2015

Entry costs and the dynamics of business formation

Lilia Cavallari

Journal of Macroeconomics 44 (2015) 312–326

Contents lists available at ScienceDirect

Journal of Macroeconomics

journal homepage: www.elsevier.com/locate/jmacro

Entry costs and the dynamics of business formation

Lilia Cavallari

University of Rome III, Department of Political Sciences, Via Chiabrera, 199, 00145 Rome, Italy

ARTICLE INFO

Article history:
Received 16 October 2014
Accepted 3 March 2015
Available online 8 April 2015

JEL classification:
E31
E32
E52

Keywords:
Entry cost
Firm entry
Firm exit
Business cycle
Business creation
Business destruction

ABSTRACT

This paper studies the implications of entry costs for business formation in a dynamic stochastic general equilibrium model with endogenous entry and exit. The paper first documents some facts about business formation in the US. Exit is more volatile than entry, both are more volatile than output and co-move over the cycle. Firms are less volatile than output and pro-cyclical. Then, it shows that a model with entry and exit can replicate these facts fairly well. In addition it captures important features of the US business cycle, outperforming models with a fixed exit rate and a fixed number of firms. The performance of the model is sensitive to changes in the composition of entry costs.

1. Introduction

The importance of firm entry and exit for the business cycle is well recognized.[1] A novel vintage of general equilibrium models has stressed the role of firm entry and creation of new products in propagating business cycle fluctuations.[2] They typically consider monopolistic competitive markets where firms produce unique varieties. With a few exceptions, that will be discussed later in the paper, these studies overlook firm exit and the destruction of products as a distinct channel for the transmission of shocks. Some authors, as Bilbiie et al. (2008, 2012) and Ghironi and Melitz (2005), focus on labor costs in the spirit of Grossman and Helpman (1991) and Romer (1990). In these models, start-up activities require labor inputs and entry costs are measured as wages. Others, as Bergin and Corsetti (2008) and Cavallari (2013a,b), assume that investors buy materials for the set-up of a new firm, so that entry costs vary with their price. How to model entry costs is an open question.

Entry costs are akin to investment costs in standard (fixed-variety) business cycle models. As for traditional models, there is some debate on the form of these costs. Specifically, the theoretical discussion is on the composition of investment/entry costs and the extent to which these are subject to nominal frictions. Studies that address the role of nominal frictions in entry models include Bergin and Corsetti (2008), Lewis and Poilly (2012) and Uusküla (2008) among others. They document a negative relation between nominal interest rate innovations and business creation and a positive relation between the former and business failures. These findings are at odds with the implications of models that measure entry costs as wages. In these models, a

E-mail address: lilia.cavallari@uniroma3.it

[1] Examples of competitive models of industry dynamics with aggregate fluctuations comprise, among others, Clementi and Palazzo (2013),Campbell (1998) and Lee and Mukoyama (2012).

[2] A non-exhaustive list of contributions includes: Bilbiie et al. (2008, 2012), Etro and Colciago (2010), Ghironi and Melitz (2005), Bergin and Corsetti (2008), Floetotto and Jaimovich (2008), Lewis (2009), Cavallari (2007), Cavallari (2010), Cavallari (2013a), Cavallari (2013b) and Russ (2007).

http://dx.doi.org/10.1016/j.jmacro.2015.03.002

monetary expansion pushes on labor demand, increasing wages and entry costs. It therefore discourages the creation of new firms. For this motive, Bilbiie et al. (2008) consider entry costs fixed in units of consumption in the sticky price version of their model, while Lewis and Poilly (2012) focus on sticky wages and Bergin and Corsetti (2008) measure entry costs as product prices. Successive research has showed that entry cost specification has important consequences also for the capacity of these models to replicate stylized business cycle facts.[3] Surprisingly, the cyclicality of entry and exit is not included among the facts that need to be explained. Furthermore, most studies in this area neglect the role of firm exit for the propagation of shocks.[4]

This paper aims to shed some light on these questions. For this purpose, it provides a dynamic stochastic general equilibrium model that combines a mechanism of firm entry à la Ghironi and Melitz (2005) and endogenous firm exit as in Lee and Mukoyama (2012). The start-up of a new firm requires a combination of labor and capital so as to address entry cost specification. Given the scope of the analysis, which is focused on the implications of sticky prices for firms dynamics, the model considers price staggering à la Calvo (1983) and a monetary policy in the tradition of the Taylor rule (Taylor, 1993) as in Cavallari (2013a).

The paper first documents some facts about entry and exit. Evidence is from plant-level data that cover almost the entire production activity in the United States over the period 1977–2011. Three facts stand out. 1. Exit is more volatile than entry and both are far more volatile than output, almost as much as investments. 2. Entry is pro-cyclical, exit is counter-cyclical and they are negatively correlated between each other. 3. The stock of producers is smoother than output and pro-cyclical.

Then, it compares the performance of the model at replicating these facts under alternative assumptions on entry, exit and the composition of entry costs. A baseline model with endogenous entry and exit replicates business formation data fairly well. In addition, it matches key facts of the US business cycle at least as well as other models. Actually, it does better at matching the smoothness of consumption, investments and hours and their correlation with output.

The baseline model fares favorably relative to a specification with a fixed number of firms because of the role of entry as a business cycle amplifier. As stressed in previous studies, this facilitates the match of macroeconomic data with no need to rely on unplausible high shocks as in traditional (fixed-variety) models. In addition, the baseline model fares better than a specification with a fixed exit rate. I stress that counter-cyclical exits help to reduce the excessive smoothness of macroeconomic variables that is commonly found in models with a fixed exit rate.

The performance of the model is sensitive to changes in the composition of entry costs. In my setup, these costs affect firms' start-ups as well as firms' failures. A free entry condition links firm value to entry costs (actually, they coincide in equilibrium). Firm value in turn is inversely related to the probability of exit. A high volatility of entry reflects a strong incentive to adjust the start-up margin over the cycle, for example by creating a new firm in cyclical upturns. Similarly, the volatility of exit reflects the incentive to modify market participation, for instance by increasing exits in cyclical downturns.

An important contribution of the paper is to clarify the role of endogenous movements in entry costs/firm value in shaping these incentives. Pro-cyclical entry costs – as when these costs are measured by wages – discourage the start-up of new firms and lead to a low volatility of entry. Pro-cyclical firm values, on the other hand, raise the benefits of staying in the market and reflect into a high volatility of exits. By the same token, counter-cyclical entry costs – as when they are measured by product prices – lead to a high volatility of entry and a low volatility of exits.

The paper is organized as follows. Section 2 documents some facts about entry and exit in the US. Section 3 presents the model. Section 4 discusses the results of simulations, illustrates the mechanism of shock propagation at work in the model and assesses its performance at replicating key facts in the data. Section 5 contains conclusive remarks.

2. Entry, exit, and the business cycle

Many studies have documented the behavior of entry and exit over the cycle. A detailed survey of this literature is beyond the scope of this paper. I will rather focus on the comovements with macroeconomic variables, overlooking other important features of firms dynamics that may vary over the cycle. Among the most prominent early studies, Chatterjee and Cooper (1993) show that net business formation and new business incorporations are strongly pro-cyclical. Similarly, Devereux et al. (1996) show that business failures are counter-cyclical.[5] Floetotto and Jaimovich (2008) confirm these patterns after accounting for heterogeneity at the industry level and for the role of small firms. Broda and Weinstein (2010) have addressed the cyclicality of product variety, documenting pro-cyclical product creation and counter-cyclical product destruction. Yet evidence about volatility and smoothness is sparse. In this section, I address this omission by providing unconditional moments for entry, exit, net entry and the number of establishments in the US economy over the period 1977–2011.

Data are annual and cover the period from 1977 to 2011. Macroeconomic data are from the Bureau of Economic Analysis (BEA). Business formation data are from the Business Dynamics Statistics (BDS) of the US Census Bureau.[6] The

[3] Cavallari (2013a) shows that measuring entry costs in terms of products helps to alleviate the comovement puzzles in international business cycle models. Cavallari (2013b) shows that it helps to overcome the difficulty of entry models in reproducing the smoothness and persistence of macroeconomic variables together with the volatility of profits and markups.

[4] A recent evidence suggests the importance of product destruction for economic activity. Bernard et al. (2010) show that the lost value from product destruction represents 30 percent of US output over a 5-year horizon.

[5] These studies provide evidence from Dun & Bradstreet Reference Book and Failure Statistics reported in U.S. Department of Commerce (1975).

[6] The BDS dataset is publicly available at http://www.census.gov/ces/dataproducts/bds/. It is part of the confidential Longitudinal Business Database (LBD). It covers most of the country's economic activity. The only major exclusions are self–employed individuals, employees of private households, railroad employees, agricultural production employees, and most government employees.

Table 1
Business formation and the cycle.

	Stand dev	Stand dev rel to GDP	Corr with GDP	Corr with entry
A: Business formation				
Entry	4.96	3.85	0.29	1
Exit	5.55	4.30	−0.14	−0.18
Establishments	0.86	0.67	0.55	0.37
Net Entry	3.51	2.81	0.15	0.40
B: Business cycle				
GDP	1.29	1	1	0.19
Consumption	1.02	0.79	0.89	0.08
Investment	5.81	4.50	0.92	0.23
Hours	1.40	1.08	0.88	0.11

Note: entry (exit) is measured by the number of establishments created (shut down) in the last 12 months; net entry is the difference between entry and exit; establishments is the total number of establishments active in each year; Business formation data are from the BDS. GDP, Consumption, Investment and Hours are measured at constant prices with base year 2009 and are not seasonally adjusted. Macroeconomic data are from the BEA. Data are annual and cover the period 1977–2011. All variables are logged and HP-filtered with a smoothing parameter of 6.25.

