Entry, Exit and Business Cycles in a General Equilibrium Model

Roberto M Samaniego*

December 2006

Abstract

The paper investigates the role played by entry and exit in the short run behavior of a general equilibrium model with industry dynamics. In order to preserve potential non-linearities in the impulse responses, I focus on the transition dynamics of the economy after shocks. Entry and exit are found to be insensitive to productivity shocks of reasonable magnitude. Moreover, the dynamics of GDP are insensitive to whether rates of entry and exit themselves fluctuate along with productivity. As an application of the model, the paper also asks whether firing costs may interact with entry and exit to affect transition dynamics after shocks.

JEL Codes: E32, J65, L11, M13.

Keywords : entry and exit, business cycles, transition dynamics, asymmetry, firing costs.

---

*I am very grateful to the Editor and two anonymous referees for many valuable suggestions, as well as participants at the 2003 Midwest Macroeconomics Meetings at the Federal Reserve Bank of Chicago, and the 2003 Meetings of the Society for Computational Economics at the University of Washington for helpful comments. Correspondence: Roberto M Samaniego, Economics Department, George Washington University, 1922 F St. NW Suite 208, Washington, DC 20052, USA. Tel: (202) 994-6153. Fax: (202) 994-6147. E-mail: roberto@gwu.edu.

1 Introduction

How important are entry and exit for macroeconomic fluctuations? Recent advances in modeling and in computation have facilitated the development of general equilibrium models of industry dynamics. Although the steady state behavior of such models is well-understood,[1] little is known regarding their short-run behavior. In particular, it is not known whether the process of *entry and exit* is important for the response of such an economy to macroeconomic shocks.

There are several reasons why entry and exit might be important for short-run dynamics. If they are endogenous, entry and exit allow the composition of the economy to respond to shocks or to policy changes, introducing a new channel for macroeconomic dynamics. Also, entry and exit are inherently non-linear decisions, and it is of interest to see whether models with entry and exit are characterized by asymmetric responses to positive and negative shocks. For instance, McQueen and Thorley (1993) find that contractions are sharper than expansions in US data, and models with endogenous entry and exit may also display this feature given that productive capacity in the form of new establishments is slow to build up but may be quick to destroy.

This paper develops a general equilibrium model with endogenous entry and exit, and studies the response of the economy to aggregate productivity shocks. Simulating a stochastic business cycle model with entry and exit presents many technical challenges: however, the business cycle literature finds that impulse response func-

---

[1] For example, building on the industry model of Hopenhayn (1992), Hopenhayn and Rogerson (1993) study job flows and firing costs, and Samaniego (2006a) studies the role of embodied technical change.

tions can be very informative about short term macroeconomic behavior. Hence, the paper focuses instead on the transition dynamics of the model economy after a persistent shock to productivity. This approach has the advantage that it should preserve any non-linearities in these "impulse responses."

I find that, perhaps surprisingly, entry and exit play very little role in the response of the model economy to aggregate productivity shocks. Entry and exit rates are not sensitive to aggregate shocks, as high-frequency changes in aggregate productivity are too small to significantly affect both the value of startups and the incentive to exit. Also, even when entry and exit are made to vary exogenously along with productivity, changes to the number of entering and exiting plants account for only a very small portion of job flows under reasonable parametrizations, so that the productive capacity of the economy and the marginal return to inputs are not significantly affected by this channel. A related finding is that shocks to rates of entry and exit *themselves* have very little aggregate impact.

Related work on the short run behavior of general equilibrium models of industry dynamics typically assumes that the determinants of entry or exit are exogenous. This includes Veracierto (2001), which studies the transition dynamics of the Hopenhayn and Rogerson (1993) framework after the removal of firing costs, and Veracierto (2003), which compares the business cycle behavior of a similar model with and without firing costs. As an application of the current results, I ask how firing costs might affect the business cycle behavior of the model economy when entry and exit are endogenous. While firing costs significantly dampen the response of the aggregate economy to shocks as in Veracierto (2003), entry and exit do not appear to play an important role, and no significant non-linearity is observed with regards to this response. Overall, the paper suggests that related work may safely abstract from entry, exit, and from any attendant asymmetry.

Section 2 describes the model environment. Section 3 defines equilibrium in the model, and Section 4 outlines the calibration procedure. Section 5 examines the response of model aggregates to different kinds of shocks, and the role of entry and exit.

2 Economic Environment

The model framework is drawn from the Samaniego (2006b), which presents a general equilibrium model similar to Hopenhayn and Rogerson (1993) except for the approach to entry and exit. The model description assumes an environment without aggregate uncertainty, as the experiments of section 5 focus on the deterministic dynamics of the model economy.

2.1 Production

There is a numeraire good, produced by a continuum of plants of endogenous mass. At any date $t \in \mathbb{N}$, a given plant is characterized by an idiosyncratic productivity shock $z_t > 0$ which is drawn from a distribution $F\left(z_{t+1}|z_t\right)$. Firms also face a sequence of aggregate productivity levels $\{s_t\}_{t=0}^{\infty}$, $s_t > 0$, which are common across establishments, and are known with perfect foresight. Each plant chooses its capital input k_t and its labor input n_t so as to maximize discounted profits. Labor is indivisible, so that n_t also equals the number of workers. The plant's production function is $\gamma^t s_t z_t k_t^{\alpha_k} n_t^{\alpha_n}$, where γ is an exogenous productivity growth factor and $\alpha_k + \alpha_n < 1$. The plant pays a wage w_t and a rental rate r_t for each unit of labor and capital that it hires, respectively, and discounts the future at rate ι_t. Let x_t denote the aggregate state of the economy, and let μ_t denote the measure of idiosyncratic shocks z_t across plants. Thus, the aggregate state variable is a triple $x_t = \{\mu_t, K_t, s_t\}$. Let Γ be the law of motion for x_t, so that $x_{t+1} = \Gamma(x_t)$.

