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Abstract

This paper provides a DSGE model with firm entry. Simulations show that the model matches the synchronization of markups and entry observed in the data while at the same time reproducing empirically plausible moments for key macroeconomic variables. Sticky prices are essential for these results.

Keywords: endogenous entry, firm dynamics, monopolistic competition, market power, markups

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1 Introduction

It is a well-established fact that firms' entry has a pro-cyclical behavior.[1] Similarly, the range of available products exhibits a pro-cyclical pattern (Broda and Weinstein, 2010). Yet, standard models of imperfect competition à la Blanchard and Kiyotaki (1987) have assumed that the number of firms and the range of products are exogenously given. Early attempts to allow for a variable number of firms, including Rotemberg and Woodford (1991) and Blanchard and Giavazzi (2003) among others, have the unappealing consequence of implying a positive relation between the number of firms and markups which is at odds with the data (Colciago and Etro (2010)). The reason is the (frictionless) free entry condition in these models requiring zero profits *in every period*. When the degree of market power increases, a firm will face higher profits for given entry costs and therefore a strong incentive to enter the market.[2] This needs not be the case as long as markups are allowed to vary over the cycle. The purpose of this paper is to do exactly this, providing a model with both endogenous entry and endogenous markups.

Drawing on recent developments in DSGE modelling, I consider a closed economy with monopolistic competition where producers are subject to a sunk entry cost, a one-period production lag and an exogenous exit shock.[3] The economy features complete financial markets and nominal rigidity à la Calvo (1983). Simulations show that the model matches the synchronization of markups and entry observed in the data while at the same time reproducing empirically plausible moments for macroeconomic variables. Sticky prices are essential for these results.

The remainder of the paper is organized as follows. Section 1 presents the model and discusses the solution strategy. Section 2 illustrates the performance of the model in reproducing the dynamics in the data and contains conclusive remarks.

2 The economy

I consider a closed economy version of the model in Cavallari (2011). The economy is populated by a continuum of agents of unit mass indexed by i. Firms are monopolistic competitors, each producing a different variety $j \in (0, N)$, where N is the number of firms.

A typical agent supplies L_t hours of work each period for the nominal wage W_t and maximizes

[1] For the US, the cyclical properties of entry have been documented by Chatterjee and Cooper (1993), Dunne et al. (1998) and Campbell (1997). More recently, see also Jaymovich and Floetotto (2008), Bilbiee et al. (2012) and Lewis (2009).

[2] This incentive reduces when entry entry costs are positively related with market power (Chang and Lai (2012)).

[3] A non-exhaustive list of contributions includes: Bilbiee et al. (2007, 2012), Ghironi and Mélitz (2005), Bergin and Corsetti (2008) and Cavallari (2007, 2010).

inter-temporal utility $E\left[\sum_{s=t}^{\infty}\beta^{s-t}U(C_s,L_s)\right]$, where C is consumption and β the subjective discount factor. The period utility is the additive-separable function $U_t = \frac{(C_t)^{1-\rho}}{1-\rho} - \frac{\varphi\chi}{1+\varphi}(L_t)^{\frac{1+\varphi}{\varphi}}$,with $\rho > 0$ and $\varphi \geq 0$. The consumption basket takes the form $C = \left[\int_0^N C(j)^{\frac{\theta-1}{\theta}}dj\right]^{\frac{\theta}{(\theta-1)}}$ with $\theta > 1$ and the corresponding price index, CPI, is $P^C = \left[\int_0^N P(j)^{1-\theta}dj\right]^{\frac{1}{(1-\theta)}}$.

Producers face an identical linear technology in the labor input $y_t(j) = Z_t L_t(j)$, where Z is an aggregate shock to labor productivity. In order to start the production in period $t+1$, at time t a firm needs to purchase f_e units of the consumption basket at the price P^C. Others, as Bilbiie et al. (2012) and Cavallari (2007), model entry in effective labor units $f_e = L$. Entry costs in this case coincide with labor marginal costs.