BDS is based on longitudinal data which are collected both at the establishment and at the firm level. In what follows, I will consider plant level data for ease of comparison with other studies. I have checked that the cyclicality of the series is almost identical with firm level data. Entry (exit) is measured by a count of establishments born (shut down) during the last 12 months of each year.

The BDS covers the practical totality of private non-agricultural activity. Such a broad coverage is remarkable, especially for studies like the one in this paper which are centered on the role of business formation for the propagation of shocks. In terms of coverage, the BDS is comparable to the Survey of Current Business, a monthly data set on business formation in the US economy collected by the BEA. The BEA has discontinued the survey in the 1990s.

Early studies focusing on the manufacturing industry include, among others, Dunne et al. (1988), Dunne et al. (1989), Campbell (1998) and more recently Lee and Mukoyama (2012). The former documents heterogeneity in the pattern of entry and exit across four-digit manufacturing industries in the 5 censuses of the Census of Manufactures (CM) available at the time. Given the short time dimension, cyclicality is clearly overlooked. The latter two studies overcome the problem using the Annual Survey of Manufactures (ASM). Campbell (1998) focuses on the role of entry and exit for the propagation of technology shocks. He documents strong comovements of entry and exit with output growth and productivity. Lee and Mukoyama (2012) analyze the behavior of entry and exit rates in booms and recessions.

In what follows, all variables are logged and HP-filtered with a smoothing parameter of 6.25 as is standard practice in business cycle studies. Table 1 reports key unconditional moments: the top panel refers to entry, exit, net entry and the stock of establishments; the bottom panel considers output, consumption, investments and hours, all measured in real terms.[7]

Three facts stand out. First, the process of business creation and destruction is quite volatile. The standard deviation of entry is almost 4 times as high as that of GDP and exit is even more volatile. Not surprisingly, the behavior of entry and exit is akin to that of investments. As we will see, the similarity with investments goes as far to their role of business cycle amplifiers. A high volatility of business formation has been stressed in previous studies. Campbell (1998) reports a standard deviation of quarterly entry and exit rates over the period 1972Q2–1988Q4 as high as 23 and 26 percent, respectively (raw data).[8] Lee and Mukoyama (2012) find higher entry rates in booms than in recessions while exit rates behave similarly in booms and recessions.

Second, business formation comoves with output. Contemporaneous correlations indicate a positive comovement of entry and a negative comovement of exit. In addition, dynamic correlations (not shown in Table 1) indicate that entry lags behind exit: there is a higher comovement of entry with output in the previous year (the correlation with past GDP is 0.71) and a higher comovement of exit with future output (the correlation with one-year-ahead GDP is −0.58). The stock of establishments comoves positively with output. These statistics confirm well-known facts about the cyclicality of business formation. Quantitatively, comovements are comparable with those found in earlier studies once proper account is given to differences in the methodological approach utilized. Campbell (1998) for instance find a correlation of entry and exit rates with GDP growth in raw data equal to, respectively, 0.26 and −0.51.

Third, entry and exit are negatively correlated between each other (the correlation is −0.18), confirming a tendency for these variables to move in opposite directions over the cycle. Both entry and exit co-move with the stock of establishments (the correlation is, respectively, 0.37 and −0.24). Overall, these statistics suggests that there are many producers at the margin of market participation, implying a constant restructuring of US economic activity over the cycle.

[7] Output is real GDP, consumption is private expenditure, investment is gross investment and employment is total hours. All series are measured at constant prices with base year 2009 and are not seasonally adjusted.

[8] These statistics are not quantitatively comparable with those in Table 1 because of differences in the source, time coverage and tranformation of data. Using non-filtered, logged data, the standard deviation of entry and exit in my data set are, respectively 13 and 14 percent.

The statistics in the bottom panel confirm well-known facts about the US business cycle. Investments are far more volatile than output and strongly pro-cyclical. Consumption is smoother than output while hours are roughly as volatile as output. All macroeconomic variables comove with GDP.

3. The economy

The model combines the entry mechanism proposed by Ghironi and Melitz (2005) with a mechanism of exit based on a stochastic exit value as in Lee and Mukoyama (2012). Accounting for both the creation of new firms and the failure of incumbents has a twofold advantage. First, it allows to gauge the performance of the model at replicating the properties of entry and exit in the data. In addition, it clarifies the role of endogenous changes in market participation for the propagation of shocks. The model is set in a framework characterized by nominal frictions à la Calvo (1983). This is meant to analyze the implications of monetary policy for firms dynamics. Despite evidence that monetary policy shocks have a non-negligible effect on firm failures, previous studies have mostly overlooked the role of firm exit in monetary transmission. Moreover, it is still not clear how nominal frictions affect the costs faced by firms when entering and exiting the market and how these costs should be modeled. As will be apparent soon, the performance of the model at replicating important facts of the business cycle depends on how entry costs are measured.

3.1. The non-linear model

3.1.1. Households

The economy is populated by L identical households.

A typical household supplies H_t hours of work each period for the nominal wage W_t and consumes a basket of goods C_t, which contains all the goods available in the market. She maximizes utility over her entire lifetime $E_t\left[\sum_{s=t}^{\infty}\beta^{s-t}U(C_s, H_s)\right]$ at the subjective discount factor β. The period utility is the additive-separable function $U_t = \frac{(C_t)^{1-\rho}}{1-\rho} - \frac{\varphi\chi}{1+\varphi}(H_t)^{\frac{1+\varphi}{\varphi}}$, where $\rho > 0$ is the inverse of the inter-temporal elasticity of substitution, $\varphi \geqslant 0$ is the Frisch elasticity of labor supply and $\chi > 0$ weights the disutility of labor.

The consumption basket takes the form $C_t = A_t^M\left[\int_0^{N_t} C_t(j)^{\frac{\theta-1}{\theta}}dj\right]^{\frac{\theta}{(\theta-1)}}$ where $j \in (0, N_t)$ denotes a unique variety, N_t is the set of varieties available in the market in each period and $A_t^M \equiv N_t^{\gamma^M - \frac{\theta}{(\theta-1)}}$. As in Benassy (1996), $\gamma^M \geqslant 0$ measures consumers' love for variety and $\theta \geqslant 1$ denotes the elasticity of substitution across varieties. The welfare-based price index is $P_t = 1/A_t^M\left[\int_0^{N_t} p_t(j)^{1-\theta}dj\right]^{\frac{1}{(1-\theta)}}$ where $p_t(j)$ is the price of variety j. For future reference, I define the real price of each variety as $\varrho_t \equiv p_t(j)/P_t$.

Households enter each period with holdings of a nominal bond B_t and of a mutual fund share s_t. The real value of a share in the mutual fund is υ_t. They receive labor income, interest income on bond holdings at the risk-free nominal interest rate i_t, dividend income on share holdings d_t and the value of selling their initial share position. These resources are allocated between purchases of bonds and shares to be carried into next period and consumption. The period budget constraint (in units of consumption) is:

$$\frac{B_t}{P_t} + s_t\left(N_t + N_t^E\right)\upsilon_t \leqslant \frac{B_{t-1}}{P_t}(1 + i_t) + s_{t-1}(1 - \delta_t)(\upsilon_t + d_t)\left(N_{t-1} + N_{t-1}^E\right) + \frac{W_tH_t}{P_t} - C_t \tag{1}$$

where δ_t is an endogenous rate of firm exit that will be defined soon and N_t^E indicates new entrants.

Households' first order conditions are given by:

$$\frac{(C_t)^{-\rho}}{P_t} = \beta E_t\left(\frac{(C_{t+1})^{-\rho}}{P_{t+1}}(1 + i_{t+1})\right) \tag{2}$$

$$(C_t)^{-\rho} = \beta(1 - \delta_t)E_t\left[\frac{d_{t+1} + \upsilon_{t+1}}{\upsilon_t}(C_{t+1})^{-\rho}\right] \tag{3}$$

$$C_t(j) = \left(A_t^M\right)^{\theta-1}\varrho_t^{-\theta}C_t \tag{4}$$

$$\frac{W_t}{P_t} = \chi(H_t)^{\frac{1}{\varphi}}(C_t)^{\rho} \tag{5}$$

3.1.2. Firms

The economy comprises a manufacturing sector, denoted by the superscript M, which produces goods used for consumption and investment purposes, and a start-up sector, denoted by the superscript E, which creates new firms/varieties. Producers face a linear technology $y_t(j) = Z_tH_t(j) + S_j$, where Z_t is an aggregate productivity shock and S_j is a firm-specific fixed factor.

