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Market Structure and the Business Cycle

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Market Structure and the Business Cycle

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Market Structure and the Business Cycle

DISCUSSION PAPER #789

by

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Abstract

The key ingredients of real business cycle models are common. The market structure is perfectly competitive, the forcing process is a technology shock, and in most cases agents are identical. Textbook market structures are introduced in a real business cycle model. The market structures studied are perfect competition, monopoly, oligopoly, and monopolistic competition. The results show that economywide monopoly or two-firm oligopoly with the technology shock of the size estimated by Prescott (1986) cannot produce the output volatility observed in the U.S. economy. However, ten-firm oligopoly can mimic the output volatility with the technology shock of the same size. Since an actual economy has much more than ten firms, it is argued that it is safe to use the competitive market structure in a study of business fluctuations. In addition, it is shown that market structure itself is not a mechanism magnifying the responsiveness of a model to a policy shock like government purchases.

1. Introduction

An unresolved question in business cycle research concerns the effect of market structure on the fit of real business cycle models. The key ingredients in real business cycle models since Kydland and Prescott (1982) and Long and Plosser (1983) are common. The market structure is perfectly competitive, the forcing process is a technology shock, in many cases agents are identical, and numerical techniques are applied to find rational expectations solutions. The reason for concentrating on the perfectly competitive market is that we can invoke the second welfare theorem and use a programming problem to solve for the equilibrium (see Kydland and Prescott (1982), Hansen (1985), and King, Plosser and Rebelo (1988)) or we can use a quasi-programming problem in cases with distortions to get equilibrium allocations (see King (1987), Kydland (1987), and Cooley and Hansen (1989)). However, we need to derive an aggregate demand function from individuals' utility maximizing problem in case of noncompetitive market structures. Since an intertemporal efficiency condition should be evaluated to get the demand function, this is, in fact, quite a task in most cases.

However, there is a special case where we do not need to evaluate the intertemporal efficiency condition to derive the aggregate demand function. In cases in which the preferences involve no income effect in labor supply, we only need the intratemporal efficiency condition between consumption and leisure in order to derive the aggregate demand function very easily. Once we have the aggregate demand function, we can analyze market structures without any difficulties. Actually preferences without income effects have been used many times in contract theories (see Azariadis (1975) and Rosen (1985)). Recently Devereux, Gregory and Smith (1990) used the same preference specification to address the problem of international consumption

correlations in a real business cycle model and Greenwood, Hercowitz and Huffman (1988) used the same specification in a study of the effects of capital utilization and varying capital depreciation on the real business cycle.

The market structures analyzed in the paper are those easily found in a economics textbook, namely perfect competition, monopoly, Cournot oligopoly and monopolistic competition (see for example Varian (1984)). However, we do not need to analyze those market structures in depth to find their qualitative implications on the size of business cycle fluctuations. When there is a supply shock (or demand shock too), goods market adjustment takes place along the average revenue curve (or demand curve) in the case of a competitive market (see Figure 1), but it takes place along the marginal revenue curve in the case of monopoly. However, demand curve is more elastic than marginal revenue curve and so the amount of adjustment is larger in the case of perfect competition than in the case of monopoly. In other words, the difference between Y_2 and Y_1 in Figure 1 is bigger than the difference between Y_2' and Y_1' . In addition, the responses of an economy with an intermediate market structure should have responses between them.

The paper analyzes these market structures and then simulates corresponding economies. The results show that monopoly with a technology shock of the size implied by Prescott (1986) cannot generate the size of the fluctuations of variables of interest. However, a ten firm oligopoly market with the shock of the same size is shown to generate sufficiently large fluctuations in the variables involved. The next section states the environment. The consumer-worker's problem is analyzed and then an aggregate demand function is derived in section 3. Section 4 describes the stationary equilibrium for each market structure. Section 5 simulates the model and

discusses the results, and section 6 concludes.

2. The Economy

The economy consists of a continuum of identical agents (or households) distributed over the closed interval $[0, 1]$. Each agent is endowed with one unit of time in each period and initial capital stock k_0 . Each agent maximizes his expected lifetime expected utility which is assumed to be time separable.

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \cdot u(c_t, l_t), \quad (2.1)$$

where c_t is consumption, l_t is leisure, and β is utility discount factor. In addition we assume the temporal preference takes the following form.

$$u(c_t, l_t) = c_t + v(l_t) \quad (2.2)$$

Each agent is risk neutral in consumption and consumption and leisure are separable. The reason why we assume the risk neutral preferences will be clear in the next section. Basically the demand for goods in each period can be explicitly defined in the case of risk neutral preferences. In fact, we use the specification (2.2) purely for an expository convenience. Even if we generalize the temporal preferences in the following way, the results in the paper hold qualitatively.

$$u(c_t, \ell_t) = G[c_t + v(\ell_t)], \quad (2.3)$$

where $G'(\cdot) > 0$ and $G''(\cdot) < 0$. This form of preferences has been used many times in the contract literature (see Azariadis (1975), Rosen (1985)). We will use one version of (2.3) in later sections. We assume that all agents are price takers and they own the firms in the economy. However, ownership and management of the firms are completely separated and so each of the agents cannot influence the firms' decision.

There are many identical firms producing homogenous output. They can collude and produce output according to monopoly rule, or they can form Cournot oligopoly. Two other market structures we will study are perfect competition and monopolistic competition¹. However, the dynamic strategies among the firms are not the issue studied here but rather the consequences of the market structures will be studied². Assume there are m firms in the economy. Each of the firms and hence the economy as a whole produces output according to a linear homogenous production function.

$$Y_t^j = \lambda_t F(K_t^j, N_t^j), \quad j = 1, 2, \dots, m, \quad (2.4)$$

where λ_t is the productivity shock common to all firms and K_t^j, N_t^j are capital

¹ If we consider monopolistically competitive market structure, we need to redefine the preferences since there are many goods. This extension will be discussed in section 4.

