Journal of Economic Theory and Econometrics, Vol. 29, No. 2, Jun. 2018, 28–47

Economic Policies with Endogenous Entry and Exit of Plants*

Yoonsoo Lee† Toshihiko Mukoyama‡

Abstract We build a general equilibrium model of industry dynamics and conduct policy experiments. The model is designed to match the entry and exit patterns in the U.S. manufacturing sector. We analyze two policies. First, we consider imposing a firing tax. Both a constant firing tax and a countercyclical firing tax increase the volatility of the entry rate and aggregate output. This finding contrasts with the stabilization effects of firing taxes in previous models with exogenous entry and exit. Second, we consider subsidies to entry costs. Countercyclical entry subsidies stabilize the entry rate and are effective in stabilizing the aggregate output over the business cycle.

Keywords plant-level dynamics, entry and exit, business cycles, firing tax, entry subsidy

JEL Classification E23, E32, L11, L60

*A part of this paper's content was circulated under the title "Entry, Exit, and Plant-level Dynamics over the Business Cycle." The research in this paper was conducted while the authors were Special Sworn Status researchers of the U.S. Census Bureau at the Michigan Census Research Data Center. The research results and conclusions expressed are those of the authors and do not necessarily reflect the views of the Census Bureau. This paper has been screened to ensure that no confidential data are revealed. This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2015S1A2A1A01026890).

†Sogang University, e-mail: ylee@sogang.ac.kr

‡Georgetown University, e-mail: tm1309@georgetown.edu

Received April 5, 2018, Revised May 22, 2018, Accepted May 29, 2018

1. INTRODUCTION

Researchers are becoming increasingly aware of the importance of firm entry in aggregate economic dynamics. Over the business cycle, firm and establishment entries vary significantly across booms and recessions.[1] The variation of entry, in turn, has a significant and persistent effect on aggregate employment.[2]

In this context, it is natural to ask how various macroeconomic policies interact with cyclical entry. In this study, we construct a Hopenhayn-style model of firm/establishment entry and exit in general equilibrium in order to examine the effects of government policies designed to help employment and start-ups (Hopenhayn, 1992). The model is based on Lee and Mukoyama (2008, 2018) and can quantitatively account for observed patterns of entry and exit of manufacturing plants in the United States. We consider two types of policies: firing taxes and entry subsidies. For each, we experiment with two different kinds of policy implementations.

We first analyze firing taxes. Our results provide new insights on the stabilization effects of firing taxes. As in Hopenhayn and Rogerson (1993), a constant firing tax reduces the average level of employment in our model. Interestingly, a constant firing tax *increases* the variance of output. This result contrasts with the stabilization effects of firing taxes in models with exogenous entry and exit, found in the past literature (e.g., Veracierto, 2008). Our finding suggests that it is important for a policy analysis to model entry and exit behavior endogenously. A constant firing tax is destabilizing because the entry rate becomes more volatile when this tax is imposed. Given the mean-reverting nature of the idiosyncratic productivity process, the firing tax has a greater impact on large plants than on small plants because the former are more likely to contract in the immediate future. Since entrants are larger during recessions than during booms, the effect of firing taxes on entrants is stronger during recessions. Therefore, the difference between the entry rates during booms and recessions widens because of the firing tax.

We also consider a countercyclical firing tax, which is intended to reduce the amount of firing during recessions. When a firing tax is imposed only during recessions, job destruction rates during recessions are reduced. However, the variance of output increases dramatically.

Second, we analyze the effects of cyclical entry subsidies. We find that subsidizing entry costs during recessions stabilize both the entry rate and the ag-

[1] See, for example, Lee and Mukoyama (2015a), Woo (2015), and Tian (2018).

[2] See, for example, Sedláček and Sterk (2017).

gregate output. This finding is consistent with recent studies that emphasize the role of entry in aggregate labor market fluctuations, such as Sedláček (2015) and Sedláček and Sterk (2017). Our experiment shows that stabilizing entry over the business cycle can stabilize the aggregate employment and output fluctuations significantly.

The rest of this paper is organized as follows. In the next section, we build a general equilibrium model of plant-level dynamics. In Section 3, we conduct policy experiments. Section 4 concludes.

2. MODEL

First we set up a dynamic general equilibrium model of plant-level employment, entry, and exit. The model is based on Lee and Mukoyama (2018) and adds the elements of economic policies that we analyze.