2.2 Entry and Exit

Aside from the numeraire, there is an intermediate or "managerial" good, one unit of which may be used to create a new establishment. Plants begin operations the period after they are created. Their initial productivity shock z_t is drawn from a distribution $\psi(z_t)$. Let p_t and p_t^e be the price of the managerial good and of a new plant, respectively: in an equilibrium with entry, $p_t = p_t^e$. At the beginning of each period, before the realization of z_t, eachplant also experiences a *continuation shock* ϕ_t, drawn from a distribution $\Phi(\phi_t)$. The plant must pay ϕ_t units of the managerial good in order to continue in operation. Thus, the input used to build plants is the same as that used to keep them running. A plant whose continuation value net of the cost $\phi_t \times p_t$ is *negative* will optimally choose to shut down. Draws of ϕ_t are independently distributed across establishments and over time.

2.3 Households

The economy is populated by a $[0, 1]$ continuum of infinitely lived households. Households are composed of a unit continuum of individuals: each one is endowed with $\bar{l} > 1$ units of time each period. There is an institutionally determined work week of length 1, so that each agent works time 1 or not at all. If employed, agents may be engaged in either production or in management. Each agent has a given level of managerial ability ξ which has a cumulative distribution Ξ over the agents in each household. If an agent with ability ξ produces the managerial good, she produces ξ units thereof. Assuming that households optimally allocate tasks among their members, only the agents with the highest values of ξ will be managers, so the household's output of the managerial good can instead be thought of in terms of a production function. Thus, if m_t members of the household are managers, this results in $\zeta(m_t)$ units of managerial output. Let $\zeta' > 0$ and $\zeta'' < 0$.[2]

The numeraire good may be consumed or invested, and household preferences are defined over the average of consumption and leisure of its members. Thus, preferences over household streams of consumption $\{c_t\}_{t=0}^{\infty}$ and leisure $\{l_t\}_{t=0}^{\infty}$ take the form

$$\sum_{t=0}^{\infty} \beta^t \left\{\ln c_t + L(l_t)\right\} \tag{1}$$

$$l_t \in [0, \bar{l}], c_t \geq 0 \forall t,$$

---

[2] This approach follows Veracierto (2001). The relationship between ζ and Ξ is as folllows. Suppose all agents with $\xi \geq \bar{\xi}$ are involved in managerial activity, and that there are m_t such agents. Then, $m_t = \int_{\bar{\xi}}^{\infty} d\Xi(\xi) = 1 - \Xi(\bar{\xi})$, and $\zeta(m_t) = \int_{\bar{\xi}}^{\infty} \xi d\Xi(\xi)$.Thus, for any $m_t \in (0, 1)$, $\zeta(m_t) = \int_{\Xi^{-1}(1-m_t)}^{\infty} \xi d\Xi(\xi)$. Assuming that $\zeta' > 0$ is equivalent to assuming that Ξ is strictly increasing and continuous over $m_t \in (0, 1)$.

With these assumptions on preferences, $h_t + m_t$ equals total employment and the household's utility function may be rewritten as follows, for a constant $\kappa = L(\bar{l}) - L(\bar{l} - 1)$:

$$\sum_{t=0}^{\infty} \beta^t \left\{ \ln c_t - \kappa(h_t + m_t) \right\}. \tag{2}$$

See Hansen (1985) and Rogerson (1988).

Using the income they derive from the above activities and from plants they already own, households purchase new plants, new capital, and consumption goods. Hence, their budget constraint is

$$\begin{aligned} c_t + i_t + p_t^e e_t &\leq \Pi_t + w_t h_t + p_t \zeta(m_t) + r_t K_t \quad (3) \\ K_{t+1} &\leq i_t + (1 - \delta) K_t. \quad (4) \end{aligned}$$

Here c_t = consumption; i_t =investment; K_t =household capital; m_t = hours spent creating the managerial good; h_t = hours spent working; Π_t = corporate income; and e_t = purchases of new plants.

3 Equilibrium

The equilibrium concept in this economy requires prices that clear markets, and decisions that maximize establishment profits and household utility given these prices. A way to make this transparent is to rewrite the economy in recursive form. As specified, the economy is non-stationary due to the presence of exogenous growth. However, there exists a balanced growth path along which entry and labor are constant, and values of w_t and p_t increase by a factor $\gamma^{\frac{1}{1-\alpha}}$ over time. Hence, we can redefine the variables in question in terms of deviations from this path, which allows a standard recursive representation as shown by King et al (2002).