² We can ask what features of the environment imply the market structures assumed in the model. We can find vast amount of papers on this topic in the literature. However, it's not the issue studied in this paper. In fact, there are no intrinsic factors in the model which dictate the market structure. It seems possible to introduce some elements leading to non-competitive market structures.

and labor used in firm j . If we define z_t as $z_t = \log(\lambda_t)$, then z_t is assumed to follow an AR(1) process.

$$z_{t+1} = \rho z_t + \varepsilon_{t+1}, \quad 0 \leq \rho \leq 1, \quad (2.5)$$

where ε_t is i.i.d. random variable with mean 0 and variance σ_ε^2 . The firms can form a monopoly or an oligopoly but act competitively in the factor markets. Here we use labor as the numeraire and so we let p_t and r_t denote the output price and rental price of capital in units of labor in period t respectively. Each firm maximizes its profit in each period.

$$\Pi_t^j = p_t Y_t^j - N_t^j - r_t \cdot K_t^j, \quad j = 1, 2, \dots, m \quad (2.6)$$

If the firms are perfectly competitive, p_t is perceived as fixed by each firm. However, if the firms have some market power, firms use their own demand functions perceived in the market to determine the quantity of inputs. We define aggregate supply of output and aggregate demands for factors as follows.

$$Y_t^s = \sum_{j=1}^m Y_t^j, \quad N_t^d = \sum_{j=1}^m N_t^j, \quad K_t^d = \sum_{j=1}^m K_t^j, \quad (2.7)$$

where m is the number of firms. In equilibrium Y_t^s should be equated to aggregate demand for output and factor demands N_t^d and K_t^d should be equated to their supplies respectively, which are determined by the household's intertemporal optimization.

There is a government which specifies the path of government purchases G_t and also taxes output. Following Baxter and King (1988), we assume the

government follows a tax rule which depends on government purchases and at the same time on the aggregate level of economic activities.

$$\tau_t = \tau(G_t, K_t, N_t), \quad (2.8)$$

where τ_t is one minus the income tax rate which is imposed on household income. In addition, we assume that the path of government purchases can be described as follows.

$$g_{t+1} = \eta \cdot g_t + \zeta_{t+1}, \quad (2.9)$$

where $g_t = \log(G_t)$ and ζ_t is a white-noise with mean $(1-\eta)\log(G)$, where G is the steady state government purchases, and variance σ_ζ^2 . Government is also constrained by its budget³. We assume that there is no government borrowing but that the differences between government expenditures and income tax revenue is financed by transfer payments or lump sum taxes, T_t . So the following is true.

$$(1-\tau_t)Y_t = G_t + T_t \quad (2.10)$$

Note here that the income tax is distortionary and that this distortion prevents us from obtaining equilibrium allocations by solving programming problems (regardless of the market structures assumed). To evaluate the impact of market structures on the fit of the model, we need a numerical

³ Variables without superscript denote equilibrium quantities. Since there is no possibility of confusion, we will abstract from superscript from now on.

method. Such numerical methods can be found in Cooley and Hansen (1989), King (1987), and Kydland (1987). We will follow the suggestions made by these authors in later sections. However, we need first to look into the problems facing the households and firms in each market structure.

3. Household's Problem and Output Demand

Each household maximizes its lifetime expected utility subject to the budget constraint. The household budget in period t is obtained as follows.

$$p_t(c_t + x_t) \leq \tau_t(n_t + r_t k_t + \pi_t) + p_t T_t, \quad (3.1)$$

where x_t is savings in the form of capital accumulation, i.e. investment, $n_t = 1 - \delta_t$, k_t is capital stock owned by the household, and π_t is profit share. The household capital stock follows the following process.

$$k_{t+1} = (1 - \delta)k_t + x_t, \quad (3.2)$$

where δ is the depreciation rate. In addition to this individual budget constraint and equation of motion of the household capital stock, we have their aggregate counterparts as follows.

$$C_t + X_t + G_t \leq Y_t \quad (3.3)$$

$$K_{t+1} = (1 - \delta)K_t + X_t, \quad (3.4)$$

where uppercase letters denote aggregate quantities. In fact, we can derive (3.3) by aggregating (3.1) and using (2.4) and (2.9), and (3.4) is an

obvious result of aggregating (3.2).

Now the representative household maximizes its lifetime utility (2.1) subject to (3.1), (3.2) and nonnegativity constraints. For later reference, we write down the household's problem.

$$\begin{aligned}
 &\text{maximize} && E_0 \sum_{t=0}^{\infty} \beta^t \cdot [c_t + v(\ell_t)] && (3.5) \\
 &\text{s. t.} && p_t(c_t + x_t) \leq (1-\tau_t)(n_t + r_t k_t + \pi_t) + p_t T_t \\
 &&& k_{t+1} = (1-\delta)k_t + x_t \\
 &&& c_t \geq 0, \quad 0 \leq \ell_t \leq 1
 \end{aligned}$$

Solving this optimization problem, each household takes the current values of prices p_t , r_t , profits π_t , and policy variables τ_t , T_t as given. In addition, it forms rational expectations on the future values of these variables by perceiving the equations of motion of the technology shock and aggregate capital stock, the aggregate resource constraint, and the policy constraint.

Forming the Lagrangian function leads to the following first order conditions:

$$1 = p_t \Omega_t \tag{3.6}$$

$$v'(\ell_t) = \tau_t \Omega_t \tag{3.7}$$

$$p_t \Omega_t = q_t \tag{3.8}$$

$$q_t = E_t [(1-\delta)q_{t+1} + \beta \cdot \tau_{t+1} \cdot r_{t+1} \cdot \Omega_{t+1}] \tag{3.9}$$

$$\lim_{t \rightarrow \infty} \beta^t \Omega_t k_{t+1} = 0, \tag{3.10}$$

where Ω_t and q_t are multipliers attached to the budget constraint and

equation of motion of the household capital stock respectively. Using (3.6) and (3.8), we have the following from (3.7) and (3.9).

$$p_t = \tau_t / v'(l_t) = \tau_t / v'(1-n_t) \quad (3.11)$$

$$1 = E_t [(1-\delta) + \beta \cdot \tau_{t+1} \cdot r_{t+1} / p_{t+1}] \quad (3.12)$$

(3.11) is the intratemporal efficiency condition, i.e. the marginal rate of substitution between consumption and leisure should be equal to the price ratio.⁴ On the other hand, (3.12) is the intertemporal efficiency condition, i.e. the marginal value of sacrificing one unit of consumption at date t , which is the marginal utility of consumption (1 due to risk-neutrality), should be the same as the discounted utility from returns to the accumulated capital at date $t+1$.

The key result from the household's problem is that the demand for output of a household is completely characterized by the intratemporal efficiency condition (3.11)⁵. Thus (3.11) holds that if the price of output rises given the tax rate, labor supplied by the household decreases. But if the tax rate rises given the output price, the labor supply of the household

⁴ Even if we use the preferences specification in (2.3), we can have the same intratemporal efficiency condition. However, the intertemporal efficiency condition will be quite different and so we can expect some differences in the fitting of the model.