The model is similar to the standard firm dynamics model, such as that of Hopenhayn and Rogerson (1993). Five assumptions distinguish our model from the standard model. First, there are aggregate productivity shocks. Our policy analysis is centered in the context of business cycles, and this is necessary in order to incorporate cyclical dynamics. Second, entry is conducted in two steps. In the first step, *potential entrants* are created. By incurring *idea costs*, a potential entrant can receive an idea that has a random quality. In the second step, each potential entrant with a given idea decides whether to enter. Upon entry, the entrant has to pay an *implementation cost*. Third, there is a positive (and stochastic) value of exiting. This is necessary for the model to match the exit pattern observed in the data. Fourth, we assume that there are adjustment costs for changing employment. This is necessary for the model to generate a level of job flows that is similar to the U.S. data. Fifth, we assume that the entry costs are cyclical. We elaborate on this assumption in more detail later.[3]

Time is discrete and has an infinite horizon. There are two economic agents, consumers and manufacturing plants. Consumers own plants, supply labor, and consume final goods. Plants hire workers and produce final goods. We keep the consumer side simple by assuming that the representative consumer exists. Plants are heterogeneous and they enter and exit over time.

[3]See Lee and Mukoyama (2018) for detailed discussions.

2.1. PLANTS AND POLICIES

First, we outline the decision for an incumbent plant that survives from the previous period. The timing for an incumbent plant in period t is as follows. In the beginning of period t, plants observe the current aggregate state, z_t. An incumbent plant starts a period with the individual state (s_{t-1}, n_{t-1}). We denote s_{t-1} as the individual plant's productivity level at period $t-1$. The variable n_{t-1} represents the employment level at period $t-1$. The value function of an incumbent plant after observing z_t is denoted as $W(s_{t-1}, n_{t-1}; z_t)$. Then, the plant observes its exit value, x_t. We assume that x_t is stochastic and can be interpreted as the scrap value of its capital (and owned land). After observing the exit value, the plant decides whether to stay or exit. We assume that it has to pay a firing tax when it exits, to adjust the employment level from n_{t-1} to zero. If the plant stays, it next observes this period's individual productivity s_t. The value function at this point is denoted as $V^c(s_t, n_{t-1}; z_t)$. After that, the plant decides the employment in the current period, n_t, and production starts. We denote the labor demand for a plant with the state (s_t, n_{t-1}) as $\phi(s_t, n_{t-1})$. The production function is assumed to be $z_t f(n_t, s_t)$, where the function $f(n_t, s_t)$ is increasing and concave in n_t. If $n_t \neq n_{t-1}$, the plant pays adjustment costs (e.g., Cooper et al., 2004). In particular, in the case of reducing employment (i.e, $n_t < n_{t-1}$), it pays a firing tax as in Hopenhayn and Rogerson (1993).

Second, we outline the timing for entrants. At the beginning of the period, the aggregate shock z_t is observed. The first step for entry is to come up with an idea. To do so, the cost c_q (which we refer to as an *idea cost*) has to be paid. Once the idea cost is paid, a potential entrant receives a random number q_t (quality of the idea). A large q_t indicates that productivity after the entry is high. The expected value of having an idea, before knowing q_t, is denoted as $V^p(z_t)$. The value of being a potential entrant who has an idea q_t is denoted as $V^e(q_t; z_t)$. Based on q_t, a potential entrant decides whether to enter. To do so, a potential entrant has to pay an additional entry cost c_e (we refer to this as an *implementation cost*). We interpret c_e as (partially sunk) investment. A potential entrant compares $V^e(q_t; z_t)$ and the implementation cost c_e in deciding whether to enter. Upon entry, the decision of the entrant is the same as that for the incumbent, except that the idiosyncratic productivity s_t depends on q_t, not s_{t-1}. After observing s_t (and thus, the value function is $V^c(s_t, 0; z_t)$ for a new plant), the plant decides the employment n_t, pays the adjustment costs, and produces.

We consider two policies. The first is the firing tax. Each plant adjusting employment from n_{t-1} to n_t has to pay $g(n_t, n_{t-1})$ units of final goods to the government, which will be paid back to the consumers in a lump-sum manner.

Second, the government subsidizes the entry costs. The idea cost is subsidized at the rate γ_t^a and the implementation cost is subsidized at the rate γ_t^e. The subsidies are financed from consumers as lump-sum taxes.

Incumbent plants' decision

The Bellman equation for an incumbent is

$$W(s_{t-1}, n_{t-1}; z_t) = \int \max\langle E_s[V^c(s_t, n_{t-1}; z_t)|s_{t-1}], x_t - g(0, n_{t-1})\rangle d\xi(x_t).$$

In the max$\langle \cdot, \cdot \rangle$, the plant decides whether to stay or to exit. We assume that the exit value x_t follows an i.i.d. distribution $\xi(x_t)$ and that the exit value distribution does not vary over the business cycle. The term $E_s[V^c(s_t, n_{t-1}; z_t)|s_{t-1}]$ is the expected value of a continuing plant $V^c(s_t, n_{t-1}; z_t)$ given the information of s_{t-1} and is calculated as

$$E_s[V^c(s_t, n_{t-1}; z_t)|s_{t-1}] = \int V^c(s_t, n_{t-1}; z_t) d\psi(s_t|s_{t-1}),$$

where

$$V^c(s_t, n_{t-1}; z_t) = \max\langle V^a(s_t, n_{t-1}; z_t), V^n(s_t, n_{t-1}; z_t)\rangle,$$

and $\psi(s_t|s_{t-1})$ is the (exogenously given) distribution of s_t given s_{t-1}. Here, $V^a(s_t, n_{t-1}; z_t)$ is the value function when the plant adjusts employment, and $V^n(s_t, n_{t-1}; z_t)$ is the value function when it does not.

