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Firm entry, markups and the monetary transmission mechanism

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ABSTRACT

Two business cycle models with endogenous firm and product entry are estimated by matching impulse responses to a monetary policy shock. The 'competition effect' implies that entry lowers desired markups and dampens inflation. Under translog preferences, where the substitutability between goods depends on their number, we find evidence of such an effect. That model generates more countercyclical markups than Dixit and Stiglitz (1977) monopolistic competition model, where price stickiness is the only source of markup fluctuations. In contrast, a model with strategic interactions between oligopolistic firms cannot generate an empirically relevant competition effect and is statistically equivalent to the Dixit–Stiglitz model.

1. Introduction

Understanding the monetary transmission mechanism, which describes how interest rate changes affect the rest of the economy, is important for central banks. Countercyclical fluctuations in the markup play a key role in this process, driving inflation and hence aggregate demand.[1] In the standard New Keynesian model, these are ascribed solely to price stickiness; other sources of markup cyclicality are neglected. In particular, firm and product turnover are an important (additional) determinant of markups, both on average and along the business cycle.[2] Theoretical models have shown that, by reinforcing the countercyclicality of markups under sticky prices, entry has the potential to magnify the effects of monetary policy shocks on inflation and output (Bilbiie et al., 2007; Bergin and Corsetti, 2008). This paper subjects the sticky-price endogenous-entry model to a rigorous empirical evaluation, which is so far missing in the literature.[3]

We develop, estimate and compare two dynamic stochastic general equilibrium (DSGE) models with endogenous entry and various real and nominal frictions. Entry affects the monetary transmission mechanism through the 'competition effect'. By intensifying competitive pressures, the arrival of an entrant increases demand elasticities and reduces desired markups, i.e. the difference between prices and marginal costs in the absence of price rigidities. This happens either because of increased substitutability between goods or because of stronger competition between oligopolistic producers.

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[1] A large literature has documented the countercyclicality of markups, starting from Bils (1987). Rotemberg and Woodford (1999) point to price stickiness as one of several potential reasons for this stylized fact.

[2] Campbell and Hopenhayn (2005) document a negative correlation between markups and entry in many sectors of the US economy. Introducing entry improves the capacity of real business cycle models to match the cyclical properties of markups. This has been shown in a model with sunk-cost-driven entry by Bilbiie et al. (2012) and in a frictionless entry model, with zero profits each period, by Cook (2001).

[3] A notable exception is Cecioni (2010), who uses single-equation estimation methods to show that a rise in the number of firms significantly lowers US inflation.

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The competition effect thus introduces fluctuations in desired markups which are positively related to inflation. Combined with procyclical entry, this effect makes markups (more) countercyclical.

Our DSGE models both incorporate the competition effect, but differ in the way preferences and industry structures are specified. The first model features translog preferences as in Feenstra (2003), where increased entry raises the substitutability between *goods*. In this model, the competition effect is demand-driven. The second model assumes strategic interactions between oligopolists, where increased entry lowers the price setting power of *firms*. In that model, the competition effect is supply-driven. We refer to the first model as 'translog model' and to the second as 'SI model'. Another important model feature is 'love of variety'. By enlarging the range of available goods, entry raises utility. More product variety implies that a given dollar buys more consumption utility and the welfare-based price index falls.[4] In the translog model, love of variety is equal to half the net price markup in steady state. In the SI model, we impose constant elasticity of substitution (CES) preferences where the love of variety parameter is separated from the elasticity of substitution between goods (see Bénassy, 1996, and the working paper version of Dixit and Stiglitz, 1977).

We estimate the parameters of the translog and SI models by matching selected impulse responses to a monetary policy shock obtained from a structural vector autoregression (VAR) model. Our VAR includes US data on net business formation, markups and profits in addition to a set of standard macroeconomic variables. Our findings can be summarized as follows. In the translog model, we uncover a significant impact of entry on the dynamics of markups and inflation through the competition effect. In contrast, the competition effect is insignificant in the SI model. As a result, the translog model generates more markup countercyclicality than the SI model. Even though profits play a prominent role for entry dynamics, both models fall short of replicating the large drop in profits following a monetary contraction. The inability to match profits is a well-known shortcoming of fixed-variety models and remains a challenge in the endogenous-entry framework.

We analyze in more detail the estimation results in the SI model. First, we show that the parameter restrictions in that model imply a small competition effect for reasonable calibrations of the deep parameters. Second, we investigate the identifiability of the love of variety parameter and find evidence of partial identification problems. Third, we demonstrate that the SI model is observationally equivalent to the Dixit and Stiglitz (1977) monopolistic competition model ('DS model'), where the competition effect is nil and love of variety equals the net steady state markup. Finally, we perform a model comparison exercise and show that the translog model is at least as accurate as the SI–DS model in describing the dynamic responses to a monetary policy shock.

The main contribution of this paper is to compare the ability of two endogenous-entry models to generate countercyclical markups through the competition effect. We are the first to provide a structural estimate of the competition effect in the transmission of monetary policy shocks.

The paper is structured as follows. In Section 2, we estimate the VAR model. Section 3 lays out two DSGE models in linearized form, while Section 4 explains the minimum distance estimation procedure and presents our results. Section 5 contains a number of robustness exercises. Section 6 concludes.

2. VAR evidence

We estimate a VAR(2)-model on log real GDP, log real consumption, wage inflation, price inflation, log net business formation, log real profits, log markups, commodity price inflation and the nominal interest rate. All variables are linearly detrended. The data sources are listed in Table 1.

We use US quarterly data over the period 1954Q4–1995Q2. The sample is not updated due to a lack of more recent data on net business formation. Our model-consistent markup measure is inversely related to the labor share and corrects for overhead labor, as explained in Section 3. Including commodity prices should help to mitigate the price puzzle by which inflation rises at first after a monetary contraction. By our recursive identification strategy, all variables except the interest rate are included in the information set of the monetary authority and react to a monetary policy shock with a one-period lag.

Fig. 1 exhibits the estimated impulse response functions (IRFs) to a contractionary one-standard-deviation monetary policy shock. The dynamics of the standard variables are consistent with Christiano et al. (2005). In line with Bergin and Corsetti (2008) and Lewis (2009), the response of net business formation is procyclical and greater than that of output and consumption. Real profits feature a downward hump-shaped pattern that is significant over four quarters. The response of markups is procyclical on impact and countercyclical at medium horizons.[5]

3. Two models

We present two DSGE models featuring endogenous entry of firms and goods subject to a fixed labor requirement, a constant firm exit rate, and sticky prices as in Bilbiie et al. (2012), BGM hereafter. Several empirically motivated frictions

[4] Broda and Weinstein (2010) show that product turnover gives rise to a significant cyclical bias in the US price index when consumers have love of variety.

[5] This result contrasts with Nekarda and Ramey (2010) who report a procyclical markup response. Their measure of the labor share differs from our (model-based) measure.

Table 1
Data.

(1): Gross Domestic Product	BEA
(2): Personal Consumption Expenditures: Services	BEA
(3): Personal Consumption Expenditures: Nondurable Goods	BEA
(4): Personal Consumption Expenditures	BEA
(5): Fixed Private Investment	BEA
(6): Government Cons. Expenditures & Gross Investment	BEA
(7): Corporate Profits after Taxes, IVA and CCAdj	BEA
(8): Compensation of Employees, Paid	BEA
(9): Gross Domestic Product: Implicit Price Deflator	BEA
(10): Consumer Price Index, all items	BLS
(11): Producer Price Index, finished goods	BLS
(12): Effective Federal Funds Rate	FRB
(13): Compensation Per Hour, nonfarm business sector	BLS
(14): All Employees: total nonfarm	BLS
(15): Average weekly hours of production workers	BLS
(16): Net Business Formation index	BEA SCB
(17): CRB Raw Industrials Sub-Index	Bridge CRB

Data sources: BEA: Bureau of Economic Analysis. BLS: Bureau of Labor Statistics. FRB: Federal Reserve Board. SCB: Survey of Current Business. Bridge CRB: Bridge Commodity Research Bureau. *Data series*: Real GDP is (1)/(9). Real consumption is (2+3)/(9). Real physical capital investment is (5)/(9). Real profits are (7)/(9). Wage inflation is the quarter-on-quarter growth rate of (13). Price inflation is the quarter-on-quarter growth rate of (9). Entry is (16). Commodity price inflation is the quarter-on-quarter growth rate of (17). The nominal interest rate is (12) at a quarterly rate. The markup is computed from Eq. (11) in the baseline model and from Eq. (31) in the model with capital. Total hours L_t are average weekly hours (14), multiplied by the number of employees (15), multiplied by 12 (number of weeks in a quarter). Entry $N_{E,t}$ is (16), which has been rescaled to be expressed in thousands as L_t, see Appendix B for details. The labor share in total goods output s_t^L is (8)/(4+6) in the baseline model and (8)/(4+5+6) in the model with capital. We set the borrowing cost $R_{w,t}$ to (12), which corresponds to a full cost channel ($\omega = 1$).

are added: external habit formation in consumption, sticky wages, price and wage indexation, a cost channel and an endogenous failure rate of entrants.