In each period, in addition to incumbents there is a finite mass of entrants, N_t^E. As in Ghironi and Melitz (2005), entry implies a one period production lag so that all firms entered in a given period are able to produce in all subsequent periods until they leave the market. First-time entrants pay a sunk cost f_t^e to start production in period $t+1$. The presence of sunk entry costs is amply documented.[9]

The start-up of a new firm requires a combination of labor and capital $N_t^E = \left(Y_t^E\right)^{1-\epsilon}(H_t)^{\epsilon}$ where $\epsilon \in (0,1)$ and capital consists of a composite basket of products $Y_t^E = A_t^E\left[\int_0^{N_t} y_t(j)^{\frac{\theta-1}{\theta}}dj\right]^{\frac{\theta}{\theta-1}}$. Here, $A_t^E \equiv N_t^{\gamma^E - \frac{\theta}{(\theta-1)}}$ is an indicator of efficiency of investment analog to love of variety for consumption. The cost of entry is therefore $f_t^e = \left(P_t^E/P_t\right)^{1-\epsilon}(W_t/Z_tP_t)^{\epsilon}$ and the price of materials is $P_t^E = 1/A_t^E\left[\int_0^{N_t} p_t(j)^{1-\theta}dj\right]^{\frac{1}{(1-\theta)}}$.

In previous studies, entry costs have been modeled either in terms of wages (see, among others, Bilbiie et al. (2012), Auray and Eyquem (2011), Auray et al. (2012), Cavallari (2007) and Cavallari (2013b)) or in terms of capital (for instance, Bergin and Corsetti (2008), Cavallari (2013a) and Arespa Castellò (2012)). For ease of comparison with these studies, I will consider a parametrization with $\epsilon = 1$ (only wage costs) and a parametrization with $\epsilon = 0$ (only capital costs).

Entrants start a new firm whenever its real value, υ_t, given by the present discounted value of the expected stream of profits $\{d_s\}_{s=t+1}^{\infty}$, covers entry costs. The free entry condition is therefore $\upsilon_t = f_t^e$.[10]

In departing from Ghironi and Melitz (2005), I consider an endogenous mechanism of exit. Firms' exit decisions have been extensively analyzed in the context of studies of industry dynamics. In these models, the solution to the optimal exit problem can be described by a threshold on some firm-specific dimension, typically firm productivity. Growing interest for the business cycle implications of firm dynamics has led many authors to incorporate exit decisions also in models of aggregate fluctuations (see, among others, Clementi and Palazzo (2013), Jaimovich (2007) and Floetotto and Jaimovich (2008)). In the context of DSGE models, it is often assumed that exit occurs at no cost on a period-by-period basis (see, for instance, Totzek (2009) and La Croce and Rossi (2014)). Therefore, firms compare the value of staying – defined as the discounted value of current and future profits – with the value of exiting, which is zero by construction. Given heterogeneous productivity across firms, a threshold productivity can be defined such that when productivity is above the threshold the firm stays; if productivity is below, the firm exits. Since firm'size and productivity have a one-to-one relation in these models, this means a 100% exit rate for small firms, i.e. firms with low productivity, and zero for large firms. However, Lee and Mukoyama (2012) document that even large plants with more than 250 employees have an exit rate of over 1%: although exit rates are indeed higher in small firms, some large firms also exit and some small firms also stay. For this motive, I consider heterogeneous scrap values of firm-specific capital S_j. At the beginning of each period, before production takes place, each firm will observe its stochastic exit value S_j and will leave the market if the scrap value of its capital is higher than the continuation value.[11] In this way, exit rates are between zero and one for firms of any size. Specifically, I assume scrap values S_j to be Pareto distributed across firms. In each period the fraction of firms that leave the market is therefore $\delta_t \equiv \Pr(S_j > \upsilon_t) = 1 - \Gamma(\upsilon_t)$ where $\Gamma = 1 - \left(\frac{S_j}{S_{\min}}\right)^{-\varkappa}$ is the cumulative distribution function of S_j, $\varkappa$ controls the curvature of the distribution and $S_{\min}$ controls the level. All firms with a scrap value draw higher than the continuation value (the share price) will leave the market: for the property of the Pareto distribution, a small fraction of firms will exit after a large rise in the scrap value (or a large fall in firm value).

The timing of entry and exit together with the one-period production lag imply the law of motion for producers $N_t = (1-\delta_t)(N_{t-1} + N_{t-1}^e)$.

3.1.3. Pricing

Firms in the manufacturing sector face a downward-sloping market demand given by:

$$y_t(j) = \varrho_t^{-\theta}\left[\left(A_t^M\right)^{\theta-1}C_t + \left(A_t^E\right)_t^{\theta-1}\left(\frac{P_t}{P_t^E}\right)^{-\theta}Y_t^E\right] \tag{6}$$

where the first addend is demand for consumption purposes and the second addend is demand for investment purposes.

I consider nominal rigidities à la Calvo (1983). In each period a firm can set a new price with a fixed probability $1-\alpha$ which is the same for all firms, both incumbents and 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.[12] As argued in

[9] Many studies infer the existence of these costs from the persistence in market participation patterns. Examples include, among others, Roberts and Tybout (1997), Campa (2004), Bernard and Jensen (2004), Bernard and Wagner (2001). Das et al. (2007) pin down the magnitude of entry costs based on their non-linear effects on market participation.

[10] The free entry condition holds as long as the mass of entrants in positive. In what follows, I assume that shocks are small enough for this condition to hold in every period.

[11] Modelling the exit decision using stochastic scrap values is popular in the industrial organization literature (see Doraszelski and Pakes (2007) and Weintraub et al. (2008)).

[12] The pre-determined price is the average market price in the preceding period.

Cavallari (2013a), the assumption that entrants behave like incumbents is without loss of generality in a setup with price staggering. The same cannot be said with price adjustment costs à la Rotemberg (1982). These costs imply that all firms (rather than a fraction of them) adjust prices simultaneously and identically in each period. Allowing entrants to make their first price-setting decision at no additional cost would then introduce heterogeneity in price levels across cohorts of firms that entered at different points in time (see the discussion in Bilbiie et al. (2008)). As the number of price setters that face no cost of adjusting to a past pricing decision moves over the cycle, the aggregate degree of price stickiness becomes endogenous. The analysis of endogenous changes in price stickiness is beyond the scope of this paper.

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. This yields:

$$p_t(j) = \frac{\theta}{\theta-1}\frac{E_t\sum_{k=0}^{\infty}(\alpha\beta(1-\delta_t))^k\frac{W_{t+k}}{Z_{t+k}}\frac{y_{t+k}(j)}{P_{t+k}C_{t+k}^{-\rho}}}{E_t\sum_{k=0}^{\infty}(\alpha\beta(1-\delta_t))^k\frac{y_{t+k}(j)}{P_{t+k}C_{t+k}^{-\rho}}} \tag{7}$$

Clearly, when $\alpha = 0$ the optimal price implies a constant markup $\frac{\theta}{\theta-1}$ on marginal costs at all dates. With $\alpha > 0$, prices are disconnected from marginal costs and profit margins turn time-varying. The expression above together with the definitions of P and P^E, yield the Calvo state equations corrected for firm entry:

$$(P_t)^{1-\theta} = \left(A_t^M\right)^{\theta-1}\left[\alpha\frac{N_t}{N_{t-1}}(P_{t-1})^{1-\theta} + (1-\alpha)N_t(p_t(j))^{1-\theta}\right] \tag{8}$$
$$\left(P_t^E\right)^{1-\theta} = \left(A_t^E\right)^{\theta-1}\left[\alpha\frac{N_t}{N_{t-1}}\left(P_{t-1}^E\right)^{1-\theta} + (1-\alpha)N_t(p_t(j))^{1-\theta}\right]$$

In these equations, an increase in N_t may reduce or increase the aggregate price level depending on how much consumers and investors value the benefit of spreading expenditure over more products relative to the benefit of acquiring more of each variety.

3.1.4. Aggregate constraints

Output of the manufacturing sector is defined as $Y_t^M \equiv \int_0^{N_t}\varrho_t y_t(j)dj$. Aggregating market demand (6) across firms yields the market clearing condition $Y_t^M = C_t + \frac{P_t^E}{P_t}Y_t^E$. Aggregate accounting implies that GDP, i.e. output of the manufacturing sector plus output of the start-up sector, coincides with labor and profit income, $Y_t = \frac{W_t}{P_t}H_t + d_tN_t$.

Labor market clearing requires labor supply to equalize labor demand from the manufacturing sector H^M plus labor demand from the start-up sector H^E:

$$H_t \geqslant H_t^M + H_t^E = \int_0^{N_t}\frac{y_t(j)}{Z_t}dj + N_t^E\left[\frac{\epsilon}{1-\epsilon}\frac{P_t^E}{W_t}\right]^{(1-\epsilon)} \tag{9}$$

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.

3.2. The linearized model

The model is solved in log-deviations from a symmetric, deterministic steady state with zero inflation (Appendix A contains the steady state of the model) . In what follows, hatted variables denote deviations from the steady state while variables without a time subscript denote steady state values.

Optimal conditions for households are given by:

$$E_t\widehat{C}_{t+1} = \widehat{C}_t + \frac{1}{\rho}\left(\widehat{i}_t - E_t\pi_{t+1}\right) \tag{10}$$
$$E_t\widehat{C}_{t+1} = \widehat{C}_t + \widehat{v}_t + \frac{1}{\rho}E_t\left(\frac{i+\delta}{1+i}\widehat{d}_{t+1} + \beta(1-\delta)\widehat{v}_{t+1}\right) \tag{11}$$
$$\widehat{H}_t = -\rho\varphi\widehat{C}_t + \varphi\widehat{w}_t \tag{12}$$

where $\widehat{w}_t$ is the (log-linearized) real wage.

