\frac{1}{s_{i,t}} \tag{A.12}$$

Under symmetric prices, the cost share in (A.9) reduces to

$$s_t = \frac{1}{N_t} \tag{A.13}$$

and the price elasticity is given by

$$\varepsilon_t = 1 + \tilde{\sigma} N_t \tag{A.14}$$

B The log-linear model

This section summarizes the full log-linearized model variants. A variable without time index denotes its steady-state value. A hat above a variable denotes the percentage deviation from its steady state.

- Consumption Euler equation:

$$\hat{\lambda}_t^C = \mathrm{E}_t\, \hat{\lambda}_{t+1}^C + \hat{R}_t \tag{B.1}$$

- Shares Euler equation:

$$\hat{v}_t = \mathrm{E}_t \left\{ \hat{\lambda}_{t+t}^C - \hat{\lambda}_t^C + \beta(1-\delta)\hat{v}_{t+1} + \big(1-\beta(1-\delta)\big)\hat{d}_{t+1} \right\} \tag{B.2}$$

- Capital Euler equation:

$$\hat{Q}_t = \mathrm{E}_t \left\{ \hat{\lambda}_{t+t}^C - \hat{\lambda}_t^C + \beta(1-\delta^K)\hat{Q}_{t+1} + \big(1-\beta(1-\delta^K)\big)\hat{r}_{t+1}^K \right\} \tag{B.3}$$

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

$$\begin{aligned}\hat{\lambda}_t^C = {} & \lambda_1 \left(\hat{V}_t + \hat{\chi}_t - b\beta\, \mathrm{E}_t \left\{ \hat{V}_{t+1} + \hat{\chi}_{t+1} \right\} \right) - \lambda_2 \left(\hat{\lambda}_t^S + \hat{S}_t - b\beta\, \mathrm{E}_t \left\{ \hat{S}_{t+1} + \hat{\lambda}_{t+1}^S \right\} \right) \\ & + \lambda_3 \left(\hat{C}_t - b\hat{C}_{t-1} - b\beta\, \mathrm{E}_t \left\{ \hat{C}_{t+1} - b\hat{C}_t \right\} \right) ,\end{aligned} \tag{B.4}$$

where

$$\begin{aligned}\lambda_1 &= \frac{C(1-b)\big(1-\beta(1-\gamma)\big)}{(1-b\beta)\big[(1-\beta(1-\gamma))C(1-b) - \gamma\psi S L^\eta\big]} \\ \lambda_2 &= \frac{\gamma\psi S L^\eta}{(1-b\beta)\big[(1-\beta(1-\gamma))C(1-b) - \gamma\psi S L^\eta\big]} \\ \lambda_3 &= \frac{\gamma\psi S L^\eta}{(1-b)(1-b\beta)\big[(1-\beta(1-\gamma))C(1-b) - \gamma\psi S L^\eta\big]}\end{aligned}$$

and the auxiliary variable

$$\hat{V}_t = -\frac{C}{C(1-b) - \psi L^\eta S} \left(\hat{C}_t - b\hat{C}_{t-1} \right) + \frac{\psi L^\eta S}{C(1-b) - \psi L^\eta S} \left(\eta \hat{L}_t + \hat{S}_t \right) \tag{B.5}$$

- Dynamics of S_t

$$\hat{S}_t = (1-\gamma)\hat{S}_{t-1} + \frac{\gamma}{1-b}\hat{C}_t - \frac{\gamma b}{1-b}\hat{C}_{t-1} \tag{B.6}$$

- Lagrange multiplier associated with S_t:

$$\hat{\lambda}_t^S = \beta(1-\gamma)\,\mathrm{E}_t\left\{\hat{\lambda}_{t+1}^S + \hat{S}_{t+1} - \hat{S}_t\right\} + \big(1-\beta(1-\gamma)\big)\left(\eta\hat{L}_t + \hat{V}_t + \hat{\chi}_t\right) \tag{B.7}$$

- Labor supply:

$$\hat{w}_t = \hat{\mu}_t^w + \hat{V}_t + \theta\hat{L}_t + \hat{S}_t - \hat{\lambda}_t^C + \hat{\chi}_t \tag{B.8}$$

- Optimal pricing equation:

$$\hat{\rho}_t = \hat{\mu}_t^p + \hat{mc}_t \tag{B.9}$$

- Price mark-up:

$$\hat{\mu}_t^p = -\xi\hat{N}_t\,, \tag{B.10}$$

where $\xi = 1 - \frac{1}{\mu_p}$ in the translog model and $\xi = 0$ in the CES models.