One may think of entry as product or firm creation; the theoretical literature often uses the two terms interchangeably. Our first model features translog consumption preferences and a demand-driven competition effect through *product* entry. Our second model assumes CES preferences and a supply-driven competition effect through *firm* entry.

We consider a symmetric equilibrium with identical households and firms. The timing of events is consistent with the recursive VAR identification scheme. The optimization decisions of households and firms are made before the realization of the monetary policy shock, except household decisions concerning assets.[6] Below, we lay out the model equations in linearized form.[7] A hatted variable denotes its deviation from the deterministic steady state. A variable that has neither a hat nor a time subscript denotes its steady state level.

3.1. Translog preferences and demand-driven competition effect ('translog model')

BGM (2012) argue that product turnover is more important than firm turnover for business cycle dynamics. First, firms that enter and exit are typically small, such that their impact on industry-wide markups may be limited. Second, product additions of existing firms matter more for output fluctuations than product innovations of entirely new firms. For these reasons, BGM (2012) propose a model with translog consumption preferences where demand elasticities depend on product diversity. Intuitively, a larger number of differentiated goods makes it easier to substitute among them as the product space becomes more crowded.

Under a preference structure as in Feenstra (2003), the price-elasticity of demand is increasing in the mass of differentiated goods N_t,

$$\varepsilon_t(N_t) = 1 + \gamma N_t, \tag{1}$$

where $\gamma > 0$ measures the price-elasticity of the spending share on an individual good.[8] In contrast with the standard New Keynesian model, the desired markup here is time-varying, $\mu_t^d = \varepsilon_t(N_t)/(\varepsilon_t(N_t) - 1)$. In linearized form, the desired markup is

$$\hat{\mu}_t^d = -\eta \hat{N}_t, \quad \text{where } \eta = \frac{1}{1+\gamma N}. \tag{2}$$

[6] All variables in t (except the interest rate) are chosen on the basis of information in $t-1$, including forward variables $E_t\{x_{t+1}\}$, where $E_t\{\cdot\}$ is the expectation operator conditional on information in t.

[7] A model appendix with the full derivation (Appendix A) and a results appendix with robustness checks (Appendix B) are available online.

[8] All elasticities have been multiplied by -1.

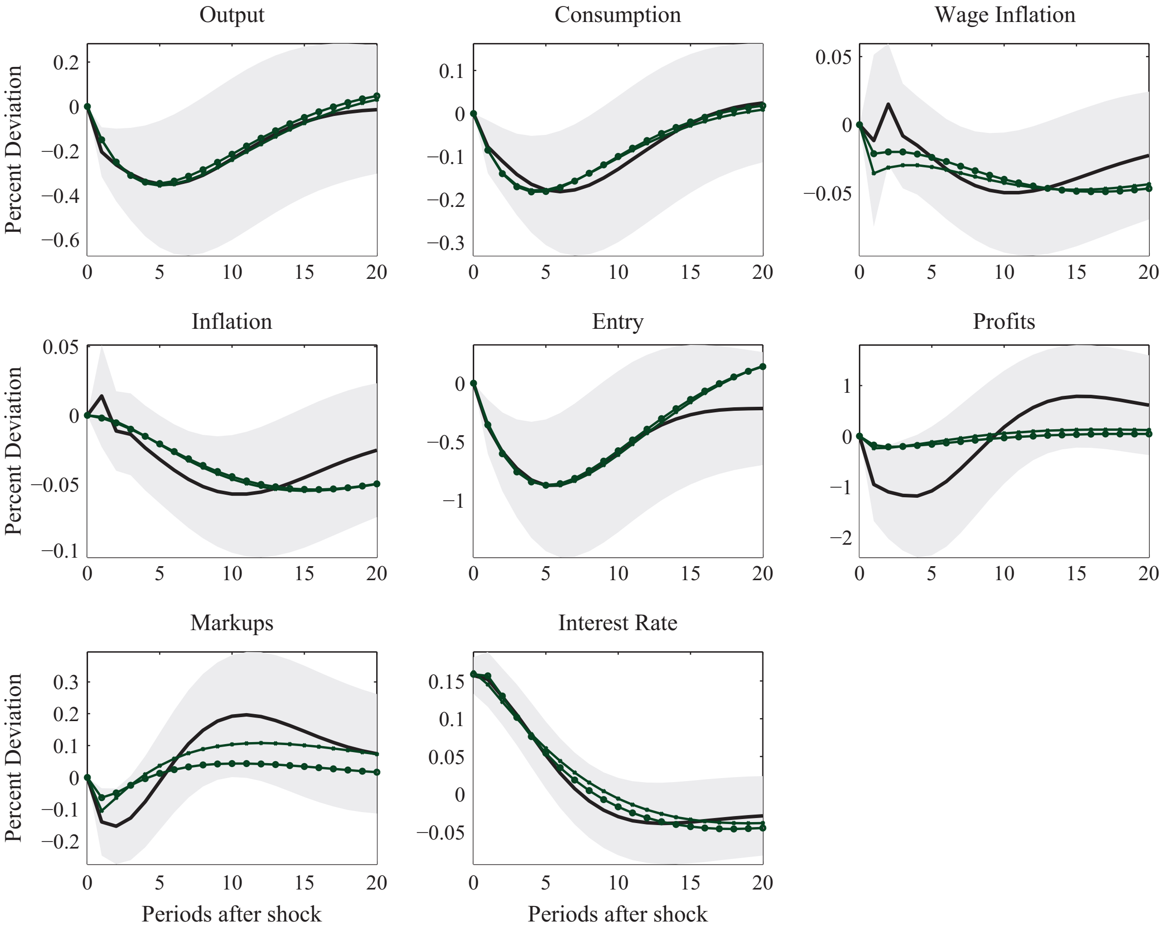

Fig. 1. Impulse responses to a monetary policy shock: benchmark models. Solid lines: VAR-based impulse response functions (IRFs). VAR identified recursively with interest rate ordered last. All impulse responses have been multiplied by 100. Gray areas correspond to 95% confidence intervals. Lines with circles: model-based IRFs in SI model. Lines with crosses: model-based IRFs in Translog model.

The elasticity of the desired markup to the mass of goods η captures the 'competition effect'. It equals the inverse steady state demand elasticity, $\eta = 1/\varepsilon$, and is decreasing in the price-elasticity of the spending share γ. Suppose that the spending share is not very elastic, γ is small. Products are not very substitutable and the demand elasticity is small, see (1). In this case, a product introduction raises the substitutability between goods by a large amount and the desired markup falls by a large amount. Thus, the competition effect is large, see (2).

Let the nominal price of an intermediate goods be denoted by p_t, and let P_t denote the welfare-based price index. The real product price $\rho_t \equiv p_t/P_t$ is related to the number of products through $\rho_t(N_t) = \exp(-\frac{1}{2}(\tilde{N} - N_t)/\gamma\tilde{N}N_t)$, where $\tilde{N} > N_t$ is the (constant) mass of all conceivable goods. In linearized form, this is

$$\hat{\rho}_t = v\hat{N}_t, \quad \text{where } v = \frac{1}{2\gamma N}. \tag{3}$$

The elasticity of the real product price to the mass of goods is $v \geq 0$. This parameter captures 'love of variety' defined as the increase in utility from spreading a certain amount of consumption over a greater number of differentiated products. A rise in product diversity raises consumption utility more than proportionately, resulting in a fall in the welfare-based price index. Love of variety is strong if the spending share is inelastic (γ is small). Since substitutability between goods is low in this case, an additional variety adds a large amount of consumption utility, see (3).

3.2. CES preferences and supply-driven competition effect ('SI model')

The second model interprets entry as business formation and considers competition between firms rather than goods. The model has a two-layer production structure as in Devereux and Lee (2001) and Floetotto and Jaimovich (2008). There is a fixed range of industries indexed by $i \in [0,1]$. Within each industry, there is a mass N_t of intermediate goods producers indexed by $f \in [0,N_t]$. An industry good bundles intermediate goods according to a CES aggregator with elasticity $\theta_f > 1$.

The final good is a CES composite of the industry goods with elasticity $\theta_i > 1$. The market structure is one of Bertrand competition with strategic interactions. Each firm takes into account the effect of its pricing decision on the industry price, taking as given the prices of other firms in the industry and the price levels of other industries. The price-elasticity of demand is

$$\varepsilon_t(N_t) = \theta_f - (\theta_f - \theta_i)\frac{1}{N_t}. \tag{4}$$

Broda and Weinstein (2006) present empirical evidence that goods are more substitutable within an industry than across industries, $\theta_f > \theta_i$. In this case, the firms' price setting power is eroded by the arrival of new entrants and the demand elasticity increases. The desired markup is decreasing in the mass of firms,

$$\hat{\mu}_t^d = -\eta \hat{N}_t, \quad \text{where } \eta = \frac{(\theta_f - \theta_i)\frac{1}{N}}{[\theta_f - (\theta_f - \theta_i)\frac{1}{N} - 1][\theta_f - (\theta_f - \theta_i)\frac{1}{N}]}. \tag{5}$$

The competition effect depends positively on the within-industry substitution elasticity θ_f (relative to the substitution elasticity across industries, θ_i). Suppose that goods are not very substitutable, θ_f is small. Each producer has a large share of the industry and a lot of monopoly power within an industry, i.e. the demand elasticity is small, see (4). In this case, market shares and hence desired markups do not change much in response to firm entry. Thus, the competition effect is small, see (5). If goods are as substitutable within as across industries ($\theta_f = \theta_i$), firm entry has no effect on desired markups and the competition effect is zero ($\eta = 0$), as in the monopolistic competition model of Dixit and Stiglitz (1977).