If the plant adjusts employment, the current period profit is

$$\pi^a(s_t, n_{t-1}, n_t; z_t) \equiv \lambda z_t f(n_t, s_t) - w_t n_t - g(n_t, n_{t-1}),$$

where $\lambda < 1$ represents the "disruption cost" type of the adjustment cost, emphasized by Cooper et al. (2004). This represents the cost of slowing down the production process when the plant adjusts employment. According to Cooper et al.'s (2004) estimation, this cost turns out to be the most important type of adjustment cost in explaining the plant-level employment dynamics observed in the data.

If the plant does not adjust employment, the profit is

$$\pi^n(s_t, n_{t-1}; z_t) \equiv z_t f(n_{t-1}, s_t) - w_t n_{t-1}.$$

Therefore,

$$V^a(s_t, n_{t-1}; z_t) = \max_{n_t} \pi^a(s_t, n_{t-1}, n_t; z_t) + \beta E_z[W(s_t, n_t; z_{t+1})|z_t],$$

and

$$V^n(s_t, n_{t-1}; z_t) = \pi^n(s_t, n_{t-1}; z_t) + \beta E_z[W(s_t, n_{t-1}; z_{t+1})|z_t]$$

hold. Here, $E_z[\cdot|z_t]$ denotes the expected value with respect to z_{t+1}, conditional on z_t.

Entrants' decision

The entrant's value function is

$$V^e(q_t; z_t) = \int V^c(s_t, 0; z_t) d\eta(s_t|q_t),$$

where $\eta(s_t|q_t)$ is the (exogenously given) distribution of s_t given q_t. For an entry decision, there is a threshold value of q_t, q_t^*, which is determined by

$$V^e(q_t^*; z_t) = (1 - \gamma_t^e)c_e, \tag{1}$$

where potential entrants with q_t above q_t^* enter. A potential entrant's value function is calculated by

$$V^p(z_t) = \int \max\langle V^e(q_t; z_t) - (1 - \gamma_t^e)c_e, 0\rangle d\nu(q_t),$$

where $\nu(q_t)$ is the (exogenously given) distribution of q_t. We assume a free entry for becoming a potential entrant, and therefore,

$$V^p(z_t) = (1 - \gamma_t^q)c_q \tag{2}$$

holds.

2.2. CONSUMERS

We assume that a representative consumer who maximizes the expected utility exists, as follows:

$$\mathbf{U} = E\left[\sum_{t=0}^{\infty} \beta^t [C_t + Av(1 - L_t)]\right],$$

where $v(\cdot)$ is an increasing and concave function, C_t is the consumption level, L_t is the employment level, $\beta \in (0,1)$ is the discount factor, and $A > 0$ is a parameter. Note that we assume a linear utility for consumption, which simplifies our analysis dramatically. This assumption implies that the plant's profit is discounted by the consumer's discount factor β. The budget constraint in each period is

$$C_t = w_t L_t + \Pi_t + R_t, \tag{3}$$

where w_t is the wage rate, Π_t is the firm's profit, and R_t is the lump-sum transfer from (or tax to) the government. We assume that there is no saving. The first-order condition in each period is

$$Av'(1 - L_t) = w_t. \tag{4}$$

2.3. GENERAL EQUILIBRIUM

The general equilibrium of the model is defined as a situation in which (i) consumers and plants optimize and (ii) the markets clear. First, we consider the steady state without shocks, that is, z_t is constant over time. This situation is similar to the stationary equilibrium of Hopenhayn and Rogerson (1993).

The general equilibrium can readily be characterized by looking at the labor market. The free-entry condition (2) determines the demand side of the labor market. In other words, the labor demand is filled until the wage rate adjusts to the level at which (2) is satisfied. The quantity of the labor demand in the steady state is given by

$$L^d = N \int \phi(s', n) d\mu(s', n), \tag{5}$$

where $\mu(s', n)$ is the stationary distribution of the plants with the state (s', n) when we set the mass of potential entry in each period to one. In other words, $\mu(s', n)$ summarize the distribution of all individual plants in the economy, both survivors from the last period and this period's entrants after receiving this period's shock.[4] $\phi(s', n)$ is the optimal employment decision rule of a plant with the state (s', n) (note that s' is the plant-level productivity in the *current* period (i.e., s_t) and n is the plant-level employment in the *previous* period (i.e., n_{t-1})).[5]

[4]Note that the stationary measure of plants are determined (i.e., computed) based on the case when we set the mass of potential entry (N) equal to one. Then, the *actual* measure of plants can be obtained by multiplying N, once the quantity is determined. This property of the linear homogeneity, following Hopenhayan and Rogerson (1993), makes the computation easy.