- Relative price:

$$\hat{\rho}_t = \omega\hat{N}_t\,, \tag{B.11}$$

where $\omega = \frac{1}{2}(\mu^p - 1)$ in the translog model, $\omega = \frac{1}{2}(\mu^p - 1)$ in the CESTrVE model and $\omega = 0$ in the CESNoVE model.

- Factor demand equation:

$$\hat{w}_t = \hat{Y}_t^C - \hat{L}_t^C - \hat{\mu}_t^p \tag{B.12}$$

$$\hat{r}_t^K = \hat{Y}_t^C - (\hat{K}_{t-1} + \hat{u}_t) - \hat{\mu}_t^p \tag{B.13}$$

- Total profit income:

$$\hat{D}_t \equiv \hat{N}_t + \hat{d}_t = \frac{1}{\mu^p - 1}\hat{\mu}_t^p + \hat{Y}_t^C \tag{B.14}$$

- Firm entry:

$$\hat{N}_{E,t} = \frac{\beta}{1+\beta}\,\mathrm{E}_t\,\hat{N}_{E,t+1} + \frac{1}{1+\beta}\hat{N}_{E,t-1} + \frac{1}{(1+\beta)\kappa_E}\big(\hat{v}_t - (\hat{w}_t - \hat{z}_t + \hat{f}_{E,t})\big) \tag{B.15}$$

- Investment in new firms:

$$\hat{I}_{E,t} = \hat{w}_t - \hat{z}_t + \hat{f}_{E,t} + \hat{N}_{E,t} \tag{B.16}$$

- Firm dynamics:

$$\hat{N}_t = (1-\delta)\hat{N}_{t-1} + \delta\hat{N}_{E,t-1} \tag{B.17}$$

- Investment in physical capital:

$$\hat{I}_t = \frac{\beta}{1+\beta}\,\mathrm{E}_t\,\hat{I}_{t+1} + \frac{1}{1+\beta}\hat{I}_{t-1} + \frac{1}{\kappa(1+\beta)}\hat{Q}_t + \hat{u}_t^I \tag{B.18}$$

- Capital accumulation equation:

$$\hat{K}_t = (1-\delta^K)\hat{K}_{t-1} + \delta^K\hat{I}_t - r^K\hat{u}_t + \delta^K\kappa(1+\beta)\hat{u}_t^I \tag{B.19}$$

- Capital utilization:

$$\hat{u}_t = \frac{\delta_1}{\delta_2}\big(\hat{r}_t^K - \hat{Q}_t\big) \tag{B.20}$$

- Total investment:

$$\hat{TI}_t = \frac{I}{TI}\hat{I}_t + \frac{vN_E}{TI}\hat{I}_{E,t} \tag{B.21}$$

- Labor in entry:

$$\hat{L}_t^E = \hat{f}_{E,t} + \hat{N}_{E,t} - \hat{z}_t \tag{B.22}$$

- Aggregate production function:

$$\hat{Y}_t^C = \hat{\rho}_t + \alpha\big(\hat{z}_t + \hat{L}_t^C\big) + (1-\alpha)\big(\hat{u}_t + \hat{K}_{t-1}\big) \tag{B.23}$$

- Gross domestic product:

$$\hat{Y}_t = \frac{Y^C}{Y}\hat{Y}_t^C + \frac{vN_E}{Y}\big(\hat{w}_t - \hat{z}_t + \hat{f}_{E,t} + \hat{N}_{E,t}\big) \tag{B.24}$$

- Goods market clearing:

$$\hat{Y}_t^C = \frac{C}{Y^C}\hat{C}_t + \frac{I}{Y^C}\hat{I}_t + \frac{G}{Y^C}\hat{G}_t \tag{B.25}$$