⁵ Unfortunately, this result does not hold for more general preference specification. Suppose the temporal preferences are specified as $u(c_t) + v(l_t)$. Then we have the following intratemporal efficiency condition,

$$p_t = \tau_t \cdot u'(c_t) / v'(l_t),$$

and hence the demand function cannot be easily characterized as in the text due to the fact that consumption is related to investment through the household resource constraint and that investment is determined by the intertemporal efficiency condition.

increases. Now by aggregating (3.11) over all households, we can derive the aggregate demand for output as a function of the tax rate and aggregate labor input N_t^6 .

$$p_t = \tau_t / v'(1 - N_t) = p(N_t, \tau_t) \quad (3.13)$$

Now we can consider (3.13) as the market demand function for output. If the market is competitive, firms take price as given, but if the market structure is a collusive monopoly, the monopolist perceives (3.13) as the market demand function for output and makes use of it.

4. Market Structure, Firm's Problem, and Equilibrium

The problem facing a firm is distinct according to the assumed market structure. So we will look into the problem by changing the market structures facing firms.

4.1 Competitive Market

Firms in the market maximize their profit but they take prices as given. That is, firm j 's problem is:

$$\begin{aligned} \Pi_t^j = \text{maximize} \quad & p_t Y_t^j - N_t^j - r_t \cdot K_t^j & (4.1.1) \\ \text{s. t.} \quad & Y_t^j = \lambda_t F(K_t^j, N_t^j) \\ & K_t^j \geq 0, \quad N_t^j \geq 0. \end{aligned}$$

⁶ The only condition needed for the aggregation is that the marginal utility of leisure function has well defined inverse function. However, suppose the preferences are more general as in the previous footnote. Then aggregation can be a serious problem.

However, since the production function is homogeneous of degree one, we do not need to solve the individual firm's problem and then aggregate the result but instead may solve the aggregated firm's problem:

$$\begin{aligned} \Pi_t = \text{maximize} \quad & p_t Y_t - N_t - r_t \cdot K_t & (4.1.2) \\ \text{s. t.} \quad & Y_t = \lambda_t F(K_t, N_t) \\ & K_t \geq 0, \quad N_t \geq 0. \end{aligned}$$

We assume that the value of technology shock is known at the beginning of each period. The first order conditions for this problem are obtained as follows

$$p_t \lambda_t F_1(K_t, N_t) - r_t = 0 \quad (4.1.3)$$

$$p_t \lambda_t F_2(K_t, N_t) - 1 = 0 \quad (4.1.4)$$

From these conditions we can solve for the supply price of output and demand price for capital services as functions of the aggregate capital stock and aggregate labor input. Now the equilibrium processes of capital stock and aggregate hours can be obtained by equating the supply price of output to its demand price and the demand price of services of capital to its supply price. However, it is not possible to find a closed form solution and so we need to use a numerical method to look at the fit of the model.

In any case, we can solve for the equilibrium quantities in two steps in our model. The first step is to solve for prices in period t as functions of the period t aggregate state. In fact this can be done in a straightforward way. First, using (3.13) in (4.1.4), N_t can be solved for as function of λ_t ,

K_t , and τ_t .

$$N_t = N^c(\lambda_t, K_t, \tau_t), \quad (4.1.5)$$

where superscript c labels competitive outcomes. Using (3.13) and (4.1.5) in (4.1.3), we can have r_t as a function of λ_t , K_t , and τ_t again.

$$r_t = r^c(\lambda_t, K_t, \tau_t) \quad (4.1.6)$$

Now the process of output price can be obtained from using (4.1.5) in (3.13).

$$p_t = \tau_t/v' (1-N_t^c) = p^c(\lambda_t, K_t, \tau_t) \quad (4.1.7)$$

If we use (4.1.7) in (3.11), we have:

$$N_t = n_t = N^c(\lambda_t, K_t, \tau_t). \quad (4.1.8)$$

So we can completely characterize the processes for prices and employment without reference to capital accumulation. The second step is to determine processes governing capital accumulation, i.e. investment. However, if we stick to the preference specification made in (2.2), then this is not difficult. Using (4.1.3) and (4.1.8), we can rewrite the intertemporal efficiency condition (3.12) as:

$$\delta = E_t \{ \tau_{t+1} \cdot \lambda_{t+1} \cdot F_1 [K_{t+1}, N^c(\lambda_{t+1}, K_{t+1}, \tau_{t+1})] \}. \quad (4.1.9)$$

Now the problem is to solve for K_{t+1} , but since we know the processes

governing τ_t and λ_t , this is not a formidable task at all. Even though we can not solve (4.1.9) analytically, we can get quite an accurate approximate solution to (4.1.9), using one of the methods developed by Baxter (1987), Coleman (1989), and Marcet (1988).

Here we note that (4.1.9) can be obtained from the following sub-problem to (3.5):

$$\text{maximize}_{\{c_t\}} E_0 \sum_{t=0}^{\infty} \beta^t \cdot [c_t + v(1-n_t)] \quad (4.1.10)$$

$$\text{s.t.} \quad p_t(c_t + x_t) \leq \tau_t(n_t + r_t k_t + \pi_t) + T_t \quad (3.1)$$

$$k_{t+1} = (1-\delta)k_t + x_t \quad (3.2)$$

$$K_{t+1} = (1-\delta)K_t + X_t \quad (3.4)$$

$$\log(\lambda_{t+1}) = \rho \log(\lambda_t) + \varepsilon_{t+1} \quad (2.5)$$

$$\tau_t Y_t = G_t + T_t \quad (2.9)$$

$$r_t = r^c(\lambda_t, K_t, \tau_t) \quad (4.1.6)$$

$$p_t = p^c(\lambda_t, K_t, \tau_t) \quad (4.1.7)$$

$$N_t = n_t = N^c(\lambda_t, K_t, \tau_t) \quad (4.1.8)$$

$$\pi_t = p_t Y_t - N_t - r_t \cdot K_t \quad (4.1.2)$$

$$c_t \geq 0,$$

where the household takes the processes of aggregate variables and n_t as given. For a recursive representation, define the state facing the household in period t as $s_t = (z_t, k_t, K_t, \tau_t, g_t)$ and its aggregate counterpart as $S_t = (z_t, K_t, \tau_t, g_t)$. In addition define $V(s_t)$ to be the equilibrium maximized value of utility from the same problem as (4.1.10) defined as of date t . Then, we can rewrite the problem (4.1.10) as:

$$V(s_t) = \max_{\{c_t\}} \{[c_t + v(1-n_t)] + \beta E_t[V(s_{t+1})]\} \quad (4.1.11)$$

s. t. the constraints in (4.1.10)

Using (4.1.11), we can now define the stationary competitive equilibrium as follows.