Product prices, CPI inflation $\pi_t \equiv \ln(\widehat{P}_t/\widehat{P}_{t-1})$ and markups $\widehat{\mu}_t$ are given by, respectively:

$$\widehat{\varrho}_t = (\theta-1)\widehat{A}_t^M + \frac{\alpha}{1-\alpha}\pi_t + \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_t - \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{t-1} \tag{13}$$

$$\pi_t = \zeta\left[(\theta-1)\widehat{A}_t^M + \left(\rho+\frac{1}{\varphi}\right)\widehat{C}_t - \frac{1}{(1-\alpha)(\theta-1)}\widehat{N}_t - \frac{(1+\varphi)}{\varphi}\widehat{Z}_t + \frac{\alpha}{(1-\alpha)(\theta-1)}\widehat{N}_{t-1}\right] + \beta(1-\delta)E_t\pi_{t+1} \tag{14}$$

$$\widehat{\mu}_t = \alpha\beta(1-\delta)(E_t\widehat{Q}_{t+1} - \widehat{w}_t + \widehat{Z}_t) \tag{15}$$

where $\zeta = \frac{(1-\alpha\beta(1-\delta))(1-\alpha)}{\alpha(\varphi+\theta)}$ and $\widehat{A}_t^M = \left(\gamma^M - \frac{\theta}{(\theta-1)}\right)\widehat{N}_t$.

Eq. (13) represents the so-called variety effect, i.e. the link between the price of each product and the number of varieties available in the market. As stressed by Benassy (1996), the sign of the variety effect depends on the marginal benefit of consuming more of each variety, γ^M, relative to the marginal benefit of consuming a larger array of varieties, $\frac{\theta}{(\theta-1)}$. Note that sticky prices increase the persistence of the variety effect.

Eq. (14) is a variant of the new-Keynesian Phillips curve corrected for firm entry as in Cavallari (2013a).[13] The term in square brackets expresses deviations of real marginal costs from their steady state value. These deviations are due to changes in market demand, $\widehat{A}_t^M$ and $\widehat{C}_t$, and changes in supply factors, $\widehat{N}_t$ and $\widehat{Z}_t$. Compared to the standard new-Keynesian Phillips curve:

$$\pi_t = \bar{\zeta}\widehat{mc}_t + \beta E_t\pi_{t+1}$$

where $\bar{\zeta} = \frac{(1-\alpha\beta)(1-\alpha)(1+\varphi)}{\alpha}$ and $\widehat{mc}_t$ denotes marginal costs, the Phillips curve (14) implies a more moderate reaction of inflation to changes in real marginal costs, i.e. $\zeta < \bar{\zeta}$. As stressed in Etro and Rossi (2015), this helps overcome the difficulty of standard new-Keynesian models to generate an empirically plausible response of inflation with no need to resort to strong nominal rigidity.[14]

Eq. (15) is derived using optimal pricing (7) together with the definition of aggregate markups $\mu_t = \int_0^{N_t} p_t(j)Z_t/W_t dj$.[15] As already discussed, markups are constant with flexible prices, $\alpha = 0$.

The law of motion of firms is:

$$\widehat{N}_t = (1-\delta)\widehat{N}_{t-1} + \delta\widehat{N}_{t-1}^E - \frac{\delta}{1-\delta}\widehat{\delta}_t$$

where $\widehat{\delta}_t = -\varkappa\widehat{\upsilon}_t$. The free entry condition is:

$$\widehat{\upsilon}_t = \epsilon(\widehat{w}_t - \widehat{Z}_t) + (1-\epsilon)(\gamma^M - \gamma^E)\widehat{N}_t \tag{16}$$

Here, entry takes place until the value of the firm, the LHS of the equation above, equalizes the sunk entry cost, the RHS. The first addend on the RHS is the wage cost while the second addend is the capital cost. Note that an increase in the number of firms may reduce or increase the price of capital in units of consumption depending on the degree of love for variety of consumers and entrants.

Other log-linear equilibrium conditions involve, in the following order, the production function, aggregate accounting and market clearing in the goods and the labor markets:

$$\widehat{Y}_t^M = \widehat{H}_t^M + \widehat{Z}_t + \widehat{Q}_t$$

$$\widehat{Y}_t = \frac{wH}{Y}\left(\widehat{w}_t + \widehat{H}_t\right) + \frac{dN}{Y}\left(\widehat{d}_t + \widehat{N}_t\right) \tag{17}$$

$$\widehat{Y}_t = \frac{C}{Y}\widehat{C}_t + \frac{\upsilon N^E}{Y}(\widehat{N}_t^E - \widehat{\upsilon}_t) \tag{18}$$

$$\widehat{H}_t = \frac{H^M}{H}\widehat{H}_t^M + \frac{H^E}{H}\widehat{H}_t^E$$

The exogenous process for productivity is:

$$\widehat{Z}_t = \rho_z\widehat{Z}_{t-1} + \epsilon_t^z$$

where innovations ϵ_t^z are distributed normally and independently of each other with variance σ_z.

Monetary policy is represented by the Taylor rule:

$$\widehat{i}_t = \phi_i\widehat{i}_{t-1} + \phi_y\widehat{Y}_t + \phi_\pi\pi_t + \epsilon_t^M$$

where innovations ϵ_t^M are distributed normally and independently of each other with variance σ_M.

---

[13] See Appendix for details on the derivation of the Phillips curve.

[14] Estimated values for the coefficient of marginal costs in the Phillips curve range between 0.03 and 0.06 (see Levin et al. (2007)). With $\varphi = 4$ and $\beta = 0.96$ as in my baseline calibration, the standard new-Keynesian Phillips curve requires almost one year of price staggering to provide a reasonable $\bar{\zeta}$ while a half year is sufficient for ζ.

[15] I used the following approximation to (7) in deriving the expression for markups: $\widehat{p}(j)_t = (1-\alpha\beta(1-\delta))\left(\widehat{W}_t - Z_t\right) + \alpha\beta(1-\delta)E_t(\widehat{p}(j)_{t+1})$.

4. Numerical analysis

This section simulates the model using second-order perturbation methods as in Schmitt-Grohe and Uribe (2004).[16] I start with a description of the mechanics of shock propagation at work in the model in the wake of productivity and monetary policy shocks. Then, I focus on productivity shocks with the purpose of comparing unconditional theoretical moments with US data.

4.1. Calibration

The calibration refers to the United States. Periods are interpreted as years. Consistent with most macroeconomic studies, the interest rate is $i = 0.04$ and $\beta = 0.96$. There is no direct information about the parameters that characterize the distribution of scrap values. The level parameter has no consequences for the dynamics of the model and can be normalized to one without loss of generality. The shape parameter is chosen to reproduce the standard deviation of the firm exit rate, implying $\varkappa = 2.1$. [17] In calibrations with a fixed exit rate, the probability of exit is set at $\delta = 0.10$ to match the empirical level of job destruction per year as in Bilbiie et al. (2012).

For ease of comparison with previous studies, the parametrization of consumers' preferences is based on Bilbiie et al. (2012): the inter-temporal elasticity of substitution is $\rho = 1$, the Frisch elasticity is $\varphi = 4$, the disutility of labor is normalized so that the steady state level of employment is equal to one and the elasticity of substitution across varieties is $\theta = 3.8$. The choice of θimplies markups as high as 35 percent. Most macroeconomic studies consider a higher θ and a lower markup more in line with aggregate data. Rotemberg and Woodford (1999) for instance document a markup of about 18 percent in US data. I have checked that using $\theta = 7.8$ so as to reproduce a steady state markup of 18 percent has no major consequences for the analysis.

The parameters of love for variety are probably the most difficult to motivate. I follow Bergin and Corsetti (2008) and set $\gamma^M = 1$ for consumption goods and $\gamma^E = 1.2$ for capital goods. This implies that an increase in the number of varieties will have a negative effect on the price of capital in units of consumption. I have also experimented with $\gamma^M \geqslant \gamma^E$.

In the baseline calibration, entry costs are in terms of both wages and capital with weights equal to, respectively, $\epsilon = 0.4$ and $1 - \epsilon = 0.6$. For ease of comparison with other studies, I consider calibrations with $\epsilon = 0$ (capital entry costs) and $\epsilon = 1$ (labor entry costs).

The degree of nominal rigidity is $\alpha = 0.49$, the middle point from the interval of values estimated by Galì et al. (2001) for the US. This implies an average duration of nominal contracts of around a half year. In the baseline calibration, the parameters of the Taylor rule draw on Bilbiie et al. (2008), $\phi_i = 0.8$, $\phi_y = 0$ and $\phi_\pi = 0.3$. I have also considered positive values for the coefficient on output in the range $\phi_y \in (0, 2)$.

The parameters of the exogenous productivity process are an annualized version of those in King and Rebelo (1999), implying $\rho_z = 0.815$ and $\sigma_z = 0.013$. Given the scope of the analysis, which is focused on matching some business cycle facts, this provides a useful benchmark. The parameters of monetary policy shocks are set at $\rho_M = 0$ and $\sigma_M = 0.01$ for the purpose of illustrating the mechanism of monetary transmission in the model.