As in Ghironi and Mélitz (2005), all firms entered in a given period are able to produce in all subsequent periods until they are hit by a death shock, which occurs with a constant probability $\delta \in (0,1)$. In each period, in addition to incumbent firms there is a finite mass of entrants, N_e. Entrants are forward looking and decide to start a new firm whenever its real value, ν, given by the present discounted value of the expected stream of profits $\{d_s\}_{s=t+1}^{\infty}$, covers entry costs:

$$\nu_t = E_t\left[\sum_{s=t+1}^{\infty}\beta(1-\delta)\left(\frac{C_{s+1}}{C_s}\right)^{-\rho}d_s\right] = f_e \tag{1}$$

The free entry condition holds as long as the mass of entrants in positive. Macroeconomic shocks are assumed to be small enough for this condition to hold in every period. Note that upon entry, firms' profits vary and can even turn negative for a while. This is a key difference relative to early models of frictionless entry, where profits are zero in every period. The timing of entry and the one-period production lag imply the following law of motion for producers:

$$N_t = (1-\delta)(N_{t-1} + N_{e,t-1}) \tag{2}$$

Finally, I assume complete financial markets. Agents can invest their wealth in a set of nominal state-contingent bonds, B, that span all the states of nature. In addition to bonds, they hold a share s of a well-diversified portfolio of firms. The budget constraint of a typical agent i is given by:

$$\sum_{\Omega} q_t(\Omega_{t+1})\frac{B_{it}}{P_t^C} + s_t(N_t + N_{e,t})v_t \leq \frac{B_{it-1}}{P_t^C} + s_{t-1}(v_t + d_t) + \frac{W_t L_{it}}{P_t^C} - C_{it} \tag{3}$$

where q is the bond price.

2.1 Equilibrium conditions

2.1.1 Consumers

Consumers' first order conditions are given by:

$$\frac{q_t\left(s_{t+1}\right)}{P_t^C}\left(C_t\right)^{-\rho}=\beta E_t\left(\frac{C_{t+1}}{P_{t+1}^C}\right)^{-\rho} \tag{4}$$

$$\left(C_t\right)^{-\rho}=\beta\left(1-\delta\right)E_t\left[\frac{d_{t+1}+v_{t+1}}{v_t}\left(C_{t+1}\right)^{-\rho}\right] \tag{5}$$

$$C_t(j)=\left(\frac{P_t(j)}{P_t^C}\right)^{-\theta}C_t \tag{6}$$

$$\frac{W_t}{P_t^C}=\chi\left(L_t\right)^{\frac{1}{\varphi}}\left(C_t\right)^{\rho} \tag{7}$$

2.1.2 Firms

Each producer sets the price for its own variety facing market demand $y_t(j)=\left(\frac{P_t(j)}{P_t^C}\right)^{-\theta}(C_t+f_eN_{e,t})$. I introduce nominal rigidities through a Calvo-type contract. In each period a firm can set a new price with a fixed probability $1-\alpha$ which is the same for all firms, both incumbent firms and new entrants, and is independent of the time elapsed since the last price change. In every period there will therefore be a share α of firms whose prices are pre-determined.[4]

Each firm sets the price for its own variety so as to maximize the present discounted value of future profits, taking into account market demand and the probability that she might not be able to change the price in the future, yielding:

$$P_t(j)=\frac{\theta}{\theta-1}\frac{E_t\sum\limits_{k=0}^{\infty}\left(\alpha\beta\left(1-\delta\right)\right)^k\frac{W_{t+k}}{Z_{t+k}}\frac{y_{t+k}(j)}{P_{t+k}^C C_{t+k}^{-\rho}}}{E_t\sum\limits_{k=0}^{\infty}\left(\alpha\beta\left(1-\delta\right)\right)^k\frac{y_{t+k}(j)}{P_{t+k}^C C_{t+k}^{-\rho}}} \tag{8}$$

The above expression can be re-arranged in a more familiar form as:

$$P_t(j)=\frac{\theta}{\theta-1}\left(1-\alpha\beta\left(1-\delta\right)\right)\frac{W_t}{Z_t}+\alpha\beta\left(1-\delta\right)E_tP_{t+1}(j) \tag{9}$$

Clearly, when $\alpha=0$ optimal pricing implies a constant markup $\frac{\theta}{\theta-1}$ on marginal costs at all dates.