[5]While the use of notation may look different from the conventional use of "$'$", it is a standard way of notation, widely used in the firm dynamics literature with adjustment cost since Hopenhayn and Rogerson (1993).

The mass of potential entry in each period is denoted as N. Here, the time subscript is omitted, because the economy is in the stationary state. The first-order condition (4) for the representative consumer characterizes the labor supply side.

From our model structure, the equilibrium can be characterized sequentially. First the equilibrium wage w^* is set from the labor-demand side, in particular from the free entry condition (2). Then, the equilibrium level of labor L^* is determined from the labor supply curve (4). Once L^* is determined, the equilibrium level of N, N^*, can be found from (5). Then, the actual measure of survivors will be $N\mu$ from the linear homogeneity. The measure of actual entrants, M, is determined as a function of N:

$$M = N \int_{q^*}^{\infty} d\nu(q).$$

Next, we examine the equilibrium in the business cycle model. Once the aggregate shock is introduced, the economy is no longer in stationary state: L^* and N^* change over time. The labor demand is now given by

$$L_t^d = L_{it}^d + N_t L_{et}^d, \tag{6}$$

where L_{it}^d is the labor demand from incumbents in period t and L_{et}^d is the labor demand from the entrants when the mass of potential entry is assumed to be one. The determination of the equilibrium is similar to the steady state case: the free-entry condition (2) determines the wage, L can be found from the labor-supply equation (4), and the labor-demand equation (6) can be used to solve for N.

Finally, the aggregate profit is given by

$$\Pi_t = Y_t - w_t L_t - R_t - N_t(1-\gamma_t^q)c_q - M_t(1-\gamma_t^e)c_e + X_t,$$

where Y_t is aggregate output, N_t is the number of potential entrants, M_t is the number of actual entrants, and X_t is the total value of exiting, which is the sum of exit values x_t for plants whose exit value minus the firing cost is greater than the expected value of continuing (i.e., $x_t - g(0,n) \geq E_{s'}[V^c(s',n)|s]$). Combining this with (3) and the government budget constraint, the equilibrium consumption is

$$C_t = Y_t - N_t c_q - M_t c_e + X_t.$$

2.4. CALIBRATION AND THE STEADY-STATE OUTCOME

The calibration follows Lee and Mukoyama (2018). We outline the calibration procedure here, for the sake of completeness, but the detailed discussions

Table 1: Benchmark parameters

β	θ	a_s	ρ_s	σ_s	λ	c_e	c_q
0.94	0.7	0.04	0.97	0.11	0.983	872.9	103.1

are delegated to that paper, which also describes the computational procedure of the model.

The general calibration strategy is to use the steady state of the model with constant z (we set $z = 1$) as the benchmark and then to calibrate the aggregate shocks separately. We set one period as 1 year. Following Hopenhayn and Rogerson (1993), we normalize the wage rate, w, in the steady state to 1. We pin down the benchmark value of N by setting aggregate employment, L, to 0.6. The value of A is calculated from (4), $w = 1$, and $L = 0.6$, together with the functional-form assumption $v(\cdot) = \ln(\cdot)$. We set $\beta = 0.94$ and returns to scale parameter $\theta = 0.7$ in the production function, sn^{θ}. These values are in the range of standard numbers in the macroeconomics literature.

The process for idiosyncratic productivity, s, is chosen so that the model generates the employment process observed in the data. We use the results of Lee and Mukoyama (2015b), who estimate the employment process with the Annual Survey of Manufactures from the U.S. Census. We assume that s follows an AR(1) process with normal disturbances:

$$\ln(s') = a_s + \rho_s \ln(s) + \varepsilon_s,$$

where

$$\varepsilon_s \sim N(0, \sigma_s^2).$$

This process is approximated by a Markov process by using Tauchen's (1986) method. We set 30 evenly spaced grids on $\ln(s)$ over the interval $[a_s/(1-\rho_s) - 3\sqrt{\sigma_s^2/(1-\rho_s^2)}, a_s/(1-\rho_s) + 3\sqrt{\sigma_s^2/(1-\rho_s^2)}]$. The constant a_s is determined so that the average value of employment matches the data average. The value of ρ_s is set to 0.97, which makes the AR(1) coefficient of the employment process in the model match the target value of 0.97. The value of σ_s is set so that the variance of the growth rate of n is close to the empirical value of 0.14.