4.2. Impulse responses

This section provides a qualitative description of the mechanics of shock propagation at work in the model. For this purpose, Fig. 1 and 2 show the impulse responses of key endogenous variables to a one standard deviation shock to labor productivity. Fig. 3 shows impulse responses to a one standard deviation shock to the nominal interest rate. The vertical axis shows percentage deviations from the steady state (a value of, say, 1 denotes a 1 percent deviation) and the horizontal axis shows the number of periods (years) after the shock. The impulse responses refer to the baseline model, (solid line), the model with capital entry costs, $\epsilon = 0$, (dashed line), and the model with labor entry costs, $\epsilon = 1$, (dotted line).

To start with, consider the baseline model. The rise in labor productivity makes the business environment more attractive for both incumbents and new firms. Incumbents take advantage of the productivity improvement by increasing their size (the intensive margin). The hike in firm size is high on impact, then it monotonically declines towards the steady state. Entrants start a new business (the extensive margin) whenever the equilibrium firm value, measured by the share price $\widehat{\upsilon}_t$, covers entry costs. The response of entry is very large on impact and takes approximately seven years to return back to the steady state. A favorable business scenario reduces the incentives to leave the market, leading to a drop in firm exits. Entry of new firms together with less exits translate into a gradual increase in the number of producers over time. Notice that the availability of more varieties leads to a fall in the product price $\widehat{\rho}_t$ because of a moderate love for variety. In the baseline calibration, in fact, the marginal benefit of consuming more products is less than the marginal benefit of consuming more of each product. For the same motive, there is a fall in the aggregate price level (not shown in Figure).

Lower prices have in principle an ambiguous effect on firms' profits. On the one side, they boost market demand, increasing revenues and profits. On the other side, however, they reduce profit margins. Interestingly, the baseline calibration

[16] Simulations are made with Dynare. The algorithm used to compute a quadratic approximation of the decision rules is described in Collard and Juillard (2001).

[17] The shape parameter is such that $\sqrt{\frac{\varkappa(S\min)^2}{(\varkappa-1)^2(\varkappa-2)}} = 5.5$.

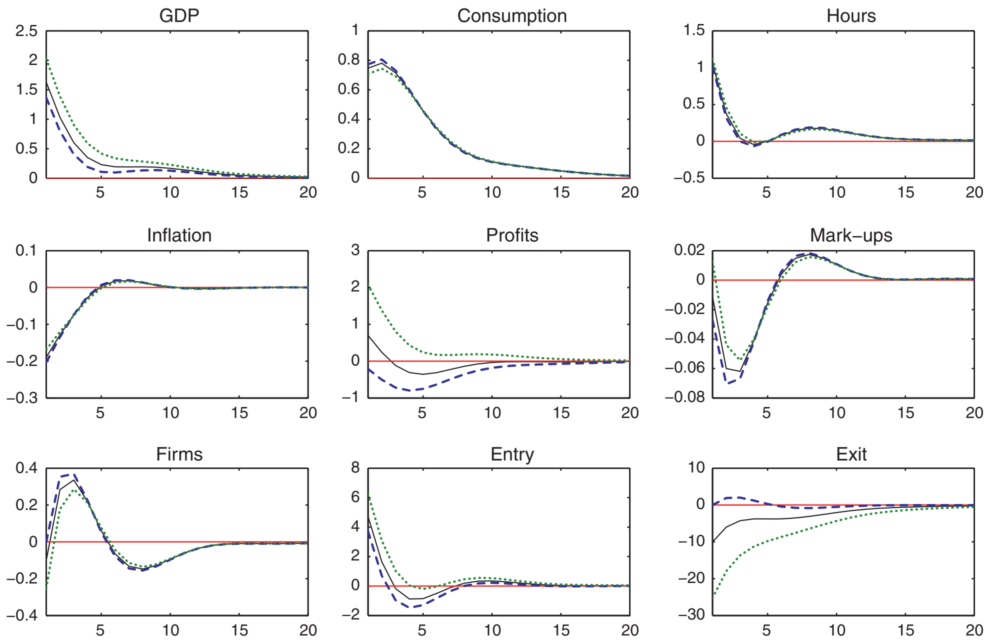

Fig. 1. IRF to a 1% labor productivity shock in the baseline calibration (solid line), with capital entry costs (dashed line) and with labor costs (dotted line).

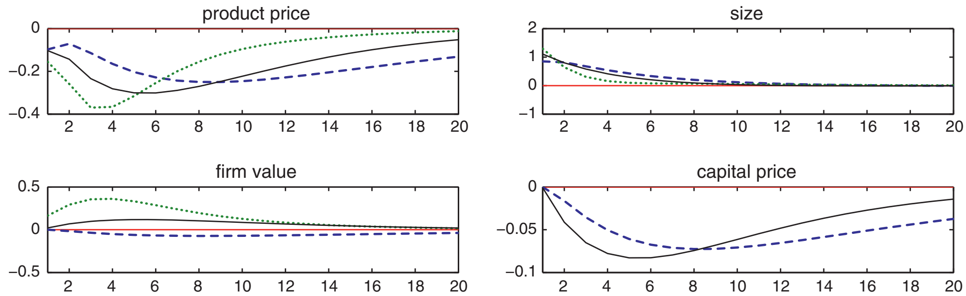

Fig. 2. IRF to a 1% labor productivity shock in the baseline calibration (solid line), with capital entry costs (dashed line) and with labor costs (dotted line).

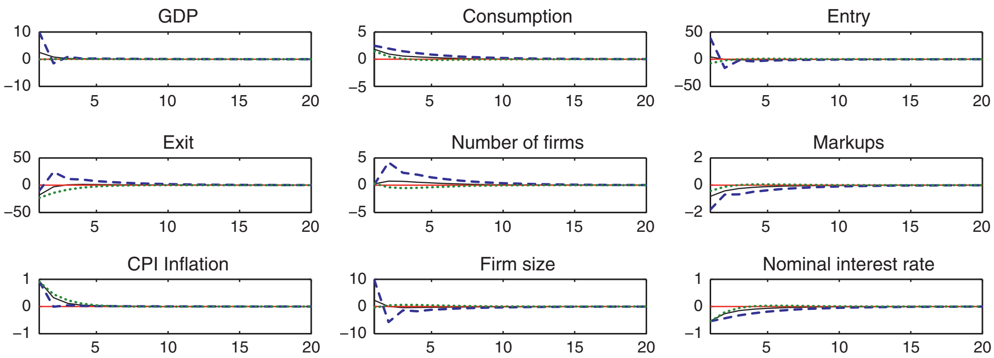

Fig. 3. IRF to a one standard deviation shock to the interest rate in the baseline model (solid line), in the model with capital entry costs (dashed line) and in the model with wage costs (dotted line).

provides pro-cyclical profits together with counter-cyclical markups in line with evidence.[18] The capacity to capture these facts simultaneously constitutes a major advantage relative to standard (fixed variety) business cycle models.

[18] Studies that document counter-cyclical mark-ups in the US include, among others, Rotemberg and Woodford (1999) and Bils (1987). In contrast with these studies, Nekarda and Ramey (2013) find that mark-ups are pro-cyclical or a-cyclical in the US.

The productivity rise leads to a less than proportional increase in consumption. This reflects the optimal allocation of resources between the manufacturing sector (consumption) and the start-up sector (entry). In cyclical upturns, the return on investments is high because the present share value is low relative to the future and because share payoffs (firms profits) are high. Agents are therefore induced to postpone consumption in the future. In the model, the only way to transfer resources over time is by creating a new firm. Finally, the increase in both investments and consumption lead hours and output above their steady state level throughout the transition. These effects are quite persistent.

Now, consider alternative calibrations where entry costs are measured as product prices or as wages. Macroeconomic dynamics is almost unaffected, with the exception of exit behavior. As it will be clear soon, the capacity to reproduce a plausible dynamics of exit has important consequences for the performance of the model at matching data. With entry costs as wages there is a sharp fall in the number of exiting firms (up to 20 times as large as the shock) together with a hike in profits and firm value. The response of exit is almost twice as large as in the baseline calibration. The reason is a pro-cyclical behavior of wages.

Mechanically, entry costs affect the exit rate through their impact on firm value (recall that in equilibrium firm value exactly covers entry costs). The value of the firm, in turn, is inversely related to the probability of exit. In cyclical upturns, the pressure on labor demand from incumbents and entrants raises wages and entry costs. High entry costs in turn boost equity prices through the free entry condition. This implies a strong incentive for incumbents to stay in the market and reduce exits. In Fig. 1, the fall of exit is very large indeed when $\epsilon = 1$. However, while a pro-cyclical behavior of wages is plausible, the same cannot be said for entry costs. Despite sparse evidence, especially at the business cycle frequency, entry costs seem to be a-cyclical or at most negatively correlated with economic activity.[19] The difficulty to match the cyclicality of entry costs in the data constitutes a major drawback of models that measure these costs with wages.

In this respect, considering additional measures, as is done in my setup, may help solve the problem. In the baseline calibration, a fall in the real price of capital P^E/P reduces the rise in entry costs brought about by wages and dampens the response of exits. In calibrations with only capital costs ($\epsilon = 0$), entry costs fall – driven by a drop in the price of capital in terms of consumption – and the response of exit turns slightly positive. The reason is a low incentive to stay in the market. The drop in entry costs, in fact, depresses share values and may lead incumbents to leave the market despite a favorable business environment.[20]

Consider now monetary policy shocks. Fig. 3 shows impulse responses to a one standard deviation shock to the nominal interest rate in the baseline model and in variants with entry costs measured as wages or as capital prices. The shock is purely temporary. Notice that interest rate smoothing implies a prolonged fall in the nominal interest rate despite the shock lasts for one period only. The model captures a reasonable mechanism of monetary transmission. A monetary easing boosts aggregate demand as long as prices are sticky. The rise in market demand in turn leads to a burst of inflation for a period of around 5 years. Falling nominal rates together with sluggish inflation reduce real interest rates and induce agents to consume more in the early part of the transition. Macroeconomic dynamics is almost identical across different parametrizations of entry costs.