[4]The simplifying assumption that entrants behave like incumbent firms is without loss of generality. Allowing entrants to make their first price-setting decision in an optimal way would have only second order effects in my setup with Calvo pricing.

With $\alpha > 0$, prices respond less than proportionally to a marginal cost shock, implying a decline in markups.

Aggregating (9) across firms yields the state equation for the producer price index, PPI:

$$(P_t)^{1-\theta} = \alpha \frac{N_t}{N_{t-1}} (P_{t-1})^{1-\theta} + (1-\alpha) N_t (P_t(j))^{1-\theta} \tag{10}$$

2.1.3 Aggregate constraints

Define real GDP as $Y \equiv \int_0^N \frac{P(j)}{PC} y(j) dj$. Goods market clearing requires output to equalize aggregate demand, $Y_t = C_t + N_{e,t} f_e$. Labor market clearing implies:

$$L_t \equiv \int_0^1 L_{it} di \geq \int_0^{N_t} \frac{y_t(j)}{Z_t} dj \tag{11}$$

The model is closed by specifying a monetary policy rule. I assume the monetary instrument is the one-period risk-free nominal interest rate, i_t, and monetary policy belongs to the class of feedback rules.

2.2 The log-linearization

The model does not provide a closed-form solution. It is log-linearized around a symmetric steady state with zero inflation. In the steady state, stochastic shocks are muted at all dates, $Z_t = 1$.

The Euler equation for bond holdings is given by:

$$E_t \widehat{C}_{t+1} = \widehat{C}_t + \frac{1}{\rho} \left(\widehat{i}_t - E_t \pi_{t+1} \right) \tag{12}$$

where a hat over a variable denotes the logdeviation from the steady state, $\pi_{t+1} = \ln P_{t+1}/P_t$ is producer inflation and E is the expectation operator. In (12), an increase in the real interest rate raises the return on bonds, therefore making it more attractive to postpone consumption in the future.

The Euler equation for share holdings is:

$$E_t \widehat{C}_{t+1} = \widehat{C}_t + \widehat{\upsilon}_t + \frac{1}{\rho} E_t \left(\frac{i+\delta}{1+i} d_{t+1} + \frac{1-\delta}{1+i} \widehat{\upsilon}_{t+1} \right)$$

Consider the optimal price (8). Using market demand and (7), re-arranging and linearizing gives:

$$E_t \sum_{k=0}^{\infty} \alpha\beta (1-\delta)^k \left[\widehat{P}_{t,t+k} - \left(\rho + \frac{1}{\varphi} \right) \widehat{C}_{t+k} + \left(1 + \frac{1}{\varphi} \right) \widehat{Z}_{t+k} - \frac{1}{\varphi} \widehat{N}_{t+k} + \frac{\theta}{\varphi} \widehat{P}_{t,t} \right] = 0$$

where $\widehat{P}_{t,t+k} = \ln P_t(j)/P_{t+k}$. Note that by definition $\widehat{P}_{t,t+k} = \widehat{P}_{t,t} - \sum_{s=1}^{k} \pi_{t+s}$, namely changes in the real price of a variety over time are given by the variety effect, the first addend, less inflation. Using (10), the variety effect is:

$$\widehat{P}_{t,t} = \frac{\alpha}{1-\alpha}\pi_t + \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_t - \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{t-1}$$

With $\alpha = 0$, an increase in the number of producers raises the real price of each variety and the more so the lower the elasticity of substitution θ. This effect is dampened with $\alpha > 0$. Combining the two equations above and re-arranging gives the new-Keynesian Phillips curve (corrected for firm entry):

$$\begin{aligned} \pi_t \quad &= \quad \zeta \left[\left(\rho + \frac{1}{\varphi} \right) \widehat{C}_t - \frac{1}{(1-\alpha)(\theta-1)} \widehat{N}_t - \frac{(1+\varphi)}{\varphi} Z_t + \frac{\alpha}{(1-\alpha)(\theta-1)} \widehat{N}_{t-1} \right] \\ &\quad +\beta(1-\delta) E_t \pi^H_{t+1} \end{aligned} \tag{13}$$

where $\zeta = \frac{(1-\alpha\beta(1-\delta))(1-\alpha)}{\alpha(\varphi+\theta)}$.