Following the point estimate of Cooper et al. (2004), we set the adjustment factor λ equal to 0.983. The exit value takes zero with probability x_0 and a positive value with probability $(1-x_0)$. The positive portion is uniformly distributed

Table 2: Data and model statistics in the steady-state

	Data	Model
Average size of continuing plants	87.5	87.6
Average size of entering plants	50.3	49.7
Average size of exiting plants	35.0	35.8
Entry rate	6.2%	5.4%
Exit rate	5.5%	5.4%
AR(1) coefficient ρ for employment	0.97	0.97
Variance of growth rate for n	0.14	0.14
Job reallocation rate	19.4%	23.0%

Note: Average size is the number of employment. Job realloction rate is the sum of job creation rate and job destruction rate.

over $[0,\bar{x}]$, where we set x_0 and $\bar{x}$ so that the exit rate and the size of the exiting plants, respectively, match the empirical values. This results in $x_0 = 0.9$ and $\bar{x} = 2500$. The entry transition function is assumed identical to the transition function for the incumbents: $\eta(s'|q) = \psi(s'|s)$. The entry costs, c_q and c_e, are calculated from the model. In particular, (1) and (2) determine the values of c_q and c_e, given $\nu(q)$ and the equilibrium value of q^* that we target. We assume that $\nu(q)$ follows $\nu(q) = B\exp(-q)$ over the lower part of the grids on s, where B is the scale parameter.[6] The target value of $\ln(q^*)$ is 0.5 in the baseline. This choice of $\nu(q)$ and q^* brings the size distribution of young plants close to the data. We set the firing tax $g(n',n)$, as zero in the baseline. Table 1 lists the main parameter values.

Table 2 compares the output of our model to the average values of the data. The job reallocation rate is taken from Davis et al. (1996, Table 2.1), and the other values are taken from Lee and Mukoyama (2015a). Everything except the job reallocation rate is used as our target for calibration. In addition, the job reallocation rate turns out to be close to the value in the data, thanks to the existence of the employment adjustment cost. Lee and Mukoyama (2018) show that the size distribution of plants is in line with the data.

[6]For more detail, we set 200 grids on x and 25 grids on q.

2.5. AGGREGATE SHOCKS AND CYCLICAL DYNAMICS

In considering the aggregate fluctuations, we assume that z_t fluctuates between two values, 1.01 and 0.99, following a symmetric Markov process. This results in a 1% standard deviation in z_t. This outcome is similar to the estimated unconditional standard deviation of Solow residuals over the sample period of Lee and Mukoyama (2015a). We calibrate the transition probabilities so that the average duration of each state is 3 years.

Lee and Mukoyama (2018) show that when c_q and c_e are constant over time, the model does not match the microeconomic facts on plant-level entry dynamics. Lee and Mukoyama (2018) further show that under the assumption that c_q is procyclical and c_e is countercyclical, the model performs well in terms of matching the data facts. A procyclical c_q can be interpreted as idea creation being more expensive during booms. The cost of hiring a good inventor is particularly higher during booms, partly because the wages for these workers are higher.[7] A countercyclical c_e can be interpreted in the context of actual cost of building plants. Based on this interpretation and evidence that the price of investment goods tends to be lower during booms (see, e.g., Fisher, 2006), c_e is suggested to be lower during booms. In addition, financing for building new plants can be more difficult during recessions.[8]

Table 3 presents the cyclical statistics when c_e is 0.8% higher during recessions and 0.8% lower during booms, and c_q is 3.3% lower during recessions and 4.1% higher during booms. These numbers follow Lee and Mukoyama (2018). The results are quantitatively in line with the data patterns described in Lee and Mukoyama (2015a).

3. POLICY EXPERIMENTS

Now we move on to our main goal of this study: policy analysis. In this section, we call the results in Table 3 our baseline case. We consider four experiments in total. In three of these, we consider a cyclical policy, in which a particular policy is imposed only during recessions.

[7] From the National Science Foundation data on R&D expenditure and costs, the cost per R&D scientist or engineer in companies performing R&D is about 8.6% higher during booms than recessions.

[8] For financial propagation, see, for example, Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), and Kiyotaki and Moore (1997). See Macnamara (2012), Zhang (2013, 2016), and Siemer (2014) for recent examples of models incorporating financial costs in firm dynamics models.