- Resource constraint:

$$\hat{Y}_t = \frac{wL}{Y}\big(\hat{w}_t + \hat{L}_t\big) + \frac{Nd}{Y}\big(\hat{N}_t + \hat{d}_t\big) + \frac{r^K K}{Y}\big(\hat{r}_t^K + \hat{K}_{t-1} + \hat{u}_t\big) \tag{B.26}$$

Shock processes

- Labor productivity:

$$\hat{z}_t = \rho_z \hat{z}_{t-1} + \varepsilon_t^z \tag{B.27}$$

- Entry costs:

$$\hat{f}_{E,t} = \rho_{f_E}\hat{f}_{E,t-1} + \varepsilon_t^{f_E} \tag{B.28}$$

- Investment-specific technology:

$$\hat{u}_t^I = \rho_I \hat{u}_{t-1}^I + \varepsilon_t^I \tag{B.29}$$

- Wage mark-up:

$$\hat{\mu}_t^w = \rho_\mu \hat{\mu}_{t-1}^w + \varepsilon_t^\mu + \nu \varepsilon_{t-1}^\mu \tag{B.30}$$

- Government spending:

$$\hat{G}_t = \rho_G \hat{G}_{t-1} + \varepsilon_t^G \tag{B.31}$$

C Data

Table C.1: Data source

Series ID	Description	Source
GDPC96	Real gross domestic product	BEA
PCND	Personal consumption expenditures: non-durable goods	BEA
PCESV	Personal consumption expenditures: services	BEA
PCDG	Personal consumption expenditures: durable goods	BEA
FPI	Fixed private investment	BEA
CBI	Change in private inventories	BEA
PRS85006033	Non-farm business hours worked index (2005=100)	BLS
PRS85006103	Non-farm business hourly compensation index (2005=100)	BLS
CES0500000008	Average hourly earnings of production	BLS
CPATAX	Corporate profits after tax with IVA and CCAdj	BEA
NBI	New business incorporations	SCB from BEA
CNP160V	Civilian noninstitutional population	BLS
GDPDEF	Gross domestic product: implicit price deflator	BEA

BEA: U.S. Bureau of Economic Analysis, BLS: U.S. Bureau of Labor Statistics, SCB: Survey of Current Businesses.

Table C.2: Construction of data series

Time Series		Construction	Description
$dl(GDP_t)$	$=$	$dl\left(\frac{GDPC96_t}{CNP160V_t}\right)$	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
$dl(WAGE1_t)$	$=$	$dl\left(\frac{PRS85006103_t}{GDPDEF_t}\right)$	growth rate of first measure of real wage
$dl(WAGE2_t)$	$=$	$dl\left(\frac{CES0500000008_t}{GDPDEF_t}\right)$	growth rate of second measure real wage
$l(HOURS_t)$	$=$	$l\left(\frac{PRS85006033_t}{CNP160V_t}\right)$	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
$dl(ENTRY_t)$	$=$	$dl\left(\frac{NBI_t}{CNP160V_t}\right)$	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.

D Robustness

Table D.1: Amplification using the estimated CES models (full sample, 1964:Q1 – 2012:Q2)

	Volatility			Amplification		
	Translog	CES-TrVE	CES-NoVE	Total	CE	VE
Std of GDP relative to ... shock						
labor prod.	1.0036	0.9343	0.9211	9.0 %	7.4 %	1.4 %
wage mark-up	0.1823	0.1648	0.1603	13.7 %	10.6 %	2.8 %
invest. spec. techn.	0.2118	0.2170	0.2135	-0.8 %	-2.4 %	1.6 %
preference	0.0743	0.0749	0.0766	-3.0 %	-0.8 %	-2.2 %
government spending	0.0630	0.0630	0.0612	2.9 %	0.0 %	2.9 %
Std of consumption relative to ... shock						
labor prod.	1.0815	0.9349	0.8973	20.5%	15.7%	4.2%
wage mark-up	0.2015	0.1756	0.1656	21.7%	14.7%	6.0%
invest. spec. tech.	0.2726	0.2799	0.2795	-2.5%	-2.6%	0.1%
preference	0.2921	0.2976	0.3012	-3.0%	-1.8%	-1.2%
gov. spending	0.1451	0.1341	0.135	7.5%	8.2%	-0.7%
Std of total investment relative to ... shock						
labor prod.	2.1817	2.3041	2.2145	-1.5%	-5.3%	4.0%
wage mark-up	0.3739	0.3621	0.3469	7.8%	3.3%	4.4%
invest. spec. tech.	1.2272	1.1692	1.1408	7.6%	5.0%	2.5%
preference	0.5996	0.6015	0.5996	0.0%	-0.3%	0.3%
gov. spending	0.3130	0.3211	0.3081	1.6%	-2.5%	4.2%