Definition 1: A stationary competitive equilibrium for the economy is a set of decision rules $c(s_t)$, $x(s_t)$, $n(s_t)$, aggregate decision rules $C(S_t)$, $X(S_t)$, $N(S_t)$, price functions $p(S_t)$, $r(S_t)$, and a value function $V(s_t)$ such that:

- (i) $N(S_t)$, $p(S_t)$, and $r(S_t)$ are obtained as (4.1.5), (4.1.7), and (4.1.6) respectively from demand and supply of inputs. Using this, $n(s_t) = N(S_t)$ is obtained from (3.11).
- (ii) $V(s_t)$ and $X(S_t)$ solve (4.1.11) and $c(s_t)$, $x(s_t)$ are the associated decision rules.
- (iii) when $k_t = K_t$, $x(s_t) = X(S_t)$ and $c(s_t) = C(S_t)$.
- (iv) $C(S_t) + X(S_t) + G_t = Y(S_t)$.

Condition (iv) in the definition is sometimes called the aggregate consistency condition. Since the government policy constraint (2.9) makes (iv) always hold in aggregate, it is redundant in a sense. Definition 1 is operational in deriving statistics from simulating a version of the model.

4.2 Monopoly Market

Suppose all firms in the economy collude and act as a monopolist. Then as in the case of competitive market, we can use the aggregate production function to find an equilibrium allocation. The firm's problem is once again

to maximize the profit but the aggregate demand for output is taken into account in the production decision.

$$\begin{aligned} \Pi_t = \text{maximize} \quad & p_t Y_t - N_t - r_t \cdot K_t & (4.2.1) \\ \text{s. t.} \quad & Y_t = \lambda_t F(K_t, N_t) \\ & p_t = \tau_t / v' (1 - N_t) \\ & K_t \geq 0, \quad N_t \geq 0 \end{aligned}$$

So we have the following first order conditions.

$$\frac{\tau_t}{v' (1 - N_t)} \cdot \lambda_t F_1(K_t, N_t) = r_t \quad (4.2.2)$$

$$\frac{\tau_t v'' (1 - N_t)}{[v' (1 - N_t)]^2} \cdot \lambda_t F(K_t, N_t) + \frac{\tau_t}{v' (1 - N_t)} \cdot \lambda_t F_2(K_t, N_t) = 1 \quad (4.2.3)$$

Once again as in the competitive market, (4.2.3) determines aggregate hours, and (3.11) and (3.13) determine individual hours to be equal to the aggregate hours as a function of z_t , K_t , τ_t .

$$N_t = n_t = N^m(z_t, K_t, \tau_t), \quad (4.2.4)$$

where superscript n labels the labor demand of the monopolist. If we compare (4.2.3) to its competitive counterpart (4.1.4), we can see that the first term in the lefthand side of (4.2.3) is the difference and so we can guess that the allocation and fluctuation characteristics will be different between the two market structures by the degree implied by that term. If we use (4.2.4) in (4.2.2), we can find r_t as a function of the same state variables.

$$r_t = r^m(z_t, K_t, \tau_t) \quad (4.2.5)$$

Using (4.2.4), the output price can also be determined as:

$$p_t = \tau_t / v' (1 - N_t^m) = p^m(z_t, K_t, \tau_t). \quad (4.2.6)$$

If we use (4.2.2) and (4.2.3) in (4.2.1), we can have the monopoly profit in period t as follows.

$$\Pi_t = - \frac{\tau_t v'' (1 - N_t)}{[v' (1 - N_t)]^2} \cdot \lambda_t F(K_t, N_t) \cdot N_t \quad (4.2.8)$$

Now the remaining discussions are the same as in the case of competitive market. To define the stationary monopoly equilibrium formally, we represent the sub-problem in a recursive form.

$$V(s_t) = \max_{\{c_t\}} \{[c_t + v(1 - n_t)] + \beta E_t [V(s_{t+1})]\} \quad (4.2.9)$$

$$\text{s.t. (3.1), (3.2), (3.4), (2.5), (2.9),}$$

$$(4.2.4), (4.2.5), (4.2.6), (4.1.1),$$

$$\text{and } c_t \geq 0.$$

Here the states s_t and S_t are as defined previously. Now the equilibrium in the case of monopoly can be defined as follows.

Definition 2: A stationary monopoly equilibrium for the economy is a set of decision rules $c(s_t)$, $x(s_t)$, $n(s_t)$, aggregate decision rules $C(S_t)$, $X(S_t)$,

$N(S_t)$, price functions $p(S_t)$, $r(S_t)$, and a value function $V(s_t)$ such that:

- (i) $N(S_t)$, $p(S_t)$, and $r(S_t)$ are obtained as (4.2.4), (4.2.5), and (4.2.6) respectively from monopoly demand for inputs and their supply. Using this, $n(s_t) = N(S_t)$ is obtained from (3.11).
- (ii) $V(s_t)$ and $X(S_t)$ solve (4.2.7) and $c(s_t)$, $x(s_t)$ are the associated decision rules.
- (iii) when $k_t = K_t$, $x(s_t) = X(S_t)$ and $c(s_t) = C(S_t)$.
- (iv) $C(S_t) + X(S_t) + G_t = Y(S_t)$.

4.3 Oligopoly Market

Suppose the market structure is Cournot oligopoly (see e.g. Varian (1984)). Then each firm takes other firms' behavior as given. From (3.13), we have

$$p_t = \tau_t / v'(1 - N_t), \quad N_t = \sum_{i=1}^m N_t^i, \quad (4.3.1)$$

and so an oligopoly firm's profit function is:

$$\begin{aligned} \Pi_t^j = \text{maximize} \quad & p_t Y_t^j - N_t^j - r_t \cdot K_t^j \\ \text{s. t.} \quad & Y_t^j = \lambda_t F(K_t^j, N_t^j) \\ & p_t = \tau_t / v'(1 - N_t), \quad N_t = \sum_{i=1}^m N_t^i \\ & K_t^j \geq 0, \quad N_t^j \geq 0, \end{aligned} \quad (4.3.2)$$

where $j=1, 2, \dots, m$. Since this firm takes other firms' behavior choosing $\{N_t^1, N_t^2, \dots, N_t^{j-1}, N_t^{j+1}, \dots, N_t^m\}$ as given, the first order conditions for the problem can be obtained as follows.

$$\frac{\tau_t}{v'(1-N_t)} \cdot \lambda_t F_1(K_t^J, N_t^J) = r_t \quad (4.3.3)$$

$$\frac{\tau_t v''(1-N_t)}{[v'(1-N_t)]^2} \cdot \lambda_t F(K_t^J, N_t^J) + \frac{\tau_t}{v'(1-N_t)} \cdot \lambda_t F_2(K_t^J, N_t^J) = 1 \quad (4.3.4)$$