Table 3: Baseline case

	Boom	Recession
Wage	1.010	0.990
q^*	0.3047	0.6335
Entry rate	7.0%	3.9%
Exit rate	5.3%	5.5%
Average size of all plants	79.5	82.4
Relative size of entrants	0.48	0.69
Relative size of exiting plants	0.41	0.41
Relative productivity of entrants	0.78	0.94
Relative productivity of exiting plants	0.84	0.84

As we discuss in this section, the effect of a firing tax has been examined in the existing literature but mostly in models with exogenous entry and exit. Recent studies on firm dynamics emphasize the adjustment at the entry margin over the business cycle (e.g., Lee and Mukoyama, 2015a; Sedláček and Sterk, 2017; Woo, 2017). We conduct analysis of the firing tax in order to investigate how the (endogenously) cyclical entry of plants affects the aggregate effect of a firing tax. The analysis of an entry subsidy is conducted in order to examine the aggregate implications of cyclical policies that affect the entry process directly.

3.1. CONSTANT FIRING TAX

First, we consider a firing tax, which is constant over time. Note that because the tax revenue is given back to consumers in a lump-sum manner, it is counted in aggregate output. We consider the following specification of the firing tax:

$$g(n_t, n_{t-1}) = \tau_t \max\langle 0, n_{t-1} - n_t \rangle.$$

We set $\tau_t = 0.1$. Since the wage is set to 1 at the benchmark, this implies that the firing tax per person is 10% of the annual wage.

The consequences of a firing tax on the allocation of employment have been analyzed by many researchers in recent years. For example, Veracierto (2008) analyzes the implications of a constant firing tax in a general equilibrium establishment-level dynamics model. Veracierto's model incorporates saving and capital stock, but entry and exit are assumed to be exogenous. Samaniego (2008) conducts a similar exercise.

Table 4: Results with a constant firing tax (10%)

	Boom	Recession
Wage	0.999	0.980
q^*	0.3042	0.6337
Entry rate	7.1%	3.8%
Exit rate	5.3%	5.5%
Average size of all plants	80.1	83.2
Relative size of entrants	0.46	0.66
Relative size of exiting plants	0.41	0.41
Relative productivity of entrants	0.77	0.94
Relative productivity of exiting plants	0.83	0.83

The results from our model with 10% firing tax are shown in Table 4. Entry and exit behavior do not show quantitatively large changes compared to the baseline case, although we observe some differences in the entry threshold, q^*, and in the entry rate. The average size of plants increases, reflecting the reluctance to fire. In terms of the average statistics, we observe changes in statistics that we usually associate with firing costs. The job reallocation rate falls from 23.0% in the baseline case to 21.3%. Average output falls by 0.9%, and average employment falls by 0.7%. We report aggregate statistics for each experiment in Appendix Table A1.

Interestingly, the variance of output *increases* slightly, by 2.4%.[9] This contrasts with Samaniego (2008) and Veracierto (2008), who find that the firing cost stabilizes. In our experiment, the variance of output by survivors *decreases* with the firing tax, as does the variance of output by unit mass of entrants. However, *the variance of the entry rate increases*, which leads to an increase in the variance of total output.[10] Intuitively, the firing tax is a tax on relatively large plants, which are more likely to reduce the number of workers (i.e., fire) in the near future (i.e., due to the mean reversion). Because plants that enter during recessions are typically larger than those that enter during booms, the former type of plants experience a larger expected tax burden, which works in the direction of reduc-

[9] The coefficient of variation also increases, since the mean decreases with the firing cost.

[10] Veracierto (2002, 2008) does not have this margin, since the entry rate is assumed constant in his model. Samaniego (2008) features endogenous entry. However, in his model, the entry rate reacts very little to the change in aggregate productivity.

Table 5: Results with a firing tax, during recessions only (10%)

	Boom	Recession
Wage	1.006	0.983
q^*	0.3046	0.6337
Entry rate	9.1%	1.8%
Exit rate	5.3%	5.7%
Average size of all plants	73.1	80.6
Relative size of entrants	0.52	0.70
Relative size of exiting plants	0.41	0.40
Relative productivity of entrants	0.80	0.97
Relative productivity of exiting plants	0.84	0.83

ing the entry rate during recessions relative to booms. In other words, firing costs are more likely to affect entrants in recessions (which are relatively larger) than those in booms (which are relatively smaller). This outcome is reflected in the difference in q^*s between Tables 3 and 4: q^* decreases in booms and increases in recessions. Although general equilibrium effects also operate, our quantitative exercise suggests that the entry rate increases with firing costs during booms and decreases with firing costs during recessions.

3.2. FIRING TAXES DURING RECESSIONS

Next, we consider the case in which the government imposes the tax only during recessions (i.e., $\tau_t = 0.1$ only when $z_t = 0.99$). This policy can be interpreted as one in which the government aims to reduce the amount of firing during bad times. The results are summarized in Table 5. The government succeeds in its intention—the average job destruction rate during recessions falls to 9.7% versus 11.6% in the baseline case. However, as we can observe from the table, the entry and exit rates fluctuate more than in the baseline case. As entrants in recessions are relatively larger and they are more likely to be affected by firing tax, the entry rate drops dramatically in recessions. As a result, the variance of output more than doubles. This finding suggests that the government policy designed to stabilize output by protecting workers in recessions may work in the opposite direction, amplifying the fluctuation.