Table D.2: Results from the Bayesian estimation including prior distribution and confidence intervals (full sample, 1964:Q1 – 2012:Q2)

		Prior distribution			Posterior distribution							
					Translog		CES-TrVE		CES-NoVE		Trans. (no profits)	
Parameters		Type	Mean	STD	Mean	[5% – 95%]	Mean	[5% – 95%]	Mean	[5% – 95%]	Mean	[5% – 95%]
Structural parameters												
Labor share in production	α	Beta	0.7	0.2	0.85	[0.80 – 0.90]	0.85	[0.83 – 0.88]	0.85	[0.83 – 0.87]	0.85	[0.80 – 0.90]
Labor utility	θ	Gamma	2.0	1.0	3.62	[1.70 – 5.48]	3.83	[1.90 – 5.67]	3.90	[1.98 – 5.77]	3.63	[1.74 – 5.51]
Wealth elast. labor supply	γ	Beta	0.5	0.2	0.80	[0.66 – 0.95]	0.79	[0.65 – 0.94]	0.80	[0.65 – 0.94]	0.79	[0.65 – 0.94]
Consumption habit	b	Beta	0.5	0.2	0.75	[0.71 – 0.80]	0.75	[0.70 – 0.80]	0.74	[0.69 – 0.79]	0.76	[0.71 – 0.8]
Investment adj. cost	κ_I	Gamma	4.0	1.0	3.83	[2.48 – 5.15]	3.68	[2.40 – 4.95]	3.59	[2.33 – 4.83]	3.82	[2.48 – 5.13]
Inv. elast. of capital util.	$\frac{\delta_2}{\delta_1}$	Igamma	1.0	1.0	0.55	[0.29 – 0.80]	0.56	[0.30 – 0.82]	0.57	[0.30 – 0.83]	0.55	[0.29 – 0.80]
Price mark-up	μ^p	Gamma	1.3	0.2	1.26	[1.16 – 1.36]	–	–	–	–	1.26	[1.16 – 1.36]
Entry adj. cost	κ_E	Gamma	4.0	1.0	1.49	[1.05 – 1.94]	1.56	[1.09 – 2.02]	1.52	[1.06 – 1.97]	1.51	[1.05 – 1.95]
Autocorrelation of shock processes												
Labor productivity	ρ_z	Beta	0.5	0.2	0.96	[0.94 – 0.98]	0.96	[0.94 – 0.98]	0.96	[0.94 – 0.98]	0.96	[0.94 – 0.98]
Wage mark-up	ρ_μ	Beta	0.5	0.2	0.97	[0.95 – 0.98]	0.97	[0.96 – 0.98]	0.97	[0.96 – 0.99]	0.97	[0.95 – 0.98]
Invest. spec. tech.	ρ_I	Beta	0.5	0.2	0.25	[0.11 – 0.38]	0.23	[0.17 – 0.32]	0.22	[0.10 – 0.34]	0.24	[0.11 – 0.37]
Gov. spending	ρ_G	Beta	0.5	0.2	0.91	[0.88 – 0.95]	0.92	[0.91 – 0.93]	0.92	[0.89 – 0.95]	0.91	[0.88 – 0.95]
Entry cost	ρ_{f_E}	Beta	0.5	0.2	0.95	[0.92 – 0.98]	0.96	[0.95 – 0.97]	0.94	[0.90 – 0.98]	0.95	[0.92 – 0.98]
Standard deviation of innovations												
Labor prod.	σ_{ε^z}	Igamma	2.0	1	0.79	[0.69 – 0.89]	0.78	[0.73 – 0.81]	0.80	[0.71 – 0.88]	0.80	[0.70 – 0.90]
Wage mark-up	σ_{ε^μ}	Igamma	2.0	1	4.28	[2.83 – 5.70]	3.48	[2.87 – 4.20]	4.42	[3.00 – 5.81]	4.30	[2.86 – 5.73]
Invest. spec. tech.	σ_{ε^I}	Igamma	2.0	1	4.02	[2.06 – 5.94]	3.53	[3.07 – 4.29]	3.93	[3.21 – 4.65]	4.03	[2.09 – 5.92]
Preference	$\sigma_{\varepsilon^\chi}$	Igamma	2.0	1	1.45	[1.03 – 1.85]	1.36	[1.07 – 1.69]	1.36	[0.99 – 1.72]	1.46	[1.04 – 1.86]
Gov. spending	σ_{ε^G}	Igamma	2.0	1	1.87	[1.71 – 2.02]	1.89	[1.73 – 2.07]	1.87	[1.71 – 2.03]	1.87	[1.71 – 2.02]
Entry cost	$\sigma_{\varepsilon^{f_E}}$	Igamma	2.0	1	2.44	[1.92 – 2.93]	2.62	[2.32 – 2.86]	1.99	[1.51 – 2.47]	2.43	[1.92 – 2.93]
Moving average parameter and loading coefficient												
Wage mark-up shock	ν	Normal	0.0	0.2	0.41	[0.26 – 0.56]	0.45	[0.38 – 0.52]	0.42	[0.27 – 0.56]	0.41	[0.26 – 0.56]
Loading coefficient	λ	Normal	1.0	2.0	0.13	[0.06 – 0.19]	0.10	[0.08 – 0.12]	0.13	[0.06 – 0.20]	0.13	[0.06 – 0.19]