As in Bénassy (1996), we separate love of variety from the elasticity of substitution between goods.[9] The real product price is

$$\hat{\rho}_t = v\hat{N}_t, \quad \text{where :} \begin{cases} \text{(a) } v \text{ unrestricted} \\ \text{(b) } v = \dfrac{1}{\theta_f - 1} \end{cases}. \tag{6}$$

In our benchmark model, the love of variety parameter v is unrestricted. We also consider the Dixit–Stiglitz preference structure, where love of variety is linked to the elasticity of substitution among differentiated goods, $v = 1/(\theta_f - 1)$.

3.3. Common model features

Differentiated intermediate goods and new firms $\hat{N}_{E,t}$ are produced using a linear technology, with labor as the only input. The aggregate production functions in the two sectors are, respectively,

$$\hat{y}_t + \hat{N}_t = \hat{L}_{C,t} \quad \text{and} \quad \hat{N}_{E,t} = \hat{L}_{E,t}. \tag{7}$$

The variable $\hat{y}_t$ is output per firm, $\hat{L}_{C,t}$ are hours worked in the sector producing goods and $\hat{L}_{E,t}$ are hours worked in the sector producing firms. Real marginal costs are $\widehat{mc}_t = \hat{w}_t + \hat{R}_{w,t}$, where $\hat{w}_t$ is the real wage. Because a fraction $\omega \in (0,1)$ of the wage costs must be paid ahead of production, marginal costs include the interest rate

$$\hat{R}_{w,t} = \frac{\omega R}{\omega R + (1-\omega)}\hat{R}_t, \tag{8}$$

where $\hat{R}_t$ is the gross rate of return on riskfree nominal bonds. This specification of the cost channel follows Christiano et al. (2010). Total output of goods is obtained by aggregating firm output levels, $\hat{Y}_t^C = \hat{\rho}_t + \hat{y}_t + \hat{N}_t$. Total goods output equals private consumption, $\hat{Y}_t^C = \hat{C}_t$, since there is neither government spending nor a foreign sector in the model. Aggregate profits depend positively on the actual markup $\hat{\mu}_t$ and on total goods output,

$$\hat{D}_t = (\varepsilon - 1)\hat{\mu}_t + \hat{Y}_t^C. \tag{9}$$

The pricing decision of intermediate goods producers implies $\hat{\rho}_t = \hat{\mu}_t + \widehat{mc}_t$. The variety effect inherent in ρ_t drives a wedge between the markup and real marginal costs. As in Rotemberg (1982), we assume that price changes are subject to an adjustment cost proportional to real firm revenues. Price adjustment costs are captured by the parameter $\kappa_p > 0$.[10] We introduce indexation to past inflation as in Ireland (2007). The price adjustment cost is a function of the firm's price change relative to $\Pi_{p,t-1}^{\lambda_p}$, where $\Pi_{p,t} \equiv p_t/p_{t-1}$ is product price inflation and $\lambda_p \in (0,1)$ is the degree of indexation. With steady state inflation equal to zero, inflation dynamics obey the following New Keynesian Phillips Curve (NKPC)

$$\hat{\Pi}_{p,t} - \lambda_p \hat{\Pi}_{p,t-1} = \phi_p(\hat{\mu}_t^d - \hat{\mu}_t) + \beta(1-\delta_N)\mathrm{E}_t\{\hat{\Pi}_{p,t+1} - \lambda_p \hat{\Pi}_{p,t}\}, \tag{10}$$

where $\phi_p = (\varepsilon - 1)/\kappa_p$ and the discount rate $\beta(1-\delta_N)$ is the product of the households' subjective discount factor $\beta \in (0,1)$ and the firms' exogenous survival rate $(1-\delta_N)$, with $\delta_N \in (0,1)$. Through the competition effect, inflation fluctuates

[9] The preference structure proposed by Bénassy (1996) had previously been explored in the working paper version of Dixit and Stiglitz (1977).

[10] For simplicity, we assume that entrants, too, face price adjustment costs. BGM (2007) shows that the impulse responses to shocks change negligibly under the alternative assumption that entrants can change their price costlessly.

inversely with entry. Desired markups depend negatively on the number of competing goods (2) or rather, competing firms (5). Lower desired markups reduce inflation through the NKPC (10).

The actual markup is inversely related to the labor share s_t^L and the firms' borrowing cost, and it corrects for overhead labor, interpreted here as the share of labor employed in startup activities. Setting startup labor equal to the number of entrants, we obtain

$$\mu_t = \frac{1}{(1-N_{E,t}/L_t)s_t^L R_{w,t}}, \tag{11}$$

where the labor share is the total wage bill over total goods output, $s_t^L = (w_t L_t / Y_t^C)$.

Households maximize expected lifetime utility. Period utility is increasing and concave in consumption with $\sigma_C \geq 1$ denoting risk aversion. Consumption displays external habit persistence $b \in (0,1)$, such that marginal consumption utility is $\hat{U}_{C,t} = -\sigma_C/(1-b)(\hat{C}_t - b\hat{C}_{t-1})$. Utility is decreasing and convex in hours worked L_t, such that marginal labor disutility is $\hat{U}_{L,t} = \sigma_L \hat{L}_t$, where $\sigma_L \geq 0$ is the inverse elasticity of labor supply to the real wage. The household budget constraint is

$$w_t L_t + RA_t = C_t + WAC_t + A_t. \tag{12}$$

Expenditure includes consumption C_t, wage adjustment costs WAC_t, and asset purchases

$$A_t = \frac{B_t}{P_t} + w_t N_{E,t} + \nu_t \mathcal{E}_t. \tag{13}$$

Income includes labor income $w_t L_t$ and the return on assets,

$$RA_t = \frac{R_{t-1}B_{t-1}}{P_t} + (1-\delta_N)(d_t + \nu_t)(\mathcal{E}_{t-1} + S_{t-1}N_{E,t-1}). \tag{14}$$

Households hold three types of assets. First, they buy riskfree nominal one-period bonds B_t at the price of one dollar per bond, which pay a gross return R_t in the next period. The first order condition for bonds is

$$\hat{U}_{C,t} = \hat{R}_t + E_t\{-\hat{\Pi}_{p,t+1}^C + \hat{U}_{C,t+1}\}, \tag{15}$$

where $\hat{\Pi}_{p,t}^C \equiv P_t/P_{t-1}$ is welfare-based inflation. Second, households buy equity $\mathcal{E}_t$ at price ν_t, which they sell one period later. The return on equity includes firm profits d_t, paid out as dividends, and the capital gain realized in the next period, discounted appropriately, such that the optimality condition on equity is

$$\hat{\nu}_t = E_t\{\hat{U}_{C,t+1} - \hat{U}_{C,t} + [1-\beta(1-\delta_N)]\hat{d}_{t+1} + \beta(1-\delta_N)\hat{\nu}_{t+1}\}. \tag{16}$$

Third, households decide on the number of startups and spend $w_t N_{E,t}$ on entry costs, where they take the aggregate real wage w_t as given. Startups financed one period ago, $N_{E,t-1}$, survive to period t with probability S_{t-1} as described below. Of those, a constant fraction δ_N exit; the remaining ones produce and earn profits. Likewise, incumbents exit with a constant probability δ_N, such that the dividend on equity holdings $\mathcal{E}_{t-1}$ is $(1-\delta_N)d_t$. The value of equity and entrants is therefore $(1-\delta_N)\nu_t$ at the end of period t.