A log-linear approximation to the number of entrants is obtained from the aggregate resource constraint:

$$\widehat{N}_{e,t} = \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\widehat{Y}_t + \left(1 - \frac{\theta(1-\beta(1-\delta))}{\beta\delta}\right)\widehat{C}_t \tag{14}$$

Note that there is a trade-off between investments in new varieties and consumption of existing goods (the coefficient on C is negative). The law of motion of firms is:

$$\widehat{N}_t = (1-\delta)\widehat{N}_{t-1} + \delta\widehat{N}_{e,t-1} \tag{15}$$

Using the property that the aggregate price markup $\mu \equiv \int_0^N \frac{P(j)}{W/Z} dj$ coincides with the inverse of the labor share, $\frac{YP^C}{WL}$, one can substitute away the real wage in (7) and together with the GDP definition obtain an expression for aggregate labor. In log-linear terms, this gives :

$$\widehat{L}_t = -\rho\varphi\widehat{C}_t + \varphi\left(\widehat{Z}_t - \widehat{\mu}_t + \widehat{P}_{t,t}\right) \tag{16}$$

where $\widehat{\mu}_t = \alpha\beta(1-\delta)\left(\widehat{P}_{t,t+1} - \widehat{P}_{t,t} + E_t\pi_{t+1}\right)$.

Finally, monetary policy follows a Taylor rule $\widehat{i}_t = \phi_i \widehat{i}_{t-1} + \phi_\pi \pi_t$ with interest rate smoothing. [5] For ease of comparisons with flexible price models, I also consider a Wicksellian regime in which

[5] Taylor rules are empirically plausible, especially in the last few decades when the objective of price stability has gained a major role in monetary policy-making. Interest rate smoothing accounts for the need to reduce swings in

the nominal interest rate is set so as to reproduce a flexible price equilibrium with zero inflation. The Wicksellian interest rates is $\widetilde{i}_t = \rho \left(E_t \; \widehat{C}_{t+1} - \widehat{C}_t \right)$, i.e. it mimics changes in the natural (real) interest rate. As is well-known, the Wicksellian policy can be implemented recurring to a credible threat to deviate from a zero inflation target, i.e. $i_t = \widetilde{i}_t + \vartheta \pi_t$ with $\vartheta > 1$.

3 Simulations and conclusions

The model is simulated using first-order perturbation methods. In line with real business cycle models, I consider productivity shocks as the main source of business cycle volatility, abstracting from interest rate innovations.

3.1 Calibration

The model is calibrated on the United States. In the simulations, periods are interpreted as quarters and $\beta = 0.99$ as is usual in quarterly models of the business cycle. The size of the exogenous exit shock δ is 0.025 as suggested by Bilbiie et al. (2007). The rate of firm disappearance is consistent with a 10 percent rate of job destruction per year as found in the US. The elasticity of substitution across varieties θ is equal to 7.88 as in Rotemberg and Woodford (1999). This yields a reasonable average markup of approximately 18 percent. Studies based on disaggregated data usually find a much lower θ, roughly around 4. Simulations with a lower elasticity deliver qualitatively identical results and will not be reported. Other preference parameters are $\varphi = 2.13$ as in Rotemberg and Woodford (1999) and $\rho = 1$ as in Bilbiie et al. (2007). I have also experimented with a full range of admissible values for ρ and φ, obtaining similar results (not reported).

Galì et al. (2001) estimate a value for the degree of nominal rigidity between 0.407 and 0.66 in the US. I take the middle point from this interval and set $\alpha = 0.49$, implying an average duration of nominal contracts of 2.3 quarters.

The vector of productivity shocks Z_t follows a univariate autoregressive process with persistence 0.975 and standard deviation of innovations 0.0072 as in King and Rebelo (1999). The parameters of the Taylor rule draw on Bilbiee et al. (2007), $\phi_i = 0.8 i^J_{t-1}$ and $\phi_i = 0.3$. Finally, as fixed costs do not affect the dynamics of the model I set $f_e = 1$ without loss of generality.

interest rates in an environment characterized by long and variable lags in monetary transmission.