Table D.3: Results from the Bayesian estimation including prior distribution and confidence intervals (subsample data, 1964:Q1 – 1998:Q3)

		Prior distribution			Posterior distribution	
Parameter		Type	Mean	Std	Mean	[5% – 95%]
Structural parameters						
Labor share in production	α	Beta	0.7	0.2	0.92	[0.87 – 0.97]
Labor utility	θ	Gamma	2.0	1.0	4.18	[1.97 – 6.30]
Wealth elast. labor supply	γ	Beta	0.5	0.2	0.79	[0.63 – 0.95]
Consumption habit	b	Beta	0.5	0.2	0.77	[0.71 – 0.82]
Investment adj. cost	κ_I	Gamma	4.0	1.0	3.77	[2.33 – 5.19]
Inv. elast. of capital util.	$\frac{\delta_2}{\delta_1}$	Igamma	1.0	1.0	0.54	[0.28 – 0.78]
Price mark-up	μ^p	Gamma	1.3	0.2	1.45	[1.32 – 1.58]
Entry adj. cost	κ_E	Gamma	4.0	1.0	1.47	[0.97 – 1.96]
Autocorrelation of shock processes						
Labor productivity	ρ_z	Beta	0.5	0.2	0.98	[0.97 – 0.99]
Wage mark-up	ρ_μ	Beta	0.5	0.2	0.95	[0.93 – 0.98]
Invest. spec. tech.	ρ_I	Beta	0.5	0.2	0.18	[0.05 – 0.30]
Gov. spending	ρ_G	Beta	0.5	0.2	0.91	[0.88 – 0.95]
Entry cost	ρ_{f_E}	Beta	0.5	0.2	0.98	[0.97 – 0.99]
Standard deviation of innovations						
Labor prod.	σ_{ε^z}	Igamma	2.0	1	0.73	[0.63 – 0.83]
Wage mark-up	σ_{ε^μ}	Igamma	2.0	1	5.02	[3.19 – 6.79]
Invest. spec. tech.	σ_{ε^I}	Igamma	2.0	1	13.1	[3.50 – 24.6]
Preference	$\sigma_{\varepsilon^\chi}$	Igamma	2.0	1	1.65	[1.12 – 2.16]
Gov. spending	σ_{ε^G}	Igamma	2.0	1	1.78	[1.60 – 1.95]
Entry cost	$\sigma_{\varepsilon^{f_E}}$	Igamma	2.0	1	2.62	[2.13 – 3.10]
Moving average parameter and loading coefficient						
Wage mark-up shock	ν	Normal	0.0	0.2	0.27	[0.09 – 0.45]
Loading coefficient	λ	Normal	1.0	2.0	0.13	[0.04 – 0.22]