However, since the environment and the firms' behavior are symmetric, we have the following.

$$K_t^J = K_t/m, \quad N_t^J = N_t/m \quad (4.3.5)$$

Using this and the fact that the production function is linearly homogenous, (4.3.3) and (4.3.4) can be rewritten as follows.

$$\frac{\tau_t}{v'(1-N_t)} \cdot \lambda_t F_1(K_t, N_t) = r_t \quad (4.3.6)$$

$$\frac{\tau_t v''(1-N_t)}{m[v'(1-N_t)]^2} \cdot \lambda_t F(K_t, N_t) + \frac{\tau_t}{v'(1-N_t)} \cdot \lambda_t F_2(K_t, N_t) = 1 \quad (4.3.7)$$

Note here that the only difference between (4.3.7) and its monopoly counterpart (4.2.3) is that the number of firms m appears in (4.3.7). If $m=1$ in (4.3.7), then it is exactly the same as (4.2.3) as in the case of monopoly, but if $m \rightarrow \infty$, then it is the same as (4.1.4) as in the case of perfect competition. Now (4.3.7) and the predetermined capital stock in period t , K_t , determine the aggregate hours.

$$N_t = N^0(z_t, K_t, \tau_t; m), \quad (4.3.8)$$

where superscript o denotes an oligopoly. Once again we have $n_t = N_t$ from (3.11) and (3.13). Using (4.3.8) in (4.3.6) and (3.13), we have the oligopoly price functions.

$$r_t = r^o(z_t, K_t, \tau_t; m) \quad (4.3.9)$$

$$p_t = p^o(z_t, K_t, \tau_t; m) \quad (4.3.10)$$

On the other hand, the profit accruing to each firm can be obtained as follows by using (4.3.3) and (4.3.4) in (4.3.2).

$$\Pi_t^j = - \frac{\tau_t v''(1-N_t)}{[v'(1-N_t)]^2} \cdot \lambda_t F(K_t^j, N_t^j) \cdot N_t^j \quad (4.3.11)$$

Now using (4.3.5), we have aggregate profits.

$$\Pi_t = \sum_{j=1}^m \Pi_t^j(S_t) = - \frac{\tau_t v''(1-N_t)}{m[v'(1-N_t)]^2} \cdot \lambda_t F(K_t, N_t) \cdot N_t \quad (4.3.12)$$

So if m goes to infinity, profit decreases to zero, which is the case of perfect competition. But if $m=1$, the profit is the same as in the case of monopoly.

Once again we can represent the sub-problem determining consumption and investment in a recursive way.

$$V(s_t; m) = \max_{\{c_t\}} \{ [c_t + v(1-n_t)] + \beta E_t [V(s_{t+1}; m)] \} \quad (4.3.13)$$

s. t. (3.1), (3.2), (3.4), (2.5), (2.9),

(4.3.8), (4.3.9), (4.3.10), (4.3.11),

and $c_t \geq 0$,

where m is exogeneous.

Definition 3: A stationary oligopoly equilibrium for the economy is a set of decision rules $c(s_t; m)$, $x(s_t; m)$, $n(s_t; m)$, aggregate decision rules $C(S_t; m)$, $X(S_t; m)$, $N(S_t; m)$, price functions $p(S_t; m)$, $r(S_t; m)$, and a value function $V(s_t; m)$ such that: given the number of firms, m ,

- (i) $N(S_t; m)$, $p(S_t; m)$, and $r(S_t; m)$ are obtained as (4.3.8), (4.3.10), and (4.3.9) respectively from oligopoly demand for inputs and supply. Using this, $n(s_t; m) = N(S_t; m)$ is obtained from (3.11).
- (ii) $V(s_t; m)$ and $X(S_t; m)$ solve (4.3.13) and $c(s_t; m)$, $x(s_t; m)$ are the associated decision rules.
- (iii) when $k_t = K_t$, $x(s_t; m) = X(S_t; m)$ and $c(s_t; m) = C(S_t; m)$.
- (iv) $C(S_t; m) + X(S_t; m) + G_t = Y(S_t; m)$.

4.4 Monopolistically Competitive Market

If we define the short run as a time period when entries and exits are limited, the short run behavior of a monopolistically competitive firm is not different from that of a monopoly firm except that there are many differentiated goods. However, the time period we have in mind is a quarter or a year, long enough to allow some degree of entry and exit. If we are to specify the entry and exit behavior, we need to specify the goods we are dealing with in a model. If a good is highly capital and/or skill intensive, a firm producing the good cannot easily exit or enter the market. The model we are discussing has one good which can be consumed or accumulated as capital and so it is highly abstract and undesirable in many

senses. It would be desirable to develop a multisector model which has not only a sector where exits and entries are possible along the business cycle frequencies but also a sector where they are not possible in the short run including the business cycle frequencies. Moreover, there may be fixed costs of exit and entry in the real world. If so, analysis of a monopolistically competitive industry is difficult.

In any case, we are interested in the effects of exit and entry along the business cycle and so we assume that exit and entry take place actively even in the short run. Once again what features of the market make this possible is not our concern here, but what implications this market structure has for aggregate fluctuations will be studied. For this we have to respecify the economy. As before, we assume there is a continuum of agents (or households) distributed over the closed unit interval. Each agent has time-separable preferences:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \cdot u\left(\sum_{i=1}^m c_t^i, \ell_t\right), \quad (4.4.1)$$

where m is the number of differentiated goods produced (in fact, it is also the number of firms in the economy). The temporal utility function is risk neutral.

$$u\left(\sum_{i=1}^m c_t^i, \ell_t\right) = \sum_{i=1}^m c_t^i + v(\ell_t) \quad (4.4.2)$$

In addition one unit of any good can be transformed to one unit of homogeneous capital and so the following relationship holds.

$$k_{t+1} = (1-\delta)k_t + \sum_{i=1}^m x_t^i \quad (4.4.3)$$

Aggregating this evolution of the individual capital stock, we have the evolution equation for the aggregate capital stock.

$$K_{t+1} = (1-\delta)K_t + \sum_{i=1}^m X_t^i \quad (4.4.4)$$

On the other hand, firms produce differentiated products, using the identical production function, homogeneous of degree one.

$$Y_t^j = \lambda_t F(K_t^j, N_t^j), \quad j = 1, 2, \dots, m \quad (4.4.5)$$

Note that the environment is absolutely symmetric in terms of preferences as well as the technology⁷. One may argue that this is a major limitation. However, this specification serves quite well for the purpose here since it enables us to look at the effects of exit and entry the business fluctuations without much complication.