In Beaudry et al. (2011), an exogenous expansion of product varieties leads to an inefficient scramble of startups, some of which fail. Following this idea, we assume that only a fraction S_t of startups becomes operational one period later. This success probability is specified as

$$S_t(N_{E,t}, N_{E,t-1}) = 1 - F_{N,t}\left(\frac{N_{E,t}}{N_{E,t-1}}\right), \tag{17}$$

where $F_N(1) = F_N'(1) = 0$ and $F_N''(1) = \varphi_N > 0$. Thus, the startup failure rate $F_{N,t}(\cdot)$ is an increasing function of the change in entry. It can be interpreted as a flow adjustment cost to extensive margin investment akin to the physical capital investment adjustment cost in Christiano et al. (2005). Mata and Portugal (1994) document that failures of new firms are positively related to entry rates. As in Lewis (2009), this specification allows us to capture the gradual response of entry to shocks. The free entry condition equates the entry cost w_t and the expected value of setting up a firm,

$$w_t = \nu_t S_t + \nu_t S_{1t} N_{E,t} + \beta E_t\left\{\frac{U_{C,t+1}}{U_{C,t}} \nu_{t+1} S_{2t+1} N_{E,t+1}\right\}, \tag{18}$$

where S_{it} is the first derivative of the success rate with respect to its ith argument. The expected value of setting up a firm has three components. Firm value ν_t is multiplied by S_t, the startup success rate. The success rate is in turn negatively related to the change in the number of entrants. A rise in $N_{E,t}$ decreases S_t and increases the future success rate S_{t+1}, ceteris paribus. In linearized form, the change in the number of entrants depends positively on its expected future value and on firm value less the entry cost,

$$\hat{N}_{E,t} - \hat{N}_{E,t-1} = \frac{1}{\varphi_N}(\hat{\nu}_t - \hat{w}_t) + \beta \mathrm{E}_t\{\hat{N}_{E,t+1} - \hat{N}_{E,t}\}. \tag{19}$$

If entrants face a success probability of 1, we obtain the static free entry condition in BGM (2012), where firm value equals the entry cost, $\hat{\nu}_t = \hat{w}_t$. The stock of firms evolves according to the law of motion

$$\hat{N}_{t+1} = (1-\delta_N)\hat{N}_t + \delta_N \hat{N}_{E,t}. \tag{20}$$

We introduce differentiated labor types that are bundled according to a CES aggregator with elasticity $\theta_w > 1$. Quadratic wage adjustment costs (captured by $\kappa_w > 0$) and indexation (captured by $\lambda_w \in (0,1)$) are introduced, such that wage setting frictions are analogous to price setting frictions. Wage inflation $\hat{\Pi}_{w,t}$ depends positively on its expected future value and on the difference between the marginal rate of substitution between labor and consumption and the real wage. With indexation, wage inflation also depends on current and lagged price inflation,

$$\hat{\Pi}_{w,t} - \lambda_w \hat{\Pi}_{p,t-1} = \phi_w[(\hat{U}_{L,t} - \hat{U}_{C,t}) - \hat{w}_t] + \beta E_t\{\hat{\Pi}_{w,t+1} - \lambda_w \hat{\Pi}_{p,t}\}, \tag{21}$$

where $\phi_w = ((\theta_w - 1)/\kappa_w)s^L$. In equilibrium, total labor supply is the sum of labor used in the production of goods and labor used in the production of new firms, weighted by their respective steady state shares, $\hat{L}_t = (L_C/L)\hat{L}_{C,t} + (L_E/L)\hat{L}_{E,t}$. Letting Y_t denote total output, the aggregate accounting identity reads

$$\frac{Y^C}{Y}\hat{Y}_t^C + \frac{\nu N_E}{Y}(\hat{w}_t + \hat{N}_{E,t}) = \frac{dN}{Y}(\hat{d}_t + \hat{N}_t) + \frac{wL}{Y}(\hat{w}_t + \hat{L}_t). \tag{22}$$

Total expenditure comprises aggregate consumption and investment in new firms. Total income is the sum of dividend income and labor income.

The central bank adjusts the interest rate in response to inflation and last period's interest rate. The feedback coefficients are τ_Π and τ_R, such that

$$\hat{R}_t = (1-\tau_R)\tau_\Pi \hat{\Pi}_{p,t} + \tau_R \hat{R}_{t-1} + \varsigma_t, \tag{23}$$

where ς_t is a first-order autoregressive monetary policy shock with persistence ρ_ς and standard error σ_ς. We assume that monetary policy stabilizes product prices rather than the welfare-based price index. The latter is typically not observed. Moreover, BGM (2007) and Bergin and Corsetti (2008) show that this is optimal in the presence of appropriate corrective fiscal policies.

4. Estimation

The welfare-based price index, which takes love of variety into account, is unobserved in the data. Measured price indexes are based on consumption baskets that are infrequently updated and do not quickly take into account the introduction of new goods. Consequently, we posit that measured inflation corresponds to the variable $\hat{\Pi}_{p,t}$. In the model, real variables are deflated by the welfare-based price index P_t. To obtain data-consistent model variables that are deflated by p_t, we divide each real variable by the real product price ρ_t. Defining the generic data-consistent variable $\hat{z}_t^R = \hat{z}_t - \hat{\rho}_t$, the model variables that correspond to the series used in our VAR are $\hat{Y}_t^R$, $\hat{C}_t^R$, $\hat{\Pi}_{w,t}$, $\hat{\Pi}_{p,t}$, $\hat{N}_{E,t}$, $\hat{D}_t^R$, $\hat{\mu}_t$, and $\hat{R}_t$. The transformed model is given in Table 2.

In the following, we estimate the two DSGE models by matching the VAR impulse responses to a monetary policy shock in Fig. 1. First, we outline the minimum distance estimation technique. Second, we discuss our estimation results. Third, we take a closer look at the results in the SI model. Finally, we perform a model comparison exercise.

Table 2
Transformed model.

$$\hat{\mu}_t = -\hat{w}_t^R - \frac{\omega}{\omega + (1-\omega)\beta}\hat{R}_t$$
$$\hat{\Pi}_{p,t} - \lambda_p \hat{\Pi}_{p,t-1} = \phi_p(-\eta \hat{N}_t - \hat{\mu}_t) + \beta(1-\delta_N)\mathrm{E}_t\{\hat{\Pi}_{p,t+1} - \lambda_p \hat{\Pi}_{p,t}\}$$
$$\hat{D}_t^R = (\varepsilon - 1)\hat{\mu}_t + \hat{C}_t^R$$
$$0 = \hat{R}_t + E_t\{-\hat{\Pi}_{p,t+1} - \frac{\sigma_C}{1-b}(\Delta\hat{C}_{t+1}^R - b\Delta\hat{C}_t^R)\} + \nu x_{1t}$$
$$\hat{v}_t^R = E_t\left\{-\frac{\sigma_C}{1-b}(\Delta\hat{C}_{t+1}^R - b\Delta\hat{C}_t^R) + [1-\beta(1-\delta_N)](\hat{D}_{t+1}^R - \hat{N}_{t+1}) + \beta(1-\delta_N)\hat{v}_{t+1}^R\right\} + \nu x_{1t}$$
$$\hat{N}_{E,t} - \hat{N}_{E,t-1} = \frac{1}{\varphi_N}(\hat{v}_t^R - \hat{w}_t^R) + \beta E_t\{\hat{N}_{E,t+1} - \hat{N}_{E,t}\}$$
$$\hat{\Pi}_{w,t} - \lambda_w \hat{\Pi}_{p,t-1} = \phi_w\left[-\sigma_L \hat{L}_t - \frac{\sigma_C}{1-b}(\hat{C}_t^R - b\hat{C}_{t-1}^R) - \hat{w}_t^R\right] + \beta E_t\{\hat{\Pi}_{w,t+1} - \lambda_w \hat{\Pi}_{p,t}\} + \nu x_{2t}$$
$$\hat{N}_{t+1} = (1-\delta_N)\hat{N}_t + \delta_N \hat{N}_{E,t}$$
$$\hat{Y}_t^R = \frac{C}{Y}\hat{C}_t^R + \frac{\nu N_E}{Y}(\hat{w}_t^R + \hat{N}_{E,t})$$
$$\hat{Y}_t^R = \frac{dN}{Y}\hat{D}_t^R + \frac{wL}{Y}(\hat{w}_t^R + \hat{L}_t)$$
$$\hat{R}_t = (1-\tau_R)\tau_\Pi \hat{\Pi}_{p,t} + \tau_R \hat{R}_{t-1} + \varsigma_t$$
$$\hat{\Pi}_{p,t} = \hat{\Pi}_{w,t} - \Delta\hat{w}_t^R$$

where

$$x_{1t} = -\frac{\sigma_C}{1-b}E_t\{\Delta\hat{N}_{t+1} - b\Delta\hat{N}_t\} + E_t\{\Delta\hat{N}_{t+1}\}$$
$$x_{2t} = \phi_w\left[\frac{\sigma_C}{1-b}(\hat{N}_t - b\hat{N}_{t-1}) - \hat{N}_t\right]$$

Table 3
Parameter restrictions.

	Translog model	SI model
Demand elasticity	$\varepsilon = 1+\gamma N$	$\varepsilon = \theta_f-(\theta_f-\theta_i)\frac{1}{N}$
Competition effect	$\eta = \frac{1}{1+\gamma N}$	$\eta = \frac{(\theta_f-\theta_i)\frac{1}{N}}{\left[\theta_f-(\theta_f-\theta_i)\frac{1}{N}-1\right]\left[\theta_f-(\theta_f-\theta_i)\frac{1}{N}\right]}$
Love of variety	$v = \frac{1}{2\gamma N}$	(a) v unrestricted, (b) $v = \frac{1}{\theta_f-1}$
Slope of NKPC	$\phi_p = \frac{\gamma N}{\kappa_p}$	$\phi_p = \frac{\theta_f-(\theta_f-\theta_i)\frac{1}{N}-1}{\kappa_p}$
Number of goods/firms	$N = \frac{\zeta}{1+\frac{\delta_N\zeta}{1-\delta_N}}$	$N = \frac{\zeta}{1+\frac{\delta_N\zeta}{1-\delta_N}}$

Note that $\zeta = (1/(\varepsilon-1))\beta(1-\delta_N)/(1-\beta(1-\delta_N))[\omega/\beta+(1-\omega)]$. We impose the additional restriction that N is equal across models.