Entry costs do matter as long as firms dynamics is concerned. In particular, the response of entry is positive as in the data except for calibrations with very high values of ϵ. With entry costs measured as wages ($\epsilon = 1$), the number of entrants actually falls at odds with data. As already discussed, the reason is an endogenous increase in wage (entry) costs that discourages the start-up of new firms. These findings confirm the difficulty – first stressed by Bergin and Corsetti (2008) – to reproduce a plausible mechanism of monetary transmission in models with entry costs measured as wages. Quantitatively, the response of entry is higher the lower ϵ. The reason is a strong incentive to invest in start-ups when entry costs fall.

As regards exit behavior, responses are negative on impact in line with estimated responses in all calibrations considered. As far as I know, this is the first attempt to capture this feature of the data. Entry costs do affect the dimension of the response. With $\epsilon = 1$, pro-cyclical costs imply a strong incentive for incumbents to stay in the market. The monetary expansion leads to a sharp fall in exit rates. On the opposite extreme with $\epsilon = 0$, counter-cyclical costs imply a much weaker incentive that reflects into a smaller drop of exits. Over time, the fall in share value brought about by entry costs may induce incumbents to leave the market and the response of exit may turn positive. In my setup, this occurs for very low values of ϵ when $\gamma^E \leqslant \gamma^M$.

In the baseline calibration, the weight of output in the monetary rule is zero as in Bilbiie et al. (2008). This stands in contrast with evidence documenting a non-negligible role of output stabilization for the conduct of the US Federal Reserve. I have therefore experimented with the whole range of values in the interval $\phi_y \in (0, 2)$. Fig. 4 and 5 show impulse responses to, respectively, nominal interest rate and productivity shocks in the baseline model and in calibrations with different weights of output in the Taylor rule.

Simulations reveal that a higher weight of output unambiguously reduces macroeconomic volatility in the aftermath of monetary policy shocks. In Fig. 4 all responses are less pronounced with a high ϕ_y : ϕ_y = 0.5 implies responses that are 50%

[19] Using the Doing Business Survey of the World Bank, Barseghyan and Di Cecio (2011) document that entry costs are negatively correlated with both output and the entry rate in a large panel of countries. On average, the correlation of start-up costs with real GDP per worker is −0.37 while the correlation with the entry rate is −0.15. The start-up cost is measured as a percentage of the economy's income per capita. It includes all legal fees and professional and legal services when these are required by the law.

[20] I have experimented with different degrees of love for variety in order to assess the role of product prices (recall that a productivity rise reduces P^E/P as long as $\gamma^E > \gamma^M$). Simulations with $\epsilon = 0$ and $\gamma^E \leqslant \gamma^M$, provide a rise in entry costs and a negative response of exits.

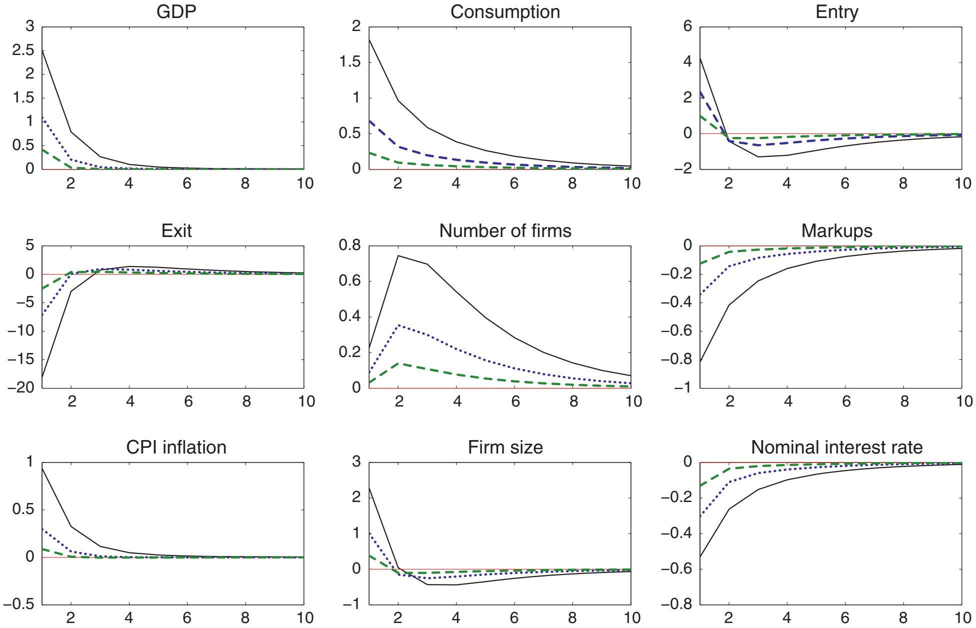

Fig. 4. IRF to a one standard deviation shock to the nominal interest rate in the baseline calibration (solid line), with $\phi_y = 0.5$ (dotted line) and with $\phi_y = 2$ (dashed line).

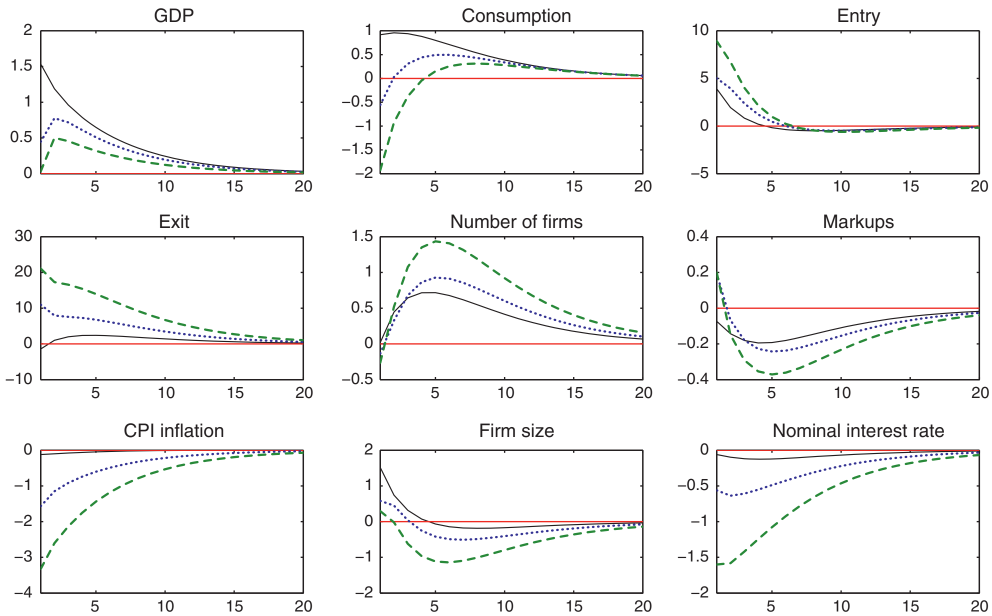

Fig. 5. IRF to a one standard deviation shock to labor productivity in the baseline calibration (solid line), with $\phi_y = 0.5$ (dotted line) and with $\phi_y = 2$ (dashed line).

lower compared to the baseline $\phi_y = 0$. With $\phi_y = 2$ responses fall by more than 4 times. As is expected, monetary authorities will have a stronger incentive (and a higher ability) to counteract the effects of shocks that move output and prices in the same direction.

A higher output weight in the Taylor rule has constrasting implications for macroeconomic dynamics in the aftermath of productivity shocks (see Fig. 5). Clearly, monetary authorities face a trade-off when shocks move output and prices in opposite directions. A high output weight moves the balance towards output stabilization (the response of output is smaller the higher ϕ_y) at the cost of nominal volatility (more deflation and strongly pro-cyclical interest rates). Interestingly, resources

Table 2
Theoretical moments.

	Baseline	Fixed exit	Fixed variety	$\epsilon = 1$	$\epsilon = 0$	Data
Stand dev rel to GDP						
Consumption	0.77	0.73	0.51	0.55	0.94	0.79
Investment	4.5	4.3	0.26	3.67	3.13	4.5
Hours	0.78	0.54	0.69	0.45	0.68	1.0
Entry	4.0	4.1	–	2.54	2.73	3.8
Exit	5.3	0	–	14.1	2.11	4.3
Firms	0.66	0.92	0	0.19	0.39	0.64
Corr with GDP						
Consumption	0.92	0.93	0.85	0.92	0.84	0.89
Investment	0.86	0.81	0.94	0.98	0.85	0.92
Hours	0.79	0.62	0.98	0.91	0.91	0.88
Entry	0.22	0.46	–	0.92	0.65	0.29
Exit	−0.76	1	–	−0.98	0.39	−0.14
Firms	0.54	0.64	1	−0.01	0.39	0.15

Note: rows contain standard deviations relative to GDP and correlations with GDP. Columns refer to calibrations in the baseline model, the model with a fixed exit rate (fixed exit), the model with no entry (fixed variety), the model with entry costs as wages ($\epsilon = 1$), the model with entry costs as capital ($\epsilon = 0$) and US data from Table 1.

shift from the manufacturing to the start-up sector: the response of entry and exit are higher the higher ϕ_y while that of consumption turns negative. Intuitively, in a deflationary scenario agents are induced to postpone consumption in the future because of high real interest rates. In addition, falling share prices reduce the benefits of staying in the market, favouring exits. This in turn will make more resources available for investments in start-ups.