Now the other features are the same as those in previous sections.

The representative household solves the following problem.

$$\text{maximize} \quad E_0 \sum_{t=0}^{\infty} \beta^t \cdot \left[\sum_{i=1}^m c_t^i + v(l_t) \right] \quad (4.4.6)$$

$$\text{s. t.} \quad \sum_{i=1}^m p_t^i (c_t^i + x_t^i) \leq \tau_t (n_t + r_t k_t + \sum_{i=1}^m \pi_t^i) + \sum_{i=1}^m p_t^i T_t \quad (4.4.7)$$

$$k_{t+1} = (1-\delta)k_t + \sum_{i=1}^m x_t^i$$

⁷ The economy consists of many firms producing identical products but the brand names are different across firms.

$$c_t^i \geq 0, \quad 0 \leq \ell_t \leq 1$$

Here the household forms expectations on the path of prices and policy variables rationally. The first order conditions for this problem are obtained as follows.

$$1 = p_t \Omega_t^i, \quad i = 1, 2, \dots, m \quad (4.4.8)$$

$$v'(\ell_t) = \tau_t \Omega_t \quad (4.4.9)$$

$$p_t^i \Omega_t^i = q_t, \quad i = 1, 2, \dots, m \quad (4.4.10)$$

$$q_t = E_t [(1-\delta)q_{t+1} + \beta \cdot \tau_{t+1} \cdot r_{t+1} \cdot \Omega_{t+1}] \quad (4.4.11)$$

$$\lim_{t \rightarrow \infty} \beta^t \Omega_t k_{t+1} = 0 \quad (4.4.12)$$

Equations (4.4.8) and (4.4.9) imply that

$$p_t^1 = p_t^2 = \dots = p_t^m = \tau_t / v'(1-n_t) = p_t. \quad (4.4.13)$$

If any good has price higher than other goods, the demand for the good drops to zero immediately. Assume that there are m goods produced and their prices satisfy (4.4.13). Aggregating (4.4.13) over all households gives the aggregate demand for good j :

$$p_t^j = \tau_t / v'(1-N_t), \quad j = 1, 2, \dots, m \quad (4.4.14)$$

So the symmetric specification of the economy implies that monopolistic competition is identical to the oligopoly case with an exception that the number of goods (or firms), m , should be determined endogenously. Given m , firm j 's profit can be determined exactly as in the oligopoly case.

$$\begin{aligned}
\Pi_t^J &= \text{maximize} && p_t Y_t^J - N_t^J - r_t \cdot K_t^J && (4.4.15) \\
&\text{s. t.} && Y_t^J = \lambda_t F(K_t^J, N_t^J) \\
&&& p_t = \tau_t / v' (1 - N_t), \quad N_t = \sum_{i=1}^m N_t^i \\
&&& K_t^J \geq 0, \quad N_t^J \geq 0,
\end{aligned}$$

and by symmetry, the first order conditions are:

$$\frac{\tau_t}{v' (1 - N_t)} \cdot \lambda_t F_1(K_t, N_t) = r_t \quad (4.4.16)$$

$$\frac{\tau_t v'' (1 - N_t)}{m [v' (1 - N_t)]^2} \lambda_t F(K_t, N_t) + \frac{\tau_t}{v' (1 - N_t)} \cdot \lambda_t F_2(K_t, N_t) = 1. \quad (4.4.17)$$

However, if any firm has positive profits, there will be an inflow of firms with differentiated products and so profits will be driven to zero and so a zero profit condition should hold in each period.

$$\Pi_t^J = [(\tau_t / v' (1 - N_t)) \lambda_t F(K_t, N_t) - N_t - r_t \cdot K_t] / m = 0 \quad (4.4.18)$$

Now (4.4.16)-(4.4.18) determine N_t , $p_t = p_t^1 = p_t^2 = \dots = p_t^m$, r_t , and the number of firms, m_t , as functions of λ_t , K_t , and τ_t .

$$N_t = N^{mc}(\lambda_t, K_t, \tau_t) \quad (4.4.19)$$

$$r_t = r^{mc}(\lambda_t, K_t, \tau_t) \quad (4.4.20)$$

$$p_t = p^{mc}(\lambda_t, K_t, \tau_t) \quad (4.4.21)$$

$$m_t = m^{mc}(\lambda_t, K_t, \tau_t), \quad (4.4.22)$$

where superscript mc labels the monopolistic competition. We have to note that the number of firms fluctuates as the aggregate productivity shock fluctuates and so a time subscript is added to it. Once again $n_t = N_t$ holds from (4.4.14) and (4.4.13).

The sub-problem determining consumption and investment can be represented in a recursive way as before. Here we can use the result that the amount of consumption of each good is the same across all goods and that their prices are identical.

$$V(s_t) = \max \left\{ \left[\sum_{i=1}^m c_t^i + v(1-n_t) \right] + \beta E_t [V(s_{t+1})] \right\} \quad (4.4.23)$$

s. t. (2.5), (2.9), (4.4.3), (4.4.4), (4.4.7),
(4.4.14), (4.4.19) - (4.4.22)
and $c_t \geq 0$,

Definition 4: A stationary monopolistically competitive equilibrium for the economy is a set of decision rules $c(s_t)$, $x(s_t)$, $n(s_t)$, aggregate decision rules $C(S_t)$, $X(S_t)$, $N(S_t)$, price functions $\{p^i(S_t), i=1,2,\dots,m\}$, $r(S_t)$, the number of firms $m(S_t)$, and a value function $V(s_t)$ such that

- (i) $N(S_t)$, $\{p^i(S_t), i=1,2,\dots,m\}$, and $r(S_t)$ are obtained as (4.4.19), (4.4.21), and (4.4.20) respectively from the demand for inputs of the monopolistically competitive firms and the supply of them. Using this, $n(s_t; m) = N(S_t; m)$ is obtained from (3.11).
- (ii) $V(s_t)$ and $X(S_t)$ solve (4.4.23) and $c(s_t)$, $x(s_t)$ are the associated decision rules.
- (iii) when $k_t = K_t$, $x(s_t) = X(S_t)$ and $c(s_t) = C(S_t)$.
- (iv) $C(S_t) + X(S_t) + G_t = Y(S_t)$.