4.1. Minimum distance estimation

We fix the parameters β, σ_L, λ_p, λ_w, κ_p and δ_N. The subjective discount factor is set to $\beta = 0.99$, implying a steady state real interest rate of 4% per annum. Following Christiano et al. (2005), we assume a quadratic labor disutility function, $\sigma_L = 1$, and we impose full indexation of prices and wages, $\lambda_p = \lambda_w = 1$. The slope of the New Keynesian Phillips Curve ϕ_p contains the price-elasticity of demand ε and the price stickiness parameter κ_p. The demand elasticity is intimately related to the competition effect, which is our main object of interest. Thus, while it is common to fix the demand elasticity and estimate the degree of price stickiness, we do the opposite here, setting $\kappa_p = 77$ as in BGM (2007).[11] Following BGM (2012), the firm exit rate δ_N is set to 0.025, so as to fit the annual job destruction rate of 10% in the US.

Of the remaining parameters, some are freely estimated, while others are subject to steady state restrictions. Table 3 presents the parameter restrictions imposed in the two models.

The parameters are partitioned as $\psi_i = (\iota, \varkappa_i)$, where $i \in \{T, SI\}$ indexes the model. The vector

$$\iota = (\sigma_\varsigma, \rho_\varsigma, \tau_R, \tau_\Pi, \sigma_C, b, \omega, \phi_w, \varphi_N) \tag{24}$$

is common across models and $\varkappa_i$ contains the model-specific parameters. In particular,

$$\varkappa_T = (\gamma, \varepsilon, \eta, v, \phi_p, N) \quad \text{and} \quad \varkappa_{SI} = (\theta_i, \theta_f, \varepsilon, \eta, v, \phi_p, N). \tag{25}$$

In the translog model, the deep parameter is the price-elasticity of the spending share γ. In the SI model, the deep parameters are love of variety v and the substitution elasticities θ_i and θ_f. Those are the parameters that we estimate. The other parameters in $\varkappa_T$ and in $\varkappa_{SI}$ must satisfy the restrictions in Table 3. In addition to these model-specific restrictions, we constrain the steady state number of products N, which is a data-driven object, to be equal across models. We first estimate the translog model to find N^T and then impose the restriction $N^{SI} = N^T$ in the SI model. In practice, in the estimation of the SI model, θ_i, θ_f and ω adjust to satisfy the constraint.[12] Let the vectors $\hat{\Phi}$ and $\Phi(\psi_i)$ denote the VAR-based and the model-based IRFs, respectively. Parameter estimates $\hat{\psi}_i$ fulfil

$$\hat{\psi}_i = \arg\min_{\psi_i \in \Psi_i} \mathcal{J}(\psi_i), \tag{26}$$

where the distance measure is

$$\mathcal{J}(\psi_i) = [\Phi^m(\psi_i)-\hat{\Phi}]'\hat{W}[\Phi^m(\psi_i)-\hat{\Phi}], \tag{27}$$

and $\hat{W}$ is a diagonal matrix with the inverse of the asymptotic variances of each element of $\hat{\Phi}$ along the diagonal. Following Christiano et al. (2005), the standard errors of the estimated parameters are obtained using the asymptotic delta function method applied to the first order condition associated with (26). Since the weighting matrix $\hat{W}$ is not optimal, the J-statistic (27) does not have a known distribution. Therefore, we resort to bootstrap techniques (Hall and Horowitz, 1996), adapted to minimum distance estimation of DSGE models by Fève et al. (2009), to reveal the distribution of the minimum distance $\mathcal{J}(\hat{\psi}_i)$. We generate 200 bootstrap replications of the VAR model. For each replication, we re-estimate the parameters of the DSGE models and compute the value of the minimum distance. The bootstrapped distribution of this distance allows us to test the null hypothesis H_0: $\mathcal{J}(\psi_i) = 0$. This methodology enables us to check whether the theoretical model passes the overidentification test implied by the choice of moments.

[11] Our results are robust to changes in the degree of price stickiness (see Appendix B).

[12] In Appendix B, we show that our results are unchanged if we impose the cross-model restriction using a joint estimation approach.

Table 4
Baseline estimation results.

		Translog model	SI model, (a) v unrestr.	SI model, (b) $v=1/(\theta_f-1)$
σ_ς	Standard error of shock	0.162 (0.012)	0.160 (0.012)	0.161 (0.012)
ρ_ς	Autocorrelation of shock	0.877 (0.047)	0.829 (0.049)	0.833 (0.049)
τ_R	Interest rate smoothing	0.046 (0.126)	0.180 (0.128)	0.170 (0.128)
τ_Π	Inflation coefficient	1.047 (0.258)	1.016 (0.148)	1.026 (0.161)
σ_C	Risk aversion	3.371 (0.682)	2.114 (6.857)	1.953 (1.019)
b	Habit persistence	0.780 (0.057)	0.839 (0.542)	0.851 (0.080)
ω	Cost channel	0.861 (0.213)	0.521 (0.184)	0.524 (0.186)
ϕ_p	Slope of price inflation curve	0.019[a] (0.003)	0.019[a] (0.006)	0.019[a] (0.006)
ϕ_w	Slope of wage inflation curve	0.005 (0.001)	0.003 (0.001)	0.003 (0.001)
φ_N	Adjustment cost (extensive margin)	9.435 (1.852)	8.213 (1.721)	8.311 (1.656)
γ	Price-elasticity of spending share	0.119 (0.063)	–	–
θ_f	Substitution elasticity within industries	–	2.624 (1.497)	2.623 (1.429)
θ_i	Substitution elasticity across industries	–	1.000 (7.460)	1.003 (7.030)
ε	Price-elasticity of demand	2.500[a] (0.237)	2.495[a] (0.457)	2.495[a] (0.446)
η	Competition effect	0.400[a] (0.038)	0.034[a] (0.087)	0.034[a] (0.082)
v	Love of variety	0.333[a] (0.053)	0.495 (4.195)	0.616[a] (0.271)
N	Number of goods/firms	12.629[a]	12.629[a]	12.629[a]
$\mathcal{J}$-statistic {p-value}		73.34 {0.208}	87.99 {0.118}	88.04 {0.107}

Baseline estimation results.
[a] Parameter is deduced from steady state restrictions as shown in Table 3. Numbers in round brackets are standard errors. Numbers in curly brackets are p-values of null hypothesis H_0: $\mathcal{J}=0$.

4.2. Results

Fig. 1 displays the IRFs predicted by the translog and SI models, together with the data responses. The performance of both models is satisfactory; the p-value in Table 4 indicates that the null hypothesis H_0: $\mathcal{J}(\psi_i)=0$ cannot be rejected in either model.

While the model fit is similar in the two cases, the translog model appears to match better the countercyclical markup dynamics at medium horizons. As in the no-entry model of Christiano et al. (2005), both models fail to reproduce the magnitude of the profit response. This confirms the profit volatility puzzle noted by Colciago and Etro (2010).

The two sets of parameter estimates are reported in Table 4. The hump-shaped response of entry can be replicated only with a large adjustment cost parameter: φ_N is greater than 8 in both models.

The deep parameter of the translog model, the price-elasticity of the spending share, is estimated at $\gamma=0.12$. In the SI model, the inter-industry substitution elasticity θ_i is close to its lower bound of 1, while the intra-industry substitution elasticity is also fairly low, $\theta_f=2.6$. These results determine the size of the demand elasticity, the competition effect and love of variety, to which we turn next.

The demand elasticity ε is close to 2.5 in both models, resulting in a NKPC slope of $\phi_p=0.019$. This result is explained by the small empirical response of the markup. Increasing ε raises the marginal cost pass-through ϕ_p, which implies from the NKPC (10) that markups must move more strongly for a given inflation response.[13] We offer two comments on this low demand elasticity. First, a high steady state markup is not unreasonable in a model with entry costs. This is because firms price at average cost (including entry costs), such that profits in excess of the entry costs are zero in the free-entry equilibrium. Second, in Smets and Wouters' (2007) model with fixed costs, the estimated steady state markup is 60%, consistent with a demand elasticity of 2.67. This value is close to our estimate.

We note that the models cannot simultaneously match both the markup and profit dynamics. More precisely, the small initial drop in markups is incompatible with the large decline in profits. By (9), profits depend positively on the markup response and on the demand elasticity, both of which are small. Therefore, while a low ε helps to fit markups, it also flattens the profit response.

In the translog model, the competition effect is significantly different from zero, $\eta=0.40$. This value implies that if the number of goods rises by 1%, desired markups decrease by 0.40%. Fig. 1 shows that the translog model goes some way in

[13] If we remove markups from the VAR, the demand elasticity estimate increases to $\varepsilon=5.33$ in both models. For more details, see Appendix B.

reproducing the countercyclical markup response at medium horizons. In contrast, the competition effect is insignificant in the SI model, such that firm entry does not generate countercyclical markups. The reason for this result is that the estimated elasticities across and within industries, θ_i and θ_f, are both small. The SI model, however, needs a large difference between these two elasticities in order to produce a competition effect. In Section 4.3, we show that *any* empirically plausible calibration of θ_i and θ_f implies a small value of η, given the parameter restrictions of the SI model.