Let V equal the expected discounted profits of a plant, so that

$$\begin{aligned} V\left(z_t, x_t\right) &= \max_{k_t, n_t} \{ s_t z_t k^{\alpha_k} n_t^{\alpha_n} - w_t n_t - r_t k_t \\ &\quad + C\left(z_t, x_t\right) \} \end{aligned} \tag{5}$$

where $C\left(z_t, x_t\right)$ is the expected continuation value of the firm, given by

$$\begin{aligned} C\left(z_t, x_t\right) &= \int \max_{X \in \{0,1\}} X \left[\frac{\gamma^{\frac{1}{1-\alpha}}}{1+\iota_t} \int V\left(z_{t+1}, x_{t+1}\right) \right. \\ &\quad \left. \times\, dF\left(z_{t+1} | z_t\right) - \phi_t p_t \right] d\Phi\left(\phi_t\right) \end{aligned} \tag{6}$$

Define $X^*\left(\phi_t, z_t, x_t\right)$ as the optimal exit rule, so that

$$\begin{aligned} X^*\left(\phi_t, z_t, x_t\right) &= \arg \max_{X \in \{0,1\}} X \left[\frac{\gamma^{\frac{1}{1-\alpha}}}{1+\iota_t} \int V\left(z_{t+1}, x_{t+1}\right) \right. \\ &\quad \left. \times\, dF\left(z_{t+1} | z_t\right) - \phi_t p_t \right] \end{aligned} \tag{7}$$

The law of motion Γ satisfies the following condition, which states that for all

Borel subsets (Z) of the state space,

$$\begin{aligned}\mu_{t+1}(Z) &= \int\int_{z_{t+1}\in Z}\left(1-X^{*}\left(\phi_t,z_t,x_t\right)\right) \\ &\quad \times d\mu_t\left(z_t\right)dF\left(z_{t+1}|z_t\right)d\Phi\left(\phi_t\right)+e_t\psi\left(Z\right)\end{aligned} \tag{8}$$

In turn, the expected discounted welfare of the household is

$$W\left(x_t\right)=\max_{c_t,h_t,m_t,e_t,i_t}\left\{\ln c_t-\kappa(h_t+m_t)+\beta W\left(x_{t+1}\right)\right\} \tag{9}$$

subject to its budget and capital constraints (3) and (4), and to the portfolio law of motion (8).

The first order condition for managerial input requires indifference between occupations, on the margin. This determines the equilibrium value of m_t:

$$w_t=p_t\zeta'(m_t). \tag{10}$$

In equilibrium, the price of a new plant p_t^e equals the value of opening a new establishment:

$$p_t^e=\frac{1}{1+\iota_t}\int V\left(z_{t+1},0,x_{t+1}\right)d\psi\left(z_{t+1}\right), \tag{11}$$

and the entrepreneurial use of the managerial good implies that

$$p_t\geq p_t^e, \tag{12}$$

with equality if there is entry. Finally, we require that goods and input markets clear:

$$h_t = \int n^* (z, x)\, d\mu, \;\; K = \int k^* (z, x)\, d\mu \tag{13}$$

$$e_t + \int \int \phi_t \left[1 - X (\phi, z_t, x_t)\right] d\mu_t d\Phi (\phi_t) = \zeta(m_t) \tag{14}$$

where n^* and k^* are optimal rules for input use.

Definition An *equilibrium* consists of sequences of prices p_t, p_t^e, w_t and r_t; allocations for consumption c_t, investment, i_t time use h_t,m_t and entry e_t; input use and exit rules n^*, k^*, X^*; and a law of motion Γ that satisfy:

1. Optimality: the decision rules and allocations solve the establishment problem (5) and the household problem (9);
2. Optimal time use: equation (10) is satisfied;
3. Feasibility: In each period allocations satisfy

$$c_t + i_t \leq \int z_t k^* (z_t, x_t)^{\alpha_k} n^* (z_t, x_t)^{\alpha_n} d\mu_t; \tag{15}$$

4. Optimal entry: equations (11) and (12) are satisfied;
5. Market clearing: equations (13) and (14) are satisfied; and
6. Rationality/consistency: Γ satisfies equations (4) and (8).

Definition A *stationary equilibrium* is an equilibrium and an aggregate state x^* such that $x_t = x^*$ for all t.

In the remainder of the paper there is entry in all the equilibria considered, so the distinction between p_t^e and p_t is suppressed.

4 Benchmark Economy

4.1 Calibration

This section provides an overview of the calibration procedure. The stationary equilibrium of the model economy is calibrated to US data following the procedure of Kydland and Prescott (1982). Since we will be interested in the behavior of the model at business cycle frequencies, period length is quarterly. In the stationary equilibrium, let $s_t = 1$ at all dates. Given that the purpose of the paper is to study the role of entry and exit in the macroeconomy, it will be important to ensure that rates of entry and exit, and the contribution of entry and exit to job flows, are empirically reasonable. These statistics will be matched by calibrating the distributions governing the idiosyncratic shock process F and the cost of continuation Φ.