Table 6: Results with entry subsidies on c_e and c_q during recessions only (0.1%)

	Boom	Recession
Wage	1.004	0.997
q^*	0.3053	0.6206
Entry rate	6.1%	4.6%
Exit rate	5.4%	5.4%
Average size of all plants	81.6	83.1
Relative size of entrants	0.47	0.67
Relative size of exiting plants	0.41	0.41
Relative productivity of entrants	0.77	0.93
Relative productivity of exiting plants	0.84	0.84

3.3. ENTRY SUBSIDIES IN RECESSIONS, TO BOTH IDEA AND IMPLEMENTATION COSTS

Looking at the data, the government might think that entry rates are too low during recessions and decide to subsidize entry costs only during recessions. Recent studies raised a concern that overall decline in start-ups and entry may have a negative impact on the long-run growth. In our model, there are two types of entry costs: the idea cost and the implementation cost. Here we consider the case where both costs are subsidized at the same rate. In particular, we assume that entry costs c_e and c_q are subsidized by 0.1% during recessions (i.e., $\gamma_t^q = \gamma_t^e = 0.001$).

A subsidy on the idea cost can be interpreted as an R&D subsidy, and a subsidy of the implementation cost can be interpreted as an investment subsidy. The results are summarized in Table 6. Entry rates are less volatile compared to the baseline case. The variance of output is substantially reduced—it becomes less than half of the variance found in the baseline case. The selection of entrants during recession is not as stringent as in the baseline case: q^* is smaller now. Since wage volatility is also smaller, the average size of plants is similar across booms and recessions. If the government's goal is to stabilize output along with entry and exit, this type of subsidy is more effective than the (cyclical or noncyclical) firing cost.

Table 7: Results with entry subsidies on c_q during recessions only (0.1%)

	Boom	Recession
Wage	1.009	0.992
q^*	0.3049	0.6338
Entry rate	6.9%	4.0%
Exit rate	5.3%	5.5%
Average size of all plants	79.9	82.5
Relative size of entrants	0.48	0.69
Relative size of exiting plants	0.41	0.41
Relative productivity of entrants	0.77	0.94
Relative productivity of exiting plants	0.84	0.84

3.4. ENTRY SUBSIDIES IN RECESSIONS, ONLY TO IDEA COST

Next, consider the case in which only the idea cost is subsidized during recessions. In particular, c_q is subsidized by 0.1% during recessions. In other words, $\gamma_t^q = 0.001$ in recessions, while $\gamma_t^e = 0$. In our interpretation, this corresponds to a subsidy of R&D activities in recessions. The results are presented in Table 7. Entry rate in recessions is lower compared to the previous section because the implementation cost (c_e) is no longer subsidized. Considering that the implementation cost (c_e) is about eight times larger than the idea cost (c_q) in our calibration, dropping the subsidy to the implementation cost makes a substantial difference. Due to the relatively smaller subsidy amount, the selection of the entrants, in terms of relative size and productivity, does not change much from the baseline case.

3.5. ENTRY SUBSIDIES IN RECESSIONS, ONLY TO IMPLEMENTATION COST

Table 8 reports the results when only the entry cost is subsidized during recessions. In particular, c_e is subsidized by 0.1% during recessions (i.e., $\gamma_t^e = 0.001$ in recessions and $\gamma_t^q = 0$ for all t). If the government thinks that higher financial costs may hinder potential entrants to enter, it may subsidize the implementation cost of start-ups. The results are somewhat similar to Table 6, in which both c_e and c_q are subsidized. This is probably due to the fact that c_e is much larger than c_q and the subsidy to c_e is thus plays a more important role

Table 8: Results with entry subsidies on c_e during recessions only (0.1%)

	Boom	Recession
Wage	1.005	0.995
q^*	0.3052	0.6203
Entry rate	6.4%	4.4%
Exit rate	5.4%	5.5%
Average size of all plants	80.8	82.8
Relative size of entrants	0.48	0.68
Relative size of exiting plants	0.41	0.41
Relative productivity of entrants	0.77	0.93
Relative productivity of exiting plants	0.84	0.84

than that to c_q. Entry rate in recessions is higher than the results of previous section, in which only idea costs are subsidized during recessions. The selection criteria q^* becomes slightly lower in recessions, and accordingly the relative size and productivity of entrants decreases a little bit compared to previous case with subsidy to c_q. Again, the government can achieve stability in entry rates. The variance of output is also small—less than half of the baseline case.