3.2 Moments

In comparing the model to properties of the data, the treatment of variety effects deserves a particular attention. As argued in Ghironi and Mélitz (2005), empirical relevant variables - as opposed to welfare-consistent variables - net out the effects of changes in the range of available products. The reason is the inability of statistical measures of CPI inflation to adjust for availability of new products as in the welfare-consistent price index. Hence, the data are closer to the producer than to the consumer price index. In what follows, any variable that in the model is measured in units of consumption is deflated by producer inflation and converted into units of output (for any variable X in consumption units the corrected measure will be $X_t^R = P_t^C X_t / P_t$).

Table 1 reports statistics of the model's artificial time series together with statistics in US data. As with the data, statistics refer to Hodrey-Prescott filtered variables with smoothing parameter of 1600. The reported statistics are averages across 100 simulations. The first column refers to the benchmark model, the second column to the variant with labor entry costs, the third column to the flexible price economy and the last column reports US data from Rotemberg and Woodford (1999).[6]

Table 1:

	Benchmark model			Labor entry costs			Flex price model			US data		
	σ_X/σ_Y	σ_{XY}	ρ_X	σ_X/σ_Y	σ_{XY}	ρ_X	σ_X/σ_Y	σ_{XY}	ρ_X	σ_X/σ_Y	σ_{XY}	ρ_X
C	0.87	0.90	0.93	0.98	0.99	0.96	1.16	0.98	0.92	0.77	0.86	0.99
L	0.89	0.89	0.86	0.88	0.52	0.71	0.06	-0.87	0.98	1.10	0.88	0.90
N_e^R	2.95	0.74	0.78	2.35	0.98	0.94	0.39	0.68	0.83	2.99	0.87	0.87
μ	0.59	-0.97	0.92	0.81	-0.92	0.86	0	0	0	0.60	-0.28	0.79

σ_X is the standard deviation of variable X, σ_{XY} is the correlation of variable X with output, Y, and ρ_X is the auto-correlation of variable X.

The benchmark model matches the volatility and persistence observed in the data fairly well.[7] It also replicates the positive comovement of consumption, employment and investment with output as well as the negative comovement of markups. Markups, however, are far more counter-cyclical than in the data. These results are robust to specifying entry costs in units of labor. In the flexible price

[6] In the variant with labor entry costs, the log-linear model is as before except for the following equations:

$$\begin{aligned} \widehat{v}_t &= \frac{1}{\varphi}\widehat{L}_t + \rho\widehat{C}_t - \widehat{Z}_t \\ \widehat{Y}_t &= \widehat{Z}_t + \widehat{L}_t + \widehat{P}_{t,t} \end{aligned}$$

[7] Entry behaves similarly to investments (Lewis, 1999). In US data, the correlation between output and net entry measured as Net Business Formation is 0.71. The standard deviation of NBF relative to that of output is 2.19.

economy, on the contrary, the performance of the model deteriorates. The volatility of employment and investments is too low compared to the data while that of consumption is too high. This is a consequence of a strong incentive to smooth labor effort over time so long as real wages are relatively stable (in equation (9) with $\alpha = 0$ nominal wages and prices move in unison). Clearly, the flexible price economy also fails to capture the dynamics of markups.

The reason why markups and entry are negatively correlated (as in the data) is easy to grasp. The favorable business conditions attract new entrants in the economy, translating into a gradual increase in the number of producers over time (see equation (15)). This in turn pushes on labor demand, raising wages and marginal costs. With sticky prices, the price of each variety will adjust only gradually, thereby implying a decline in firms' markups.

In line with Bilbiie et al (2012), my findings suggest that firm entry may help reduce the distance between theoretical predictions and business cycle facts. In this paper, I have shown that sticky prices are essential for capturing the synchronization of entry and markups observed in the data. Clearly, this is only a first step towards a model that incorporates other relevant aspects of firms' demography, from endogenous exit to the duration of a firm's life. This is ground for future research.

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