Continuation shocks are drawn from the set $\{0, \phi, \infty\}$ for some $0 < \phi < \infty$. The corresponding probabilities are $\{1 - \lambda_\phi - \lambda_\infty, \lambda_\phi, \lambda_\infty\}$. Parameter λ_∞ serves as an exogenous hazard rate, whereas λ_ϕ will lead to shocks that some establishments are able to survive. Idiosyncratic shocks z are taken over a grid of 30 points. Given a particular grid, multiplying it by any factor affects only the size and not the relative composition of the economy, so all that matters are the upper and lower bounds. The upper value was chosen to be one. The lower value is a parameter $\underline{z} < 1$. The functional form for F is set to yield an AR(1) process $\ln z_{t+1} = \nu + \rho_z \ln z_t +$

ε_{t+1}, where $\varepsilon_t \tilde{} N(0,\sigma_z^2)$. First, note that ν is overspecified and cannot be pinned down, amounting to a normalization on the size of the economy. Hence, ν is chosen implicitly via the equation $\nu = (1-\rho_z) E[\log z]$, where the expectation is with respect to the stationary distribution of F.[3] The distribution of entrant productivity ψ is chosen as a uniform distribution over the lower portion of the grid up to some level $\bar{\psi}$, as in Hopenhayn and Rogerson (1993). Finally, the functional for for the managerial good is $\zeta(m) = m^{\zeta}$, as in Veracierto (2001).

The value for β corresponds to an annual interest rate of 4%, and $\alpha_n = 0.63$. Both of these values are standard in the business cycle literature. The value of α_k assumes that proprietary income $1-\alpha_k-\alpha_n$ comprises 12% of GDP, which roughly equals the share of profits, dividends and interest income in the National Income and Product Accounts. Depreciation δ is computed from the steady state optimization condition $\delta = I/K + 1 - \gamma$. γ is set so that annual growth equals 2% of GDP. The disutility of labor κ is chosen so that employment is 80%, and the value of $\zeta = 0.1$ leaves 1.25% of employment in the managerial form – values of ζ between 0.2 and 0.05 yield similar results.

The autocorrelation of the size of surviving establishments after T quarters is ρ_z^T. Hopenhayn and Rogerson (1993) report that, in the Longitudinal Research Database, the five-year autocorrelation ρ_z^{20} equals 0.93. Hence, $\rho_z = 0.9964$.

TABLE 1 ABOUT HERE

---

[3] See the results of King et al (2002). An alternative is to set ν so as to match the average plant size. Samaniego (2006a) compares the calibrated economy to several alternative models, and does not find that results are sensitive to this aspect of calibration.

The remaining six parameters are chosen to ensure that there is a reasonable link between plant dynamics and job flows, using a simulated annealing algorithm – see Bertsimas and Tsitsiklis (1993). These variables are $\phi, \lambda_\phi, \lambda_\infty, \sigma_z, \bar{\psi}$ and $\underline{z}$. The six statistics they match are: the 5-year exit rate; the 5-year exit rate of establishments aged 6 years or less; the proportion of establishments aged 6 or less that are small (at most 30% of average size); the proportion of employment that undergoes job creation in each quarter; the proportion of job creation due to birth; and the proportion of job destruction due to exit. These statistics are selected because they are related to the role played by entry and exit in the benchmark economy. Table (1) lists the resulting parameter values, and Table (2) displays the steady-state statistics that characterize the benchmark economy. The matches are tight. In particular, it is worth underlining the following features of the data that are also present in the calibrated model. First, plants are more likely to shut down when they are young. Second, young plants are typically quite small. Third, new plants are responsible for 8% of quarterly job creation, whereas closing plants are responsible for 13% of quarterly job destruction. It turns out that about three quarters of all exit can be attributed to shocks that some plants would survive.

TABLE 2 ABOUT HERE

5 Impulse response functions

5.1 Productivity shocks.

We now turn to the transition dynamics of the model economy. Starting from the steady state value of x_t, we study the response of the model economy to a sequence of productivity values that gradually return to the steady state.

In the real business cycle literature, productivity shocks follow an autoregressive process:

$$\log s_{t+1} = \rho_s \log s_t + \eta_{t+1}, \eta_t \tilde{} N(0, \sigma_s^2). \tag{16}$$

I adhere to this tradition in the following manner to infer what consitutes the magnitude of high-frequency productivity fluctuations. Suppose that, at time $t = 0$, the measure μ_t corresponds to the steady state measure. Set initial productivity $s_0 = e^{2\sigma_s}$, and apply no further shocks to the economy. Thus, $\log s_{t+1} = \rho_s \log s_t$ for $t > 0$. This yields a large yet not unreasonably sized shock, after which the economy gradually reverts to its steady state. Following Cooley and Prescott (1995), I set the persistence of aggregate productivity $\rho_s = 0.95$, and use their reported value of $\sigma_s = 0.007$.

The first striking result is the insensitivity of entry and exit rates to productivity shocks in the benchmark economy – see Figures (1) and (2). Along the transition path, each of them varies by less than 0.5% of their steady state values. The reason is likely that the uncertainty in productivity from ψ and F is far greater than the size of an aggregate shock of reasonable magnitude. For instance, the values of z_t over which ψ has positive support range from 0.3 to 0.66, whereas Cooley and Prescott

(1995) report that σ_s is considerably smaller. As a result, the value of a new plant in transition p_t deviates by at most 0.6% from its steady state level. Similarly, the value of an incumbent changes little in transition, so incentives to exit do not change significantly either.