Love of variety v is 0.33 in the translog model and 0.49 in the SI model. The estimate in the latter model has a very large standard error, which may indicate that this parameter is poorly identified.[14] In Section 4.3, we perform two exercises to detect potential identification problems. A rise in the number of goods and firms has a positive effect on consumer surplus, by increasing product diversity, and a negative effect on producer surplus, by decreasing profits. These two opposing effects on welfare cancel out in Dixit and Stiglitz (1977) monopolistic competition model, where love of variety v equals the net steady state markup $\mu-1$. If v is greater (smaller) than $\mu-1$, there is insufficient (excess) entry in equilibrium. This distortion can be removed with an appropriate fiscal or monetary policy.[15] In the translog model, love of variety equals half the net steady state markup. Therefore, there is excess entry, calling for entry taxes or long run inflation.

Regarding the standard parameters, our estimates are largely consistent with the literature, notably Christiano et al. (2005) and Smets and Wouters (2007). Several results are worth highlighting, though.

The estimates of the cost channel ω are 0.86 and 0.52 in the translog and SI model, respectively. In Fig. 1, we observe a procyclical markup response in the short run. This requires an increase in marginal costs in response to a monetary contraction, which is delivered through the cost channel as marginal costs rise along with borrowing costs. In the translog model, the cost channel must be higher to counteract the competition effect.

The slope of the wage inflation curve is small but significantly different from zero. In an estimated model without entry, the wage inflation curve becomes steeper and hence the implied Calvo wage stickiness parameter is lower.[16] As pointed out in Lewis (2009), wage stickiness is key for an endogenous-entry model to generate a negative, and hence empirically plausible, response of entry to monetary contractions.

Our estimate of risk aversion is $\sigma_C = 3.37$ in the translog model and $\sigma_C = 2.11$ in the SI model. The markup is more countercyclical in the translog model due to the competition effect. Real wages, which are inversely related to markups, therefore decrease more in the translog model. Since the real wage represents the price of leisure relative to consumption, this implies a larger drop in consumption for a given elasticity of intertemporal substitution. Put differently, for a given consumption response, intertemporal smoothing and therefore σ_C needs to be higher. Strikingly, the estimates of the utility parameters σ_C and b, risk aversion and habit formation, have much larger standard errors in the SI model than in the translog model. This uncertainty may reflect a partial identification problem in the SI model, to which we turn below.

4.3. A closer look at the SI model

In the SI model, the love of variety estimate is very imprecise, while the competition effect is nil. In this section, we analyze the reasons for these findings and discuss their implications. We first compute the implied competition effect for a range of plausible substitution elasticities within and across industries. Second, we carry out two diagnostic tests for identification proposed by Canova and Sala (2009). Third, we test the hypothesis that the SI model is observationally equivalent to Dixit and Stiglitz (1977) model.

We compute the competition effect η from (5), given reasonable ranges for the substitution elasticity within industries θ_f and across industries θ_i. Notice that the steady state number of firms is no longer constrained to match N in the translog model. Fig. 2 varies θ_f and θ_i between 1 and 4. Along the 45°-line, the substitution elasticities coincide and hence the competition effect is nil. We only consider values below the 45°-line as plausible; there, industry goods are less substitutable than intermediate goods within an industry and the competition effect is positive. As we move clockwise, the gap between the elasticities widens, such that the competition effect increases.

To calculate a probable value and an upper bound for the competition effect, we consult Broda and Weinstein (2006), who estimate the elasticity of substitution among goods at the sectoral level. Their median estimate of the substitution elasticity between 3-digit level goods (corresponding roughly to our θ_i) is 2.50 over the sample 1972–1988. At the most disaggregated level, their median substitution elasticity (our θ_f) is 3.7. The implied competition effect is small, $\eta = 0.016$. Broda and Weinstein (2006) highest estimate of θ_f is 17. Setting $\theta_i = 1$ and $\theta_f = 17$ therefore yields the highest plausible value for the competition effect, $\eta = 0.056$. Clearly, estimating η will not yield a large value given the restrictions of the SI model. For values of γ between 0.05 and 1 in the translog model, the range of the demand elasticity is 1.8–6 and the competition effect lies between 0.5 and 0.17. Thus, the translog model is a better candidate to generate a competition effect.

In the following, we analyze the identifiability of the love of variety parameter. Consider Table 2. The parameter appears in the first order conditions for equity, bonds, and wages. Since love of variety v appears in conjunction with risk aversion σ_C and habits b, it is questionable whether all three parameters can be identified separately. Log consumption

[14] This finding is robust to introducing trend inflation. See Appendix B.

[15] For details, see Bilbiie et al. (2008, 2011), Chugh and Ghironi (2011) and Lewis (in press).

[16] See Appendix B for details.

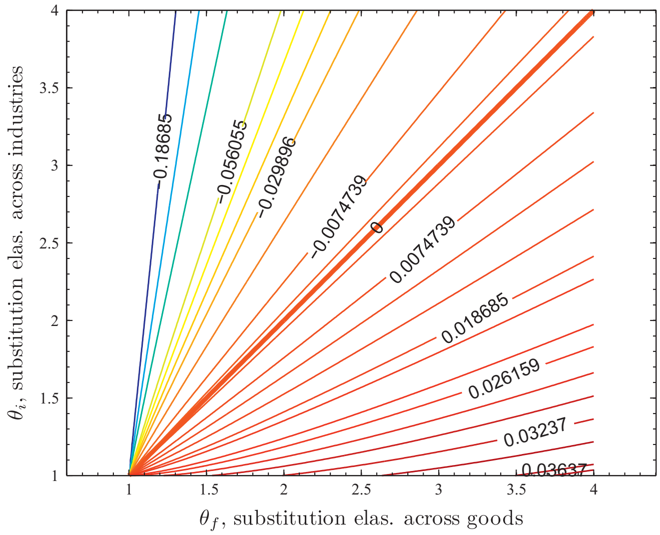

Fig. 2. Competition effect in SI model. Figure shows competition effect η in SI model for different values of inter-industry and intra-industry substitution elasticities, θ_i and θ_f. Discount factor and firm exit rate are set to calibrated values, $\delta_N = 0.025$ and $\beta = 0.99$. Cost channel is set to zero, $\omega = 0$. Assuming a higher value for $\omega \in (0,1)$ has only minor effect on η since for any ω, borrowing cost R_w is close to 1.

utility and no habits imply the love of variety parameter drops out from the model.[17] In the terminology of Canova and Sala (2009), this is a case of under-identification. In a first exercise, we investigate which values of v, σ_C and b deliver small changes in the *population* objective function computed as

$$\mathcal{J}^p = [\Phi^m(\hat{\psi}) - \Phi^b(\psi)]' I [\Phi^m(\hat{\psi}) - \Phi^b(\psi)], \tag{28}$$

where I is the identity matrix and $\Phi^m(\hat{\psi})$ are the model-based IRFs under the estimated parameter values displayed in Table 4, which we will refer to as ‘true’ values. The object $\Phi^b(\psi)$ are the model-based IRFs, where we draw 10,000 values of the three parameters v, σ_C and b from uniform distributions and the remaining parameters are set to their true values. The parameters measuring habit formation and love of variety are drawn from a standard uniform distribution; the unit interval is considered by Bilbiie et al. (2011) as a reasonable range for v. For the risk aversion parameter we consider the interval (0,10) as our admissible range. We construct the distribution of the distance function (28) and select those draws that fall into the lowest 0.1% of that distribution. In Table 5, we report the minimum, the maximum and the median values of v, σ_C and b of the selected draws, together with the true values.

The range between the minimum and the maximum is what Canova and Sala (2009) call the ‘weak identification region’ and describes those parameterizations that produce small deviations from the true model. For all three parameters, the weak identification region is large, covering almost the entire admissible range. This suggests that many parameter combinations are compatible with a small objective function. In particular, Dixit–Stiglitz calibration $v = 1/(\theta_f - 1) = 0.62$ is contained within the weak identification region.

We perform a second exercise to detect potential *sample* identification problems. We compute $n = 1000$ bootstrap replications of the VAR. For each replication, we re-estimate the parameters and construct their distribution across replications. Fig. 3 displays the distributions of selected parameters for the translog model (left panel) and the SI model (right panel).

A parameter is well identified if its distribution is bell-shaped, i.e. unimodal and tight around the mode. This is particularly true for the shock parameters σ_ς and ρ_ς, the adjustment cost φ_N, and to a lesser extent for the utility parameters σ_C and b.[18] In the SI model, the love of variety parameter, in contrast, does not have a well-behaved distribution. Almost half of the values are above 1 and therefore outside our admissible range. These results show that the love of variety estimate is likely to fall into a range that is much wider than what we consider plausible.

The distributions of σ_C and b are better behaved in the restricted SI model (imposing Dixit–Stiglitz preferences, $v = 1/(\theta_f - 1)$) than in the unrestricted model variant.[19] We carry out the same experiment for the translog model. The left panel of Fig. 3 shows that the distributions of γ, σ_C and b across bootstrap replications are single-peaked and tight around the mode, indicating that these parameters are reasonably well identified.

[17] In Table 2, we see that $x_{1t} = x_{2t} = 0$ if $\sigma_C = 1$ and $b = 0$.