4.3. Second moments

This section compares the second moments implied by the model with the evidence discussed above. Theoretical moments are computed by simulating the model for 2100 periods and dropping the first 200 observations. As is common in models with endogenous varieties, all variables that are measured in consumption units are divided by the product price so as to net out the effect of changes in the range of available varieties. As stressed by Ghironi and Melitz (2005), the correction is necessary because statistical measures of CPI inflation are unable to adjust for the availability of new products as in the welfare-based price index. In addition, all variables are HP-filtered with a smoothing parameter of 6.25 for consistence with data.

In the data, entry and exit are a simple count of the number of firms that have entered or left the market in the previous year. The corresponding theoretical measures are, respectively, N_t^e and $\delta_t N_t$. Investments in the model are given by the real value of start-up investments $\upsilon_t P_t^E N_t^e / P_t$, a measure not directly comparable with investments in the data. Nonetheless, the properties of these variables are in principle similar: the creation of new firms contributes to the accumulation of a state variable, the stock of firms, which behaves much like capital in standard (fixed variety) business cycle models.

Table 2 reports summary statistics for consumption, investments, hours, entry, exit and the number of firms. The top rows display the standard deviation of each variable relative to the standard deviation of GDP while the bottom rows display the correlation of each variable with GDP. Columns refer to different parametrization of the model except for the last one which reports US data from Table 1. Given the scope of the analysis, which is focused on the role of entry and exit for the propagation of shocks, I compare the baseline model with a version that features a given exit rate (fixed exit) and a version with a fixed number of firms (fixed variety). For ease of comparison with previous studies, I also consider simulations with entry costs as wages, $\epsilon = 1$, and with entry costs as capital, $\epsilon = 0$.

The baseline model can reproduce important facts about business formation. Entry and exit are far more volatile than output and the ranking of volatility is consistent with the data. Entry is pro-cyclical, exit is counter-cyclical, they are negatively correlated between each other (the correlation, not shown in Table, is −0.62) and both are correlated with the stock of firms (the correlation is, respectively, 0.11 and −0.16). Firm volatility is very close to the data. On a less positive tone, exits are too counter-cyclical while firms are too pro-cyclical compared to the data. Remarkably, the model can match these facts together with key properties of the US business cycle. In particular, consumption and investments are as smooth and pro-cyclical as the data. On the other hand, hours are too smooth and less pro-cyclical than the data.

A comparison across specifications reveals interesting insights about the role of entry and exit in the model. First, models that allow for some form of firm dynamics outperform the model with a fixed number of firms: the second moments of all variables are indeed closer to the data when firms are allowed to enter and/or exit the market. The fact that firm dynamics helps to improve the performance of artificial economies at matching business cycle data was stressed by Bilbiie et al. (2012) and confirmed by subsequent studies. The model in this paper makes no exception.

Second, the baseline model fares favorably relative to a specification with fixed exit. In particular, it generates a volatility of the stock of producers very close to the data. In addition, it provides more plausible moments for investments and hours. I view the performance of the model with endogenous exit as a relative success. It generates second moments that are comparable with those of other entry models. In addition, it captures the properties of business formation in the data fairly well. Last but not least, it clarifies the role of exit in the propagation of shocks. Intuitively, counter-cyclical exit movements help to attenuate the excessive smoothness of macroeconomic variables that is typically found in models with a given exit rate.

Consider now entry costs. I have experimented with the whole range of admissible values for ϵ although only a few illustrative cases are reported in Table 2 for the sake of brevity. The quantitative performance of the model is sensitive to changes in the composition of entry costs in the neighborhood of extreme values. The baseline model, which features both labor and capital costs, performs better than specifications with either labor ($\epsilon = 1$) or capital costs ($\epsilon = 0$). In particular, these fail to generate a volatility of investments, entry, hours and firms as high as in the data. Moreover, the model with $\epsilon = 0$ (capital costs) provides too volatile consumption and too smooth exits. In addition, it implies pro-cyclical exit at odds with the data. As already stressed, the reason is a counter-cyclical behavior of entry costs which implies an incentive for incumbents to leave the market in cyclical upturns. In the model with $\epsilon = 1$, on the contrary, consumption is too smooth, exit is too volatile and too counter-cyclical. The reason in this case is the pro-cyclical movement of wages, which implies a strong incentive for firms to stay in the market and reduce exits. A lesson one might draw from these exercises is the importance of entry cost specification. A model aimed at reproducing a plausible mechanism of entry and exit needs to incorporate endogenous movements in these costs as close as possible to the data. Strongly pro-cyclical costs amplify the effects of entry and exit far beyond what is observed in the data. Excessive counter-cyclicality, on the opposite extreme, dampens the propagation of shocks.

Yet only a few studies have considered the implications of entry costs for the performance of theoretical economies at matching data. In open economies, Cavallari (2013a) shows that imported materials in the setup of new firms help to replicate positive comovements in the international business cycle. Others, have suggested that capital costs perform favorably compared to wage costs at replicating a plausible mechanism of monetary transmission (Bergin and Corsetti, 2008) together with important features of the domestic business cycle (Cavallari, 2013b). The reason is easy to grasp. A monetary expansion, by reducing the price of capital in terms of consumption, fosters entry of new firms as in the data. With labor costs, on the contrary, the pressure on labor demand implied by a monetary easing raises wages and discourages entry. These studies are silent about the implications of entry costs for firm exit. A contribution of this paper is to address this omission.

In my setup, sunk costs affect the incentives for firms to move in and out of the market. A low volatility reflects a weak incentive to adjust investments at the extensive margin, for example by creating a new business in cyclical upturns or by exiting the market in cyclical downturns.

A comparison with a standard (fixed-variety) business cycle model may be useful at this stage to clarify the role of entry costs. With $\epsilon = 1$, productivity shocks are akin to aggregate shocks in a two-sector business cycle model. The productivity improvement stimulates investments in production capacity (the intensive margin) as well as the creation of new firms (the extensive margin), as would happen in a two-sector business cycle model. Over time, the pressure on labor demand from new and incumbent firms raises wages and entry costs. In contrast to a standard real business cycle model, here there is a hike in sunk costs. This in turn discourages the creation of new firms relative to investments in the manufacturing sector, reflecting into a low volatility of entry. On the other hand, high sunk costs boost firm value through the free entry condition, implying a strong incentive for incumbent firms to stay in the market and reduce exits. The volatility of exits is therefore high.

With capital entry costs, $\epsilon = 0$, the productivity rise is akin to a sectoral shock in the manufacturing industry. As in standard business cycle models, there are positive spillovers towards the start-up sector (an increase in entry and/or a decrease in exit in cyclical upturns). However, these spillovers are moderate because of sunk costs. The drop in entry costs reduces the incentive for incumbents to stay in the market, reflecting into a low volatility of exit.

5. Conclusions

This paper studied the business cycle implications of fluctuations in the number of producers in a dynamic stochastic general equilibrium model with endogenous entry and exit. It compared the performance of the model at replicating important features of US data under alternative assumptions about firms' dynamics and the composition of entry costs.

The contribution of the paper is twofold. First, it re-assesses the cyclicality of entry and exit using US data at the plant level. Firms' entry and exit are far more volatile than output, they are negatively correlated between each other and both co-move with output. The stock of firms is less volatile than output and pro-cyclical. Then, it presents a model which can replicate these facts together with key business cycle moments.

Simulations show that a baseline model with endogenous entry and exit fares favorably relative to specifications with a fixed number of firms or a fixed exit rate. In particular, allowing for endogenous exit helps to match the smoothness of consumption and investments in the data together with their correlation with output. The ability of the model to match the data is sensitive to changes in the composition of entry costs.

Acknowledgements

I wish to thank the Editor David Van Hoose, two anonymous reviewers and participants in conferences held at Queen Mary University (EEFS 2011), East London University (INFER 2011), Università La Sapienza (Advances in Macroeconomic Theory and Policy 2011) for many useful comments. The usual disclaimer applies.