TABLE 3 ABOUT HERE

Thus, to assess the potential impact of entry and exit on aggregate fluctuations requires redefining shocks so that entry and exit respond exogenously along the transition. I examine several alternatives. First, let the rate of entry to vary exogenously along with productivity. This is termed the "Entry shock" economy. I assume that the logarithm of e_t follows an autoregressive process: a positive productivity shock coincides with an increase in $\log e_t$ of two standard deviations, and a negative productivity shock coincides with a decrease in $\log e_t$ of two standard deviations. See Figure (1).

Second, concurrent with the productivity shock, I allow the rate of exogenous exit λ_∞ to vary. This is termed the "Exit shock" economy: see Figure (2). I assume that the logarithm of λ_∞ also follows an autoregressive process with the standard deviation and persistence reflected in Table 3. A positive productivity shock coincides with a decrease in $\log \lambda_\infty$ of ten standard deviations. Similarly, a negative productivity shock coincides with an increase in $\log \lambda_\infty$ of ten standard deviations, which approximately doubles the exit rate. Third, I allow both entry and exit to vary at the same time as the shock. This is denoted the "Entry and Exit" economy.[4]

---

[4] These extensions reflect the fact that entry is procyclical and exit is countercyclical: see Camp-

FIGURES 1 AND 2 ABOUT HERE

Comparing across these economies, the dynamics of aggregate output are insensitive to even large changes in rates of entry and exit – see Figures (3) and (4). Moreover, there is no evidence of significant asymmetry between the effects of positive and negative shocks. This is regardless of whether or not entry and exit rates co-vary with the productivity shock. Although, like capital, establishments are durable resources, nonetheless changes in the composition of the economy are not an important way in which agents smooth consumption over time when there are productivity shocks.

FIGURES 3 AND 4 ABOUT HERE

5.2 Entry and exit shocks only

A related result is that entry and exit themselves appear to play little if any role in *generating* aggregate fluctuations – see Figure (5). If productivity is held constant and entry or exit rates are varied exogenously as described above, output departs its trend by as little as 0.2% – an order of magnitude less than when the economy experiences productivity shocks. Calibrated steady state rates of entry and exit are only $2-3\%$, so even doubling or halving of the rate of entry or exit does not significantly affect the productive capacity of the economy. For example, when there is an exogenous increase in the exit rate, the reallocation of labor across surviving firms is insufficient to significantly affect the marginal return to labor, and aggregate

---

bell (1998).

productivity is almost unaffected. This is not to say that changes in entry and exit rates *cannot* affect aggregates. For example, if there is a shock to λ_∞ such that 10% of all plants are shut down in period zero, GDP does drop by about 1%, as does employment. Since s_t is held constant along the transition path, this reflects decreasing returns to scale as resources from the exiting plants are reallocated across the survivors, or left idle. However, this effect is negligible for levels of plant turnover that are consistent with the data. The same applies to asymmetry: whereas decreases in exit rates are unlikely to have much short-term impact – given that exit rates are small to begin with – in principle, sufficiently large increases in λ_∞ can eliminate an arbitrarily large proportion of establishments. However, this does not occur in the model economy for reasonable parametrizations.

FIGURE 5 ABOUT HERE

A related paper is Campbell (1998), which develops a vintage capital model in which entry and exit occur because of *plant-embodied technical change.* In that model, entrants are more productive than incumbents on average – which makes them larger – whereas Dunne et al (1989) show that entrants are usually much smaller than incumbents, so that quarterly job destruction from exit only comprises about 2% employment. The current model is calibrated to match the magnitude of entry and exit and the contribution of entry and exit to job flows and, independently of whether rates of entry and exit associated with plant-embodied technical change might be an important channel of growth, they appear to matter little for higher frequency fluctuations as captured by the impulse response to productivity shocks.[5]

5.3 An application to firing costs

As noted, general equilibrium versions of the Hopenhayn (1992) model of entry and exit have been used to study the long-run effects of firing costs. The effects of firing costs on short-run dynamics are also of interest, however. From an empirical perspective, Cogley (1990) finds that short run fluctuations are typically larger in the US than in a sample of European countries, and regulation may play a role in these differences.

Veracierto (2003) studies the impact of firing costs on standard business cycle statistics: however, the model abstracts from endogenous entry and exit, and uses a linear computational method. Contractionary shocks encourage hiring, whereas expansionary shocks do not, suggesting that firing costs may affect the optimal response to shocks asymmetrically, and that, given that about a quarter of all firing is due to exit in steady state, that exit might have a role to play in any such asymmetry. Moreover, Campbell and Fisher (2000) show that labor adjustment costs in partial equilibrium may lead to asymmetric responses to positive and negative shocks, and whether a general equilibrium model also displays this feature cannot be assessed when symmetry is imposed by the computational method. The current framework is suitable for assessing whether the short run response of economies with different

---

[5] To capture the concept of plant-embodied technical change, I subjected the model to changes in the productivity distribution of entrants ψ. Recall that in steady state ψ is a uniform distribution over the lower half of the shock range. I made a positive shock coincide with a one-shot change in ψ to a uniform distribution over the entire range of shocks, and a negative shock with a change in ψ to include only the lowest possible shock value. Once more, the transition paths of GDP were difficult to tell apart.

levels of firing costs is characterized by non-linearities, and whether entry and exit have a role to play in this response.