5. Simulation

5.1 *Specification and Calibration*

We specify the model which will be used in the simulation as follows.

$$u(c_t, l_t) = \log[c_t + \alpha \cdot \log(l_t)] \quad (5.1.1)$$

$$Y_t^j = \lambda_t (K_t^j)^\theta (N_t^j)^{1-\theta}, \quad j = 1, 2, \dots, m \quad (5.1.2)$$

Note that (5.1.1) is one version of the preference specification in (2.3). Even though we use (2.3) rather than (2.2), we can proceed exactly in the same way as in the previous section. However, the preferences are not risk neutral any more. The preference specification (5.1.1) is made to reduce the parameter values as few as possible, and the production specification (5.1.2) is Cobb-Douglas, which is common in the equilibrium business cycle literature.

We pin down the parameter values by looking at the growth and micro observations from the actual economy. First, we set the capital share parameter as $\theta=0.36$ and depreciation rate of the economy as $\delta=0.025$, which implies a 10 percent annual depreciation rate. Second, we set the utility discount factor as $\beta=0.99$, which implies 4 percent steady state annual interest rate. The only preference parameter α is determined by the fact that hours devoted to the market work is about one third of the endowment of time. Lastly, we have to specify the policy parameters. Since our interest is in the impact of market structure on the fluctuation characteristics of the model economy, we will specify the government sector as simply as possible and so we will borrow the parameter values in the most simple case in Baxter and King (1988). That is, government spending is

given as 10 percent of output in the steady state and is assumed to fluctuate around the steady state. On the other hand, since the tax code does not change quarterly or annually, τ_t is assumed to stay at its steady state level, which is assumed as 30 percent. So we denote the tax rate as τ without any time subscript from now on.

Finally, parameters involved in the technology shock and government purchase processes are specified as follows. The AR(1) parameter in the technology shock process is assumed to be $\rho = .95$, which implies high serial correlation, and the size of the shock is $\sigma_\varepsilon = .009$, which is a value around the upper bound of the range estimated by Prescott (1986)). The AR(1) parameter of the government purchase process is assumed to be $\eta = .90$. The size of the policy shock is assumed to be the same as that of technology shock to see how the policy affects the fluctuation characteristics of the model.

5.2 Solution Method

The method used to solve the dynamic rational expectation model we have is based on the method suggested in Kydland (1987) and developed in Cooley and Hansen (1989). Since the problem we have is very simple (even though we have non-competitive market structures), the method used in the simulation of the model is not a central issue. For example, we can apply the method developed by King, Plosser and Rebelo (1988) without any difficulty. In any case, we have the processes governing aggregate employment and the prices from the equilibrium conditions in factor markets and so the remaining problem is to determine the allocation of income between consumption and investment.

To illustrate the solution method, we take the case of a competitive output market. Using the specification (5.1.1) and (5.1.2), we can rewrite

the conditions (4.1.3) and (4.1.4) as follows.

$$\frac{\theta}{\alpha} \cdot \tau \cdot \lambda_t K_t^{\theta-1} N_t^{1-\theta} (1-N_t) = r_t \quad (5.2.1)$$

$$\frac{1-\theta}{\alpha} \cdot \tau \cdot \lambda_t K_t^{\theta} N_t^{-\theta} (1-N_t) = 1 \quad (5.2.2)$$

From (5.2.2), we can solve for the aggregate employment N_t as function of the state of the economy. But it is not possible to solve for the explicit solution even with this simple specification (since θ is a fraction). So we linearize (5.2.2) around the steady state, which can be obtained in a straightforward way. If we take logarithm of the both sides of (5.2.2), we have the following.

$$\begin{aligned} \log\left(\frac{1-\theta}{\alpha}\right) + \log(\tau) + \log(\lambda_t) \\ + \theta \log(K_t) - \theta \log(N_t) + \log(1-N_t) = 0 \end{aligned} \quad (5.2.3)$$

Now we can linearize the last term in the lefthand side using a first order Taylor series expansion around the steady state.

$$\log(1-N_t) = \gamma_{00} - \gamma_{01} \log(N_t), \quad (5.2.4)$$

where $\gamma_{00} = \log(1-N) + (N/(1-N)) \log(N)$ and $\gamma_{01} = N/(1-N)$ and variables without subscripts denote the steady state values. Using (5.2.4) in (5.2.3) gives the following.

$$\log(N_t) = [\gamma_{10} + \gamma_{13} \log(\tau)] + \gamma_{11} \log(\lambda_t) + \gamma_{12} \log(K_t), \quad (5.2.5)$$

where $\gamma_{10} = [\log(\frac{1-\theta}{\alpha}) + \gamma_{00}] / (\theta + \gamma_{01})$, $\gamma_{11} = \gamma_{13} = 1 / (\theta + \gamma_{01})$, and $\gamma_{12} = \theta / (\theta + \gamma_{01})$.

Using the specified parameter values and $N=3$ (which is the target value to be obtained by changing α) yields the elasticities of aggregate labor with respect to state variables: $\gamma_{11} \cong \gamma_{13} = 1.16$, and $\gamma_{12} = 0.42$.

Now the prices can be obtained as functions of state variables. Taking logarithm of both sides of the output price equation gives:

$$\log(p_t) = [\gamma_{20} + \gamma_{23} \log(\tau)] + \gamma_{21} \log(\lambda_t) + \gamma_{22} \log(K_t), \quad (5.2.6)$$

where $\gamma_{20} = \log(1/\alpha) + \gamma_{00} - \gamma_{01} \gamma_{10}$, $\gamma_{21} = -\gamma_{01} \gamma_{11}$, $\gamma_{22} = -\gamma_{01} \gamma_{12}$, and $\gamma_{23} = 1 - \gamma_{01} \gamma_{13}$. From (5.2.1), we have the rental price of capital as a function of states.

$$\log(r_t) = [\gamma_{30} + \gamma_{33} \log(\tau)] + \gamma_{31} \log(\lambda_t) + \gamma_{32} \log(K_t), \quad (5.2.7)$$

where $\gamma_{30} = \log(\theta/\alpha) + \gamma_{00} + (1 - \theta - \gamma_{01}) \gamma_{10}$, $\gamma_{31} = 1 + (1 - \theta - \gamma_{01}) \gamma_{11}$, $\gamma_{32} = -(1 - \theta) + (1 - \theta - \gamma_{01}) \gamma_{12}$, $\gamma_{33} = 1 + (1 - \theta - \gamma_{01}) \gamma_{13}$.