Appendix A

A.1. Steady state

The model is solved in log-deviation from a symmetric steady state equilibrium with zero inflation. Assuming $Z = 1$, the steady state of the economy is such that:

$$\upsilon = \delta^{\frac{-1}{\chi}} S_{\min} \quad N = \left(\upsilon \frac{\theta^{\epsilon}}{(1-\theta)^{\epsilon}}\right)^{\frac{1}{\gamma-\epsilon-\gamma^{E}(1-\epsilon)}}$$

Other variables are given by:

$$i = \frac{1-\beta}{\beta}, \quad d = \frac{(1-\beta(1-\delta))}{\beta(1-\delta)}\upsilon, \quad \mu = \frac{\theta}{(\theta-1)}, \quad \frac{p(j)}{P} = N^{\gamma-1}, \quad \frac{p(j)}{P^{E}} = N^{\gamma^{E}-1}$$

$$\frac{P^{E}}{P} = N^{\gamma-\gamma^{E}}, \quad w = \frac{N^{\gamma-1}(\theta-1)}{\theta}, \quad Y^{M} = d\theta N^{\gamma}, \quad H^{M} = d\theta, \quad Y = dN\left[\theta N^{\gamma-1} + \frac{\epsilon\beta\delta}{1-\beta(1-\delta)}\right]$$

$$C = \upsilon\left[\frac{1-\beta(1-\delta)\theta N^{\gamma} - (1-\epsilon)\beta\delta N}{\beta(1-\delta)}\right], \quad H = \theta d\left[1 + \frac{\epsilon\beta\delta N^{2-\gamma}}{1-\beta(1-\delta)(\theta-1)}\right] \quad N^{E} = \frac{\delta}{(1-\delta)}N$$

A.2. Derivation of the Phillips curve

To derive the Phillips curve (14), I log-linearize the optimal price (7) together with market demand (6) and the market clearing condition in the labor market (9), obtaining:

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

Note that by definition $\widehat{\varrho}_{t,t+k} = \widehat{\varrho}_{t,t} - \sum_{s=1}^{k} \pi_{t+s}$, which I substitute in the expression above. Using

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

and re-arranging gives Eq. (14) in the main text.

References

Arespa Castellò, M., 2012. A new open economy macroeconomic (NOEM) model with endogenous portfolio diversification and firms entry. Mimeo, Universitàt Autonoma de Barcelona

Auray, S., Eyquem, A., 2011. Do changes in product varieties matter for fluctuations and monetary policy in open economies? Int. Finance 14 (3), 507–539.

Auray, S., Eyquem, A., Poutineau, J.C., 2012. The effect of a common currency on the volatility of the extensive margin of trade. J. Int. Money Finance 31, 1156–1179.

Barseghyan, L., Di Cecio, R., 2011. Entry costs, industry structure, and cross-country income and TFP differences. J. Econ. Theory 146 (5), 1828–1851.

Benassy, J.P., 1996. Taste for variety and optimum production patterns in monopolistic competition. Econom. Lett. 52 (1), 41–47.

Bergin, P., Corsetti, G., 2008. The external margin and monetary policy. J. Monetary Econom. 55 (7), 1222–1237.

Bernard, A., Jensen, J.B., 2004. Why some firms export. Rev. Econom. Stat. 86, 561–569.

Bernard, A., Wagner, J., 2001. Export entry and exit by German firms. Welktwirtschaftliches Archiv 137, 105–123.

Bernard, A., Redding, S.J., Schott, P.K., 2010. Multiple-product firms and product switching. Am. Econom. Rev. 100 (1), 70–97.

Bilbiie, F., Ghironi, F., Mélitz, M., 2008. Monetary policy and business cycles with endogenous entry and product variety. In: Acemoglu, D., Rogoff, K., Woodford, M. (Eds.), NBER Macroeconomic Annual 2007, vol. 22. University of Chicago Press, Chicago, IL, pp. 299–353.

Bilbiie, F., Ghironi, F., Mélitz, M., 2012. Endogenous entry, product variety and business cycles. J. Polit. Econom. 120 (2), 304–345.

Bils, M., 1987. The cyclical behavior of marginal cost and price. Am. Econom. Rev. 77 (5), 838–855.

Broda, C., Weinstein, D., 2010. Product creation and destruction: evidence and price implications. Am. Econom. Rev. 100 (3), 691–723.

Calvo, G., 1983. Staggered prices in a utility-maximizing framework. J. Monetary Econom. 12, 983–998.

Campa, J., 2004. Exchange rates and trade: how important is hysteresis in trade? Eur. Econom. Rev. 48, 527–548.

Campbell, J., 1998. Entry, exit, embodied technology and business cycles. Rev. Econom. Dynam. 1, 371–408.

Cavallari, L. 2007. A macroeconomic model of entry with exporters and multinationals. B.E. J. Macroecon. 7, 1, (Contributions), Article 32.

Cavallari, L., 2010. Exports and FDI in an endogenous-entry model with nominal and real uncertainty. J. Macroeconom. 32, 300–313.

Cavallari, L., 2013a. Firms' entry, monetary policy and the international business cycle. J. Int. Econom. 91, 263–274.

Cavallari, L., 2013b. A note on firm entry, markups and the business cycle. Econom. Modell. 35, 528–535.

Chatterjee, S., Cooper, R. 1993. Entry and exit, product variety and the business cycle. NBER Working Paper No. 4562.

Clementi, Palazzo, D., 2013. Entry, exit, firm dynamics and aggregate fluctuations. NBER Working Paper No. 19217.

Collard, F., Juillard, M., 2001. Accuracy of stochastic perturbation methods: the case of asset pricing models. J. Econom. Dynam. Control 25, 979–999.

Das, S., Roberts, M., Tybout, J., 2007. Market entry costs, producer heterogeneity, and export dynamics. Econometrica 75 (3), 837–873.

Devereux, M.B., Head, A.C., Lapham, B.J., 1996. Aggregate fluctuations with increasing returns to specialization and scale. J. Econom. Dynam. Control 20, 627–656.

Doraszelski, U., Pakes, A., 2007. A framework for applied dynamic analysis in IO. In: Armstrong, M., Porter, R. (Eds.), Handbook of Industrial Organization, vol. 3. North-Holland, Amsterdam.

Dunne, T., Roberts, M.J., Samelson, L., 1988. Patterns of firm entry and exit in U.S. manufacturing industries. The RAND J. Econom. 19 (4), 495–515.

Dunne, T., Roberts, M.J., Samuelson, L., 1989. The growth and failure of U.S. manufacturing plants. Quart. J. Econom. 104, 671–698.

Etro, F., Colciago, A., 2010. Endogenous market structures and the business cycle. Econom. J. 120, 1201–1233.
Etro, F., Rossi, L., 2015. New-Keynesian Phillips curve with Bertrand competition and endogenous entry. J. Econom. Dynam. Control 51, 318–340.
Floetotto, M., Jaimovich, N., 2008. Firms dynamics, markups variations and the business cycle. J. Monetary Econom. 55 (7), 1238–1252.
Galì, J., Gertler, S., Lopez-Salido, D., 2001. European inflation dynamics. Eur. Econom. Rev. 45 (7), 1237–1270.
Ghironi, F., Melitz, M., 2005. International trade and macroeconomic dynamics with heterogeneous firms. Quart. J. Econom. 20, 865–915.
Grossman, Helpman, E., 1991. Innovation and Growth in the Global Economy. MIT Press, Cambridge, MA.
Jaimovich, N., 2007. Firms dynamics and markups variations: implications for sunspot equilibria and endogenous economic fluctuations. J. Econom. Theory 137, 300–325.
King, R., Rebelo, S., 1999. Resuscitating business cycles. In: Taylor, J., Woodford, M. (Eds.), Handbook of Macroeconomics 1B. Elsevier, Amsterdam, pp. 927–1007.
La Croce, C., Rossi, L. 2014. Endogenous firms dynamics and banking in a DSGE framework. Mimeo
Lee Y., Mukoyama, T., 2012. Entry, exit, and plant-level dynamics over the business cycle. Mimeo.
Levin A., Lopez-Salido J., Yun, T., 2007. Strategic complementarities and optimal monetary policy. CEPR Discussion Papers 6423.
Lewis, V., 2009. Business cycle evidence on firm entry. Macroeconom. Dynam. 13, 605–624.
Lewis, V., Poilly, C., 2012. Firm entry, markups and the monetary transmission mechanism. J. Monetary Econom. 59 (7), 670–685.
Nekarda, C., Ramey, V., 2013. The cyclical behavior of the price-cost markup. NBER Working Paper No. 19099.
Roberts, M., Tybout, J., 1997. The decision to export in colombia: an empirical model of entry with sunk costs. Am. Econom. Rev. 87, 545–564.
Romer, P., 1990. Endogenous technological change. J. Polit. Economy 98, 71–102.
Rotemberg, J., 1982. Monopolistic price adjustment and aggregate output. Rev. Econom. Stud. 49 (4), 517–531.
Rotemberg, J., Woodford, M., 1999. The cyclical behavior of prices and costs. In: Taylor, J.B., Woodford, M. (Eds.), The Handbook of Macroeconomics, vol. 1. Elsevier, Amsterdam, pp. 1051–1135.
Russ, K., 2007. The endogeneity of the exchange rate as a determinant of FDI: a model of money, entry and multinational firms. J. Int. Econom. 71, 344–372.
Schmitt-Grohe, S., Uribe, M., 2004. Solving dynamic general equilibrium models using a second-order approximation to the policy function. J. Econom. Dynam. Control 28, 755–775.
Taylor, J.B., 1993. Discretion versus policy rules in practice. Carnegie-Rochester Ser. Public Policy 39, 195–214.
Totzek, A. 2009. Firms' heterogeneity, endogenous entry, and exit decisions. Mimeo.
U.S. Department of Commerce, 1975. Historical Statistics of the United States. USGPO, Washington.
Uusküla L., 2008. Limited participation or sticky prices? New evidence on firm entry and failures. Bank of Estonia Working Papers No. 07.
Weintraub, G.Y., Benkard, C.L., Van Roy, B., 2008. Markov perfect industry dynamics with many firms. Econometrica 76, 1375–1411.