[18] Fig. 3 also shows that in the case of τ_Π, a large probability mass is concentrated close to the lower bound of 1, which is imposed to ensure determinacy. This result is consistent with the estimates obtained in Table 4.

[19] Conversely, fixing the degree of risk aversion σ_C and leaving the love of variety unrestricted improves the identifiability of b and v. For $\sigma_C = 2$, the distribution of v has a peak at around 0.04.

Table 5
Weak identification regions.

	Range	'True' value	Minimum	Maximum	Median
Love of variety v	[0,1]	0.495	0.000	0.997	0.495
Risk aversion σ_C	[0,10]	2.114	0.003	9.998	4.972
Habit formation b	[0,1]	0.839	0.000	0.996	0.496

This exercise computes the weak identification regions as in Canova and Sala (2009) for the three utility parameters: love of variety v, risk aversion σ_C and habit formation b. We draw values for these parameters simultaneously from uniform distributions, the ranges of which are given in the second column. The other parameters are held fixed at their estimated ('true') values. We construct the distribution of the population distance function (28) across draws and select those draws for which the population J-statistic falls into the lowest 0.1 percentile. Of the selected draws, we report the minimum, maximum and median values of v, σ_C and b.

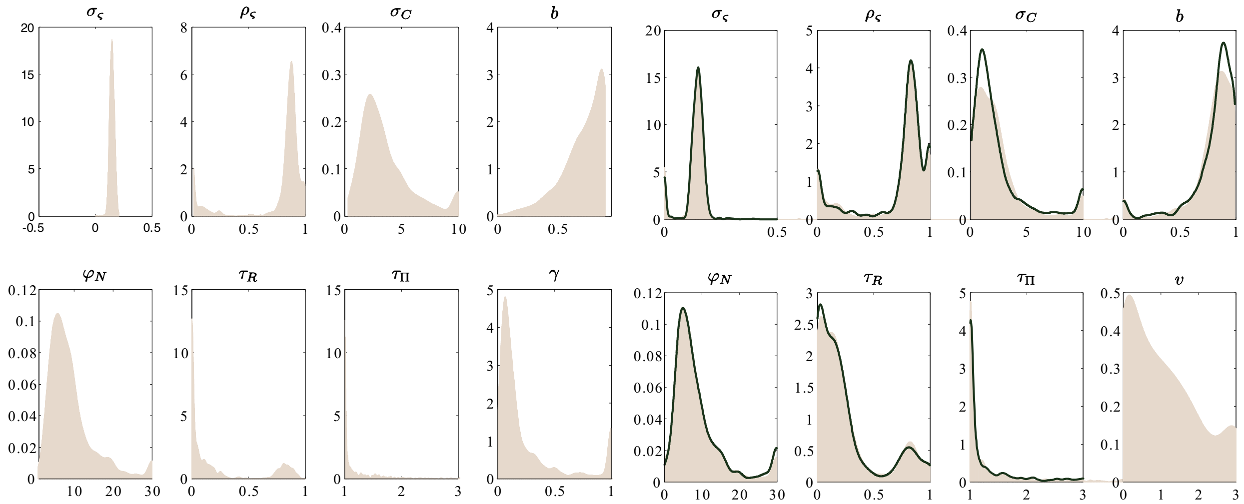

Fig. 3. Parameter distributions across VAR bootstrap replications: Translog model (left panel) and SI model (right panel). We estimate both models using $n=1000$ VAR bootstrap replications. Figure shows distributions of selected parameter estimates across replications. Left panel: Translog model. Right panel: unrestricted SI model (shaded areas), restricted SI model (solid lines).

In Table 4, we report the estimation results of the restricted SI model where we impose the restriction $v=1/(\theta_f-1)$. The standard errors of risk aversion σ_C and habit formation b, are considerably reduced relative to the unrestricted SI model and are close to the respective standard errors in the translog model. In addition, the overall model fit deteriorates only slightly; the J-statistic increases only marginally when we impose the restriction.

Taken together, our results suggest that, given our data set and objective function, we cannot separately identify love of variety, risk aversion, and the degree of habit formation. Imposing an extra restriction on the love of variety parameter, as in the translog or Dixit–Stiglitz models, helps to identify the other utility parameters. However, even if the population identification problem can be overcome by appropriately re-specifying the model, macroeconomic data may fail to contain information necessary to identify the degree of love of variety. Fundamentally, variety gains are not adequately incorporated in cost-of-living measures, as mentioned above. Bils and Klenow (2001) conjecture that 'quantifying the aggregate importance of new products [...] is probably not feasible'.

Given the lack of a competition effect and the large uncertainty surrounding the love of variety estimate in the SI model, we test formally if the model is observationally equivalent to Dixit and Stiglitz (1977) monopolistic competition model, where $\theta_i=\theta_f$ and $v=1/(\theta_f-1)$. We perform a distance metric test as in Meier and Müller (2006). The test statistic is given by

$$\mathcal{J}_r(\hat{\psi}_i)-\mathcal{J}(\hat{\psi}_i)\overset{a}{\sim}\chi^2(m), \tag{29}$$

where $\mathcal{J}_r(\hat{\psi}_i)$ is the value of the sample J-statistic under the restrictions to be tested and m is the number of restrictions. Since $\mathcal{J}_r(\hat{\psi}_{SI})=90.47$, $\mathcal{J}(\hat{\psi}_{SI})=87.99$ and $\chi^2_{10\%}(2)=4.6$, we cannot reject the null hypothesis that the Dixit–Stiglitz restrictions hold in the SI model at the 10% confidence level.

4.4. Model comparison

This section compares the ability of two models, the translog model and restricted SI model, to replicate the empirical dynamics of each variable separately. Along the lines of Dupor et al. (2010), Carrillo (2012) proposes the Root Mean Squared Error (RMSE) between the theoretical and empirical impulse responses as a measure of model accuracy. Similarly

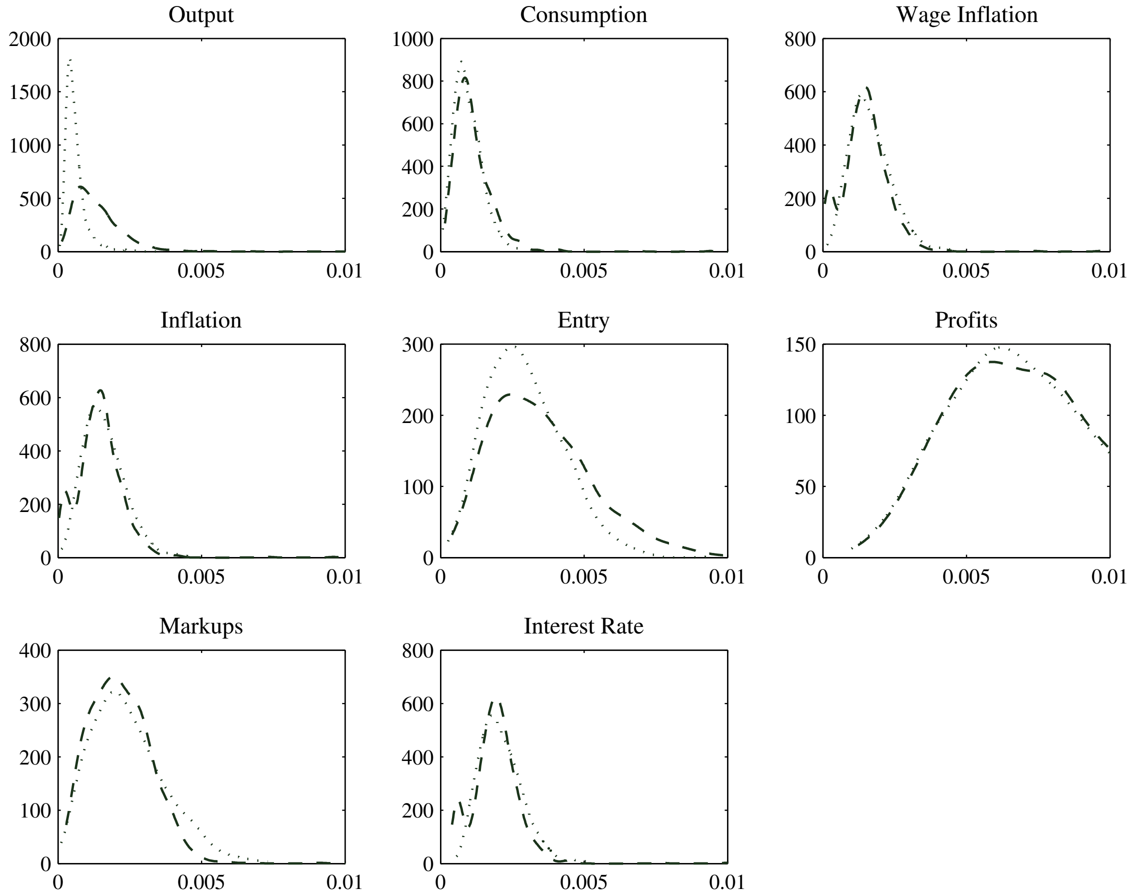

Fig. 4. Root Mean Squared Error (RMSE) distributions across VAR bootstrap replications. We estimate both models using $n=1000$ VAR bootstrap replications. For each variable and bootstrap iteration, Root Mean Squared Error is computed as $RMSE^i_{x,j} = \sqrt{(1/H)\sum_{h=1}^{H}(\Phi_{x,j,h}(\hat{\psi}_i)-\hat{\Phi}_{x,j,h})^2}$, $j=1,\dots n$, where $\Phi_{x,j,h}(\hat{\psi}_i)$ is model-based IRF and $\hat{\Phi}_{x,j,h}$ is VAR-based IRF of variable x, at horizon h and iteration j. Dashed line: SI model. Dotted line: translog model.

to the previous section, the theoretical models are re-estimated on $n=1000$ bootstrap replications of the VAR. For each variable and bootstrap iteration, we compute the RMSE as

$$RMSE^i_{x,j} = \sqrt{\frac{1}{H}\sum_{h=1}^{H}(\Phi_{x,j,h}(\hat{\psi}_i)-\hat{\Phi}_{x,j,h})^2}, \quad j=1,\dots n, \tag{30}$$

where $\Phi_{x,j,h}(\hat{\psi}_i)$ is the model-based IRF and $\hat{\Phi}_{x,j,h}$ is the VAR-based IRF of variable x, at horizon h and iteration j. Fig. 4 plots the distribution of the RMSE across bootstrap replications.