Table D.4: Second moments (subsample data, 1964:Q1 – 1998:Q3)

	X	σ_X		$\sigma_X/\sigma_{\Delta\hat{Y}^r}$		1st autocorr.		$corr(X, \Delta\hat{Y}^r)$	
		Data	Model	Data	Model	Data	Model	Data	Model
Output growth	$\Delta\hat{Y}^r$	0.90	0.96	1.00	1.00	0.29	0.20	1.00	1.00
Consumption growth	$\Delta\hat{C}^r$	0.52	0.61	0.57	0.63	0.36	0.39	0.52	0.39
Investment growth	$\Delta\widehat{TI}^r$	3.43	4.01	3.80	4.17	0.21	0.14	0.87	0.88
Hours	$\hat{L}$	4.03	3.37	4.46	3.50	0.96	0.97	0.11	0.14
Profit growth	$\Delta\hat{D}^r$	5.85	1.20	6.48	1.25	0.26	0.17	0.50	0.80
Firm Entry growth	$\Delta\hat{N}_E$	3.10	3.95	3.43	4.11	−0.02	0.43	0.20	0.10

Table D.5: Standard deviations, relative volatilities, and amplification indicators (subsample data, 1964:Q1 – 1998:Q3)

	Volatility			Amplification			
	Translog	CES-TrVE	CES-NoVE	Total	CE	VE	$Corr(X, N)$
Std of GDP relative to ... shock							$X = Y^r$
labor prod.	1.041	0.941	0.931	11.8%	10.6%	1.1%	0.96
wage mark-up	0.162	0.146	0.144	12.5%	11.0%	1.4%	0.88
invest. spec. tech.	0.098	0.105	0.106	-7.6%	-6.7%	-0.9%	-0.60
preference	0.059	0.059	0.059	0.0%	0.0%	0.0%	0.07
gov. spending	0.065	0.068	0.068	-5.0%	-4.6%	-0.4%	-0.22
Absolute std of GDP							
All five shocks	0.0548	0.0501	0.0497	10.3%	9.4%	0.8%	0.82
Std of consumption relative to ... shock							$X = C^r$
labor prod.	1.318	1.111	1.041	26.6%	18.6%	6.7%	0.99
wage mark-up	0.176	0.140	0.131	34.4%	25.7%	6.9%	0.98
invest. spec. tech.	0.129	0.140	0.143	-9.8%	-7.9%	-2.1%	-0.60
preference	0.290	0.297	0.295	-1.7%	-2.4%	0.7%	-0.14
gov. spending	0.141	0.120	0.115	22.6%	17.5%	4.4%	0.96
Absolute std of consumption							
All five shocks	0.0665	0.0565	0.0535	24.3%	17.7%	5.6%	0.87
Std of total investment relative to ... shock							$X = TI^r$
labor prod.	1.473	1.657	1.633	-9.8%	-11.1%	1.5%	0.72
wage mark-up	0.346	0.372	0.365	-5.2%	-7.0%	1.9%	0.58
invest. spec. tech.	0.489	0.479	0.481	1.7%	2.1%	-0.4%	-0.08
preference	0.572	0.582	0.575	-0.5%	-1.7%	1.2%	0.27
gov. spending	0.279	0.291	0.286	-2.5%	-4.1%	1.8%	0.45
Absolute std of total investment							
All five shocks	0.1136	0.1204	0.1190	-4.5%	-5.7%	1.2%	0.49

Note: The contemporaneous correlation in column seven is based on simulated data from the translog model.