Suppose that, in addition to the wage, there is firing tax of τ periods of the equilibrium wage that must be paid for any decrease in labor input. The revenues of the firing tax are redistributed to households as a lump sum T_t. Thus, the plant's costs are $w_t n_t + r_t k_t + \tau \times w_t \max\{0, n_{t-1} - n_t\}$. The agents' problems and the measure are redefined accordingly.

FIGURES 6 AND 7 ABOUT HERE

Figure (6) clearly shows that employment protection provisions of reasonable magnitude can have a significant dampening effect upon the response of GDP to aggregate shocks. The maximum deviation from trend GDP in the benchmark economy after the shock is 2.6%, whereas it is about 1.8% for the economy with firing costs. The response of employment to firing costs in Figure (7) is particularly striking: employment hardly reacts at all to the shock. It varies by over 2% in the benchmark economy, but by a maximum of only 0.6% in the economy with firing costs.

Suppose the interest rate is constant. With a high elasticity of labor supply, in the absence of firing costs equilibrium employment is sensitive to shocks, and can be used to finance investment to smooth consumption over time. A general equilibrium version of the model inherits this behavior – interest rates vary by at most 4% of their steady state value in the undistorted economy. After a technology shock, employment immediately rises, and then declines along with productivity. With a job destruction tax, this kind of intertemporal substitution becomes very costly.[6]

Interestingly, results are similar irrespective of whether the shock is positive or negative: there are no visible non-linearities. This is not immediate for two reasons, since the direct effect of firing costs is on the firing margin, not the hiring margin. In the presence of firing costs, equilibrium employment decision rules are characterized by a range of inactivity, so that firms only hire or fire if they undergo a shock whereby their past employment differs significantly from the level that would be optimal conditional on changing employment – see Veracierto (2003) for details. For a given n_{t-1}, the band of inactivity is approximately of width 0.15. This is significantly larger than the magnitude of most aggregate shocks – again, $\sigma_s = 0.007$. Moreover, while asymmetric *changes* in this band of inactivity in response to shocks might yield aggregate asymmetry, the bands themselves change so little that any such asymmetry is difficult to detect. This suggests why the smoothing effects of firing costs are not asymmetric: shocks do not significantly affect the probability of exiting the band of inactivity for a given plant, so the effect of smoothing in transition is ultimately dependent on the degree to which plant-level hiring is smoothed in steady state.

6 Summary

The paper shows that entry and exit appear not to be important for the response of a general equilibrium model of establishment dynamics to transitory shocks. Empir-

---

[6] This suggests that hours worked might be more variable in countries in which there are high firing costs, since this would allow more intertemporal smoothing when the employment margin is restricted. Rank correlations between the standard deviation of hours worked per person and the measures of firing costs reported in Nicoletti et al (2000) and in Addison and Texeira (2005) for OECD countries are positive in 12 of 14 cases, ranging from -0.10 to 0.54.

ically reasonable changes in entry and exit rates are not large enough to significantly affect the marginal return to physical inputs. Thus, research that abstracts from entry and exit in order to study aggregate shocks can do so without loss of generality. The results also suggest that changes to entry and exit rates are unlikely to play an important role in generating asymmetry in high-frequency macroeconomic time series. The dynamics of entry and exit would thus seem more relevant to lower frequency events – such as the response to structural shocks, or the process of economic growth itself.

7 Bibliography

Addison, John T. and Teixeira, Paulino. (2005). "What have we learned about the Employment effects of Severance pay? Further iterations of Lazear et al." Empirica, 32 (3-4), 345-368.

Bertsimas, Dimitris and Tsitsiklis, John. (1993). “Simulated Annealing.” Statistical Science 8, 10-15.

Campbell, Jeffrey R. (1998). "Entry, Exit, Embodied Technology, and Business Cycles." Review of Economic Dynamics 1, 371-408.

Campbell, Jeffrey R. and Fisher, Jonas D. M. (2000). "Aggregate Employment Fluctuations with Microeconomic Asymmetries." American Economic Review 90, 1323-45.

Cogley, Timothy. (1990). “International Evidence on the Size of the Random Walk in Output.” Journal of Political Economy 98, 501-518.

Cooley, Thomas and Prescott, Edward. (1995). "Economic Growth and Business Cycles." Frontiers of Business Cycle Research, Edited by Cooley, Thomas. Princeton: Princeton University Press.

Davis, Steven J. and Haltiwanger, John. (1992). “Gross Job Creation, Gross Job Destruction, and Employment Reallocation.” Quarterly Journal of Economics 107, 819-863.

Dunne, Timothy, Roberts, Mark J. and Samuelson, Larry. (1989). “The Growth and Failure of U.S. Manufacturing Plants.” Quarterly Journal of Economics 104, 671-698.

Hansen, Gary D. (1985). “Indivisible Labor and the Business Cycle.” Journal of Monetary Economics 16, 309-327.

Hopenhayn, Hugo. (1992). “Entry, Exit and Firm Dynamics in Long Run Equilibrium.” Econometrica 60, 1127-1150.

Hopenhayn, Hugo and Rogerson, Richard. (1993). “Job Turnover and Policy Evaluation: A General Equilibrium Analysis.” Journal of Political Economy 101, 915-938.

King, Robert; Plosser, Charles and Rebelo, Sergio. (2002) "Production, Growth and Business Cycles: Technical Appendix." Computational Economics, 20 (1-2): 87-116.