A distribution close to zero indicates that the model is successful in fitting the variable's observed dynamics. We find that the two models perform equally well in matching the impulse responses of most variables, including the markup. Only the output response is predicted more accurately in the translog model; the RMSE distribution is closer to zero.

5. Robustness

Our estimation results have shown that the translog model generates countercyclical markups through the competition effect. In order to test the robustness of this finding, Table 6 reports the results of three alternative estimation exercises.[20] The first estimates the model using the consumer price index (CPI) and the producer price index (PPI) as alternatives to the GDP deflator. The second estimates the model under non-zero steady state inflation. The third considers capital as a factor of production.[21]

[20] We present analogous exercises for the restricted SI model, i.e. imposing $\nu = 1/(\theta_f - 1)$, in Appendix B.

[21] Detailed derivations of the models with trend inflation and capital are provided in Appendix A. Notice that the equation determining the steady state number of firms N changes. In the model with capital, the parameter restrictions on ε, η, ν and ϕ_p are as in Table 3. In the model with trend inflation, the restrictions on ε, η, ν and ϕ_p are different from those in Table 3.

Table 6
Translog model: robustness exercises.

		PPI	CPI	$\Pi \neq 1$	Capital
σ_ς	Standard error of shock	0.157 (0.013)	0.154 (0.014)	0.172 (0.017)	0.156 (0.012)
ρ_ς	Autocorrelation of shock	0.836 (0.066)	0.899 (0.085)	0.943 (0.024)	0.825 (0.062)
τ_R	Interest rate smoothing	0.118 (0.142)	0.038 (0.158)	0.501 (0.058)	0.182 (0.120)
τ_Π	Inflation coefficient	1.069 (0.376)	1.091 (0.612)	5.373 (1.967)	1.257 (0.427)
σ_C	Risk aversion	3.540 (0.777)	5.659 (1.268)	2.232 (0.568)	2.894 (0.943)
b	Habit persistence	0.759 (0.069)	0.706 (0.098)	0.860 (0.041)	0.835 (0.064)
ω	Cost channel	0.744 (0.199)	0.654 (0.177)	0.930 (0.237)	1.000 (0.195)
ϕ_p	Slope of price inflation curve	0.022[a] (0.004)	0.025[a] (0.004)	0.016[b] (0.003)	0.046[a] (0.006)
ϕ_w	Slope of wage inflation curve	0.006 (0.002)	0.004 (0.001)	0.008 (0.003)	0.001 (0.001)
φ_N	Adjustment cost (extensive margin)	7.962 (1.615)	9.698 (1.822)	8.005 (1.637)	18.268 (4.224)
φ_K	Adjustment cost (intensive margin)	–	–	–	13.091 (3.786)
γ	Price-elasticity of spending share	0.368 (0.038)	0.345 (0.032)	0.085 (0.028)	0.432 (0.144)
ε	Price-elasticity of demand	2.716[a] (0.283)	2.896[a] (0.271)	2.217[b] (0.199)	3.560[a] (0.426)
η	Competition effect	0.149[a] (0.084)	0.177[a] (0.087)	0.411[b] (0.067)	0.281[a] (0.034)
v	Love of variety	0.291[a] (0.048)	0.264[a] (0.038)	0.451[b] (0.040)	0.195[a] (0.032)
N	Number of goods/firms	11.500[a]	10.700[a]	14.402[b]	5.924[b]
$\mathcal{J}$-statistic {p-value}		112.50 {0.064}	97.47 {0.074}	110.22 {0.104}	99.35 {0.174}

Robustness exercises. 'PPI' and 'CPI' use the respective price index as a measure of p_t rather than the GDP deflator. '$\Pi \neq 1$' estimates model augmented with non-zero steady state inflation, where $\Pi = 1.005$. 'Capital' estimates model augmented with capital in goods production.

[a] Parameter is deduced from steady state restrictions as shown in Table 3.

[b] Parameter is deduced from steady state restrictions that differ from those in Table 3 (see Appendix A). Numbers in round brackets are standard errors. Numbers in curly brackets are p-values of null hypothesis H_0: $\mathcal{J} = 0$.

When we estimate the model using as our price index p_t the PPI or the CPI, the price-elasticity of the spending share increases. This raises the demand elasticity and the slope of the NKPC, and reduces the competition effect. Risk aversion increases in the estimation with CPI. The remaining parameter estimates are not strongly affected by the measure of the price index. Notice, however, that the model fit worsens substantially, due to the stronger response of inflation to the monetary policy shock.[22]

As a second robustness exercise, we derive the translog model under trend inflation. We estimate the model under a steady state inflation rate of 2% per year, $\Pi = 1.005$.[23] Under full indexation, the model reduces to the benchmark model. Table 6 therefore reports the estimation results for a lower degree of indexation, $\lambda_p = \lambda_w = 0.65$.[24] With trend inflation, the demand elasticity is slightly reduced to $\varepsilon = 2.22$, which flattens the NKPC and makes the competition effect somewhat larger. The coefficient on inflation in the Taylor rule is substantially larger with $\tau_\Pi = 5.37$.

Finally, we derive the translog model under the assumption that the production of goods requires capital in addition to labor. We assume a Cobb–Douglas production function with a capital share $\alpha = 0.33$. Physical capital depreciates at rate $\delta_K = 0.025$. Investment is subject to a flow adjustment cost $\varphi_K > 0$ as in Christiano et al. (2005). Marginal costs are a weighted average of the wage rate (including borrowing costs) and the rental rate. We derive the markup as

$$\mu_t = \frac{1-\alpha}{(1-N_{E,t}/L_t)s_t^L R_{w,t}}. \tag{31}$$

In computing the labor share s_t^L, we take into account that total goods output Y_t^C includes investment. Fixed private investment is added to the VAR. The price-elasticity of the spending share increases relative to baseline, $\gamma = 0.43$, while the steady state number of firms is halved. As a consequence, the demand elasticity increases to $\varepsilon = 3.56$ and the NKPC becomes steeper, $\phi_p = 0.046$. The competition effect is smaller, but still significant, in the model with capital, $\eta = 0.28$. The parameter measuring adjustment cost in extensive margin investment almost doubles, $\varphi_N = 18.27$. Adjustment costs at the intensive margin are a lot higher than in fixed-variety models, $\varphi_K = 13.09$. We cannot reject the null hypothesis H_0: $\mathcal{J} = 0$, i.e. the model with physical capital is not rejected by the data.

[22] See figure in Appendix B.

[23] The results are not sensitive to whether or not we remove a linear trend from inflation prior to estimation.

[24] This value corresponds to the upper bound estimates in Ascari et al. (2011). Ascari and Rossi (2012) show that the determinacy region of the Rotemberg model is reduced for a large degree of price indexation.

6. Conclusion

The present paper considers two business cycle models with endogenous firm and product entry. Through the competition effect, entry makes markups more countercyclical. In a model with translog preferences ('translog model'), the substitutability between goods and hence demand elasticities are positively related to *product* entry. In an alternative model with strategic interactions between oligopolists ('SI model'), *firm* entry reduces the market power of incumbents. We estimate the models by matching impulse responses to a monetary policy shock in US data, where entry is measured as net business formation. We find that both models perform equally well in replicating the empirical responses. However, the translog model produces countercyclical markups through a significant competition effect, while the SI model does not. This has some bearing on the estimates of certain other parameters, more specifically the degree of risk aversion and the cost channel. We go on to show that in the SI model, the competition effect is small for any reasonable calibration of the substitution elasticities within and across industries. Therefore, that model is observationally equivalent to the Dixit–Stiglitz monopolistic competition model where all markup countercyclicality is due to price stickiness. As an additional contribution, we show that an attempt to estimate the love of variety parameter jointly with the degrees of risk aversion and habit persistence is subject to identification problems.

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Appendix. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org.10.1016/j.jmoneco.2012.10.003.

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