4. CONCLUSION

This study analyzed the effects of firing costs and entry subsidies in a general equilibrium model with aggregate shocks. The model is quantitatively consistent with the entry and exit patterns in the U.S. manufacturing data.

We found that both a constant firing tax and a countercyclical firing tax increase the volatility of the entry rate and aggregate output. Countercyclical entry subsidies stabilize the entry rate and aggregate output over the business cycle. Our findings suggest that it is important to model entry and exit endogenously in assessing the effects of such policies.

REFERENCES

Bernanke, B. and M. Gertler (1989). "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review* 79, 14–31.

Carlstrom, C. T. and T. S. Fuerst (1997). "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review* 87, 893–910.

Cooper, R.; J. C. Haltiwanger; and J. Willis (2004). "Dynamics of Labor Demand: Evidence from Plant-level Observations and Aggregate Implications," NBER Working Paper 10297.

Davis, S. J.; J. C. Haltiwanger; and S. Schuh (1996). *Job Creation and Destruction*, Cambridge, MIT Press.

Fisher, J. D. M. (2006). "The Dynamic Effects of Neutral and Investment-Specific Technology Shocks," *Journal of Political Economy* 114, 413–451.

Gertler M. and A. Trigari (2009). "Unemployment Fluctuations with Staggered Nash Wage Bargaining," *Journal of Political Economy* 117, 38–86.

Hopenhayn, H. A. (1992). "Entry, Exit, and Firm Dynamics in Long Run Equilibrium," *Econometrica* 60, 1127–1150.

Hopenhayn, H. and R. Rogerson (1993). "Job Turnover and Policy Evaluation: A General Equilibrium Analysis," *Journal of Political Economy* 101, 915–938.

Kiyotaki, N. and J. Moore (1997). "Credit Cycles," *Journal of Political Economy* 105, 211–248.

Lee, Y. and T. Mukoyama (2008). "Entry, Exit and Plant-Level Dynamics over the Business Cycle," Federal Reserve Bank of Cleveland Working Paper, 07-18R.

Lee, Y. and T. Mukoyama (2015a). "Entry and Exit of Manufacturing Plants over the Business Cycle," *European Economic Review* 77, 20–27.

Lee, Y. and T. Mukoyama (2015b). "Productivity and Employment Dynamics of US Manufacturing Plants," *Economics Letters* 136, 190–193.

Lee, Y. and T. Mukoyama (2018). "A Model of Entry, Exit and Plant-Level Dynamics over the Business Cycle," mimeo.

Macnamara, P. (2012). “Firm Entry and Exit with Financial Frictions,” mimeo. University of Manchester.

Samaniego, R. M. (2008). “Entry, Exit and Business Cycles in a General Equilibrium Model,” *Review of Economic Dynamics* 11, 529–541.

Sedláček, P. (2015). “Lost Generations of Firms and Aggregate Labor Market Dynamics,” mimeo. University of Bonn.

Sedláček, P. and V. Sterk (2017). “The Growth Potential of Startups over the Business Cycle,” *American Economic Revoew* 107, 3182–3210.

Siemer, M. (2014). “Firm Entry and Employment Dynamics During the Great Recession,” FEDS Working paper 201456.

Tauchen, G. (1986). “Finite State Markov-Chain Approximations to Univariate and Vector Autoregressions,” *Economics Letters* 20, 177–181.

Tian, C. (2018). “Firm-Level Entry and Exit Dynamics over the Business Cycles,” *European Economic Review* 102, 298–326.

Veracierto, M. L. (2002). “Plant-Level Irreversible Investment and Equilibrium Business Cycles,” *American Economic Review* 92, 181–197.

Veracierto, M. L. (2008). “Firing Costs and Business Cycle Fluctuations,” *International Economic Review* 49, 1–39.

Woo, J. (2015) “The Cyclicality of Entry and Exit: A General Equilibrium Analysis with Imperfect Information,” mimeo. University of Rochester.

Zhang, L. (2013).“Entry, Exit, and Capital Structure over the Business Cycle,” mimeo. UCLA.

Zhang, L. (2016). “Financial Leverage, Job Reallocation, and Firm Dynamics over the Business Cycle,” mimeo. UCLA.

Appendix

Table A1: Aggregate statistics for each experiment

	Output		Employment		Job reallocation rate
	Average	Variance	Average	Variance	Average
Baseline	.8563	.0002	.5998	.0000	.2302
Constant firing tax	.8488	.0002	.5956	.0000	.2125
Firing tax, during recessions	.8523	.0004	.5977	.0000	.2196
Entry subsidies on c_e and c_q	.8580	.0001	.6002	.0000	.2302
Entry subsidies on c_q only	.8569	.0002	.5999	.0000	.2302
Entry subsidies on c_e only	.8578	.0001	.6001	.0000	.2303