Kydland, Finn E. and Prescott, Edward C. (1982) "Time to Build and Aggregate Fluctuations." Econometrica 50, 1345-70.

McQueen, Grant and Thorley, Steven. (1993). “Asymmetric business cycle turning points.” Journal of Monetary Economics, 31, 341-362.

Nicoletti, Giuseppe; Scarpetta, Stefano and Boylaud, Oliver. (2000). “Summary Indicators of Product Market Regulation with an Extension to Employment Protection Legislation.” OECD Economics Department Working Paper 226.

Rogerson, Richard. (1988). “Indivisible Labor, Lotteries, and Equilibrium.” Journal of Monetary Economics 21, 3-16.

Samaniego, Roberto M. (2006a). "Can Technical Change Exacerbate the Effects of Labor Market Sclerosis?" Mimeo: George Washington University.

Samaniego, Roberto M. (2006b). "Do Firing Costs affect the Incidence of Firm Bankruptcy?" Macroeconomic Dynamics 10(4), September 2006, 467-501.

Veracierto, Marcelo. (2001). "Employment Flows, Capital Mobility, and Policy Analysis." International Economic Review 42, 571-595.

Veracierto, Marcelo. (2003). Firing Costs and Business Cycle Fluctuations. Federal Reserve Bank of Chicago Working Paper Series, WP 2003-29.

Parameter	Value
α_k	0.25
α_n	0.63
δ	0.0143
$\underline{z}$	0.3
ρ_z	0.9964
σ_z	0.021

Parameter	Value
$\bar{\psi}$	0.66
λ_∞	0.0051
λ_ϕ	0.0197
ϕ	8.8
ζ	0.1
κ	1.0186

Table 1: Parameters used in Calibration

Statistic	US Data	Model
5-year exit rate, all ages	36%	37%
5-year exit rate, 0-6 yrs	39%	39%
Proportion of plants aged 0-6 yrs	30%	36%
Proportion of plants aged 6-20 yrs	34%	35%
Proportion of plants aged 0-6 yrs that are "small"	74%	74%
Employment	80%	80%
Quarterly job creation, % of employment	5%	6%
Quarterly job creation via birth, %	8%	8%
Quarterly job destruction via exit, %	12%	13%

Table 2: Sample Statistics

Statistic	Log entry rate	Log exit rate	Log productivity
Autocorrelation	0.49	0.61	0.95
Std. dev.	0.19	0.17	0.007
Shock size	2× *s.d.*	10× *s.d.*	2× *s.d.*

Table 3: Magnitude and persistence of different shocks. Sources: Cooley and Prescott (1995) and the Longtitudinal Research Database. Entry and exit rates are based on data kindly made available on the website of John Haltiwanger at http://www.econ.umd.edu/ haltiwan

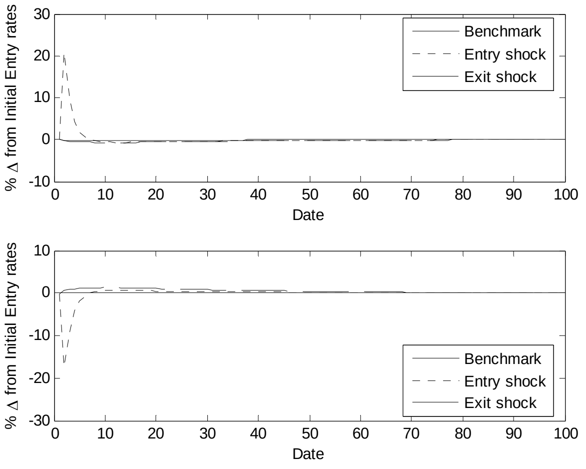

Figure 1: Transition dynamics of quarterly entry rates. The benchmark economy experiences only productivity shocks. The "entry shock" and "exit shock" economies experience concurrent changes in entry and exit rates, respectively.

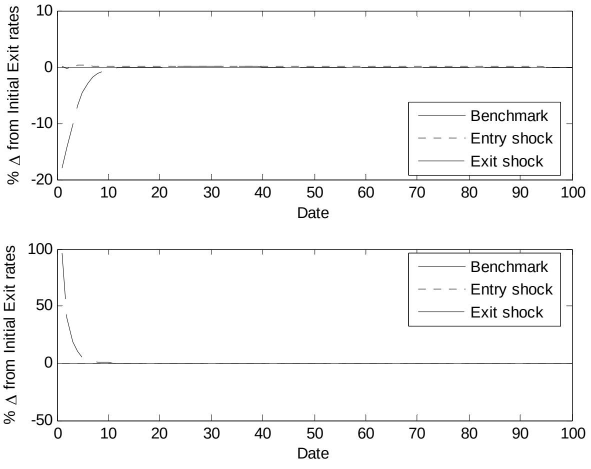

Figure 2: Transition dynamics of quarterly exit rates. "Benchmark" is the model economy with productivity shocks. "Exit shock" is the economy in which the shock also affects exit rates. "Entry shock" is the economy in which the shock also affects entry rates.

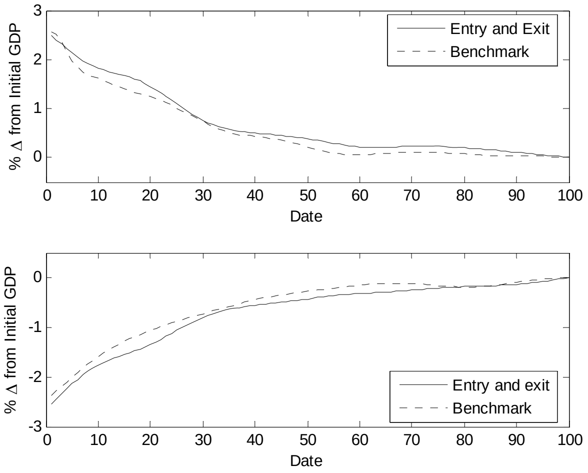

Figure 3: Transition dynamics of GDP after different kinds of shocks.

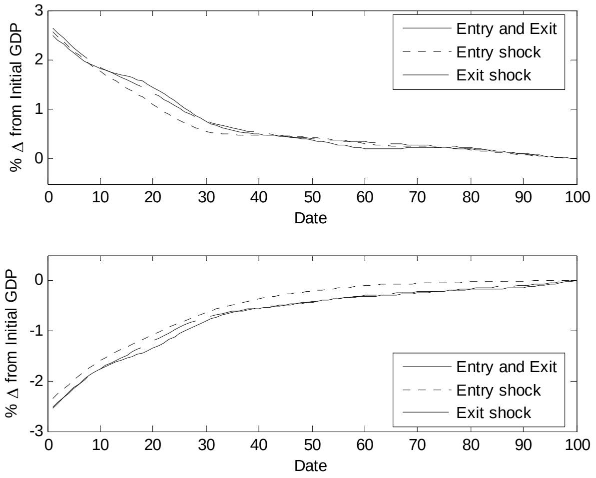

Figure 4: Transition dynamics of GDP after different kinds of shocks.

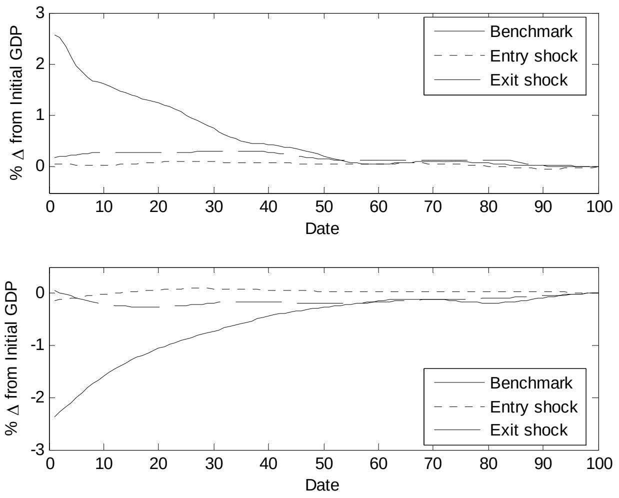

Figure 5: Transition dynamics of GDP after different kinds of shocks. "Benchmark" refers to the economy with productivity shocks. "Entry shock" is an economy with exogenous changes in the rate of entry but no productivity shock to s_t. Similarly, "Exit shock" is an economy experiencing exogenous changes in λ_∞, while $s_t = 1$.

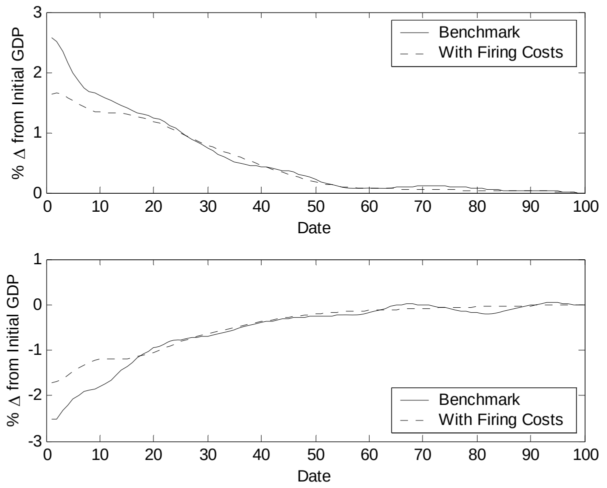

Figure 6: Deviations from Trend GDP with productivity shocks. The benchmark economy has no firing costs, whereas the distorted economy has firing costs worth one year's wages ($\tau = 4$).

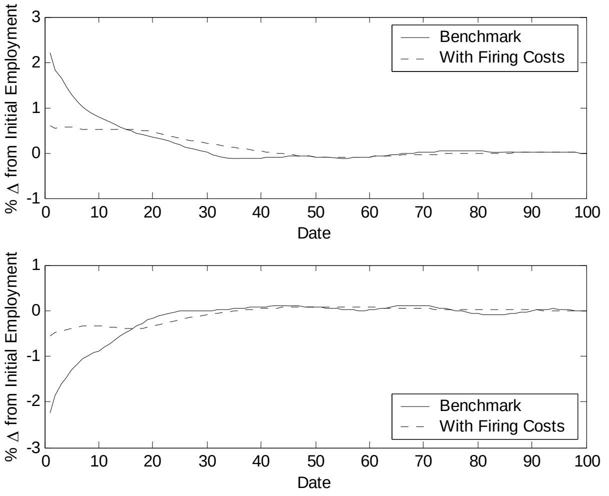

Figure 7: Deviations from Trend Employment