The remaining problem is to solve for the consumption-investment decision as defined in (4.1.11). Here we can apply the method developed by Cooley and Hansen (1989) by taking into account the processes of N_t , p_t , and r_t obtained as (5.2.5) - (5.2.7). Note that the profits of the firms are zero and we assume that the policy constraint (2.9) holds. The first step to get decision rules for consumption and investment is to approximate the objective function. For this we solve the individual resource constraint (3.1) and then substitute the result in the objective function.

$$\begin{aligned} u(c_t, l_t) &= \log[c_t + \alpha \cdot \log(l_t)] \\ &= \log\{[\tau_t(n_t + r_t k_t) + p_t((1 - \tau_t)Y_t - G_t)]/p_t - x_t \\ &\quad + \alpha \cdot \log(1 - n_t)\} \end{aligned}$$

$$= u(x_t, s_t), \quad (5.2.8)$$

where s_t is the vector of individual state variables. The next step is to approximate (5.2.8) using a quadratic function. There are at least a couple of approximation methods, namely Taylor series expansion or the method suggested in Kydland and Prescott (1982). We will follow Kydland and Prescott's method here simply due to a couple of conveniences. In any case, (5.2.8) can be approximated as:

$$u(x_t, s_t) = (x_t \quad \bar{s}_t^{-T})Q \begin{pmatrix} x_t \\ \bar{s}_t \end{pmatrix}, \quad (5.2.9)$$

where $\bar{s}_t = (1 \ z_t \ k_t \ K_t \ g_t)^T$, $z_t = \log(\lambda_t)$, the superscript T denotes transpose of a matrix, and Q is a symmetric matrix obtained from the approximation. Now the problem (4.1.11) can be rewritten in linear-quadratic form:

$$s_t^T V s_t = \max \{ (x_t \quad \bar{s}_t^{-T})Q \begin{pmatrix} x_t \\ \bar{s}_t \end{pmatrix} + \beta \cdot s_{t+1}^T V s_{t+1} \} \quad (5.2.10)$$

$$\text{s.t. } (2.5), (3.2), \text{ and } (3.4).$$

To solve for an equilibrium, we have to iterate Bellman's equation (5.2.10), and this involves choosing an aggregate decision rule for investment X_t as a function of aggregate state $\bar{S}_t = (1 \ z_t \ K_t \ g_t)^T$. The iteration steps can be summarized as follows.

Step 1: We choose an initial value for the value function V_0 and use V_0 in the right hand side of (5.2.10) to solve for the individual decision rule for investment. Note here that since $u(x_t, s_t)$ is quadratic, we guess V is also quadratic. Suppose the decision rule for investment obtained in this

step is:

$$x_t = \bar{\Gamma}_4^T s_t + \gamma_{45} X_t, \quad (5.2.11)$$

where we denote $\bar{\Gamma}_4 = (\bar{\gamma}_{40} \ \bar{\gamma}_{41} \ \bar{\gamma}_{42} \ \bar{\gamma}_{43} \ \bar{\gamma}_{44})^T$.

Step 2: We use the equilibrium condition (iii) in Definition 1, and solve for aggregate decision rule for the investment from (5.2.11).

$$X_t = \gamma_{40} + \gamma_{41} z_t + \gamma_{42} K_t + \gamma_{43} g_t = \Gamma_4^T S_t, \quad (5.2.12)$$

where $\gamma_{40} = \bar{\gamma}_{40}/(1-\bar{\gamma}_{45})$, $\gamma_{41} = \bar{\gamma}_{41}/(1-\bar{\gamma}_{45})$, $\gamma_{42} = (\bar{\gamma}_{42} + \bar{\gamma}_{43})/(1-\bar{\gamma}_{45})$, and $\gamma_{43} = \bar{\gamma}_{44}/(1-\bar{\gamma}_{45})$.

Step 3: Using the initial guess V_0 and the decision rules (5.2.11) and (5.2.12), we evaluate the righthand side of (5.2.10) and the resulting matrix V_1 will be the value function used in the next iteration.

Step 4: Repeat Steps 1 - 3 until V_{j+1} is close to V_j and satisfies a stopping rule. If V_j is sufficiently close to V_{j+1} , the value function can be claimed to have converged. The decision rule associated with the converged value function is used to generate artificial time series from each of the model economies. In each case of the market structure, 25 data sets with 115 observations are generated to get the mean statistics of those simulations.

5.3 Results

Table 1 contains summary statistics obtained from U.S. data from the periods between the third quarter of 1955 and the first quarter of 1984. These statistics are quite familiar in the real business cycle literature,

and the characteristics of the statistics reported, namely standard deviations and correlation coefficients, have been well-explained by many authors (e.g., Kydland and Prescott (1982, 1988), Hansen (1985), and King, Plosser and Rebelo (1988)). One note is that the consumption series used to derive the statistic is the one constructed by Christiano and it includes consumption of nondurables and services and in addition services from durables.⁸ If we exclude the services from durables in the series, the standard deviations of consumption series increases to 1.29.

Table 2 contains the results from the case of a competitive market. Without the government, output fluctuates more in the model than in the actual U.S. economy and this means that the model can have fluctuations of the same size as the actual economy with a far smaller technology shock. In addition, we have to note the following facts. With preferences nonseparable between consumption and leisure and with only a substitution effect in the labor supply, consumption fluctuates more than in a model with preferences separable between consumption and leisure (see e.g., Hansen (1985)). As a corollary to this fact, investment in the model fluctuates far less and this can be a disadvantage of the model. However, if we look at the fit of the labor market of the model, we can see that it is relatively good. The fluctuations of aggregate hours and productivity are very close to the actual ones, and these numbers are greater than those obtained in the case of indivisible labor by Hansen (1985). Since Kydland and Prescott (1982), every author in the real business cycle literature has emphasized the ratio of fluctuations in aggregate hours relative to productivity. In Kydland and Prescott's model it is close to one and it is about 2.7 in the Rogerson

⁸ Tom Cooley provided me with the data set.

(1984) and Hansen (1985) indivisible labor model. In the competitive case of the model the ratio is 2.3 and it is 1.58 in U.S. economy, and so the model has no problem in terms of the size of fluctuations in the labor market.

Most serious problem of the model economy is in matching the correlations. In the model, output, consumption, investment, hours and productivity are highly intercorrelated, and in most of the cases the correlation coefficients are close to one. This is a common characteristic of most real business cycle models with only a technology shock. This stochastic singularity problem seems to be stubborn and requires more investigation. Consumption has far lower correlation coefficients with other variables in U.S. economy than in the model, and this is also true in the case of productivity. Especially, Christiano and Eichenbaum (1988) cast doubt about the fit of real business cycle models by pointing out the low correlation between aggregate hours and productivity, which is .10 in U.S. economy but 1.0 in the model economy.

If we introduce the government sector in the model, output fluctuations increase a little but the increase is marginal (see Table 1. B). The most significant changes take place in the fluctuations of components of output. Once we introduce the government sector with the same size of the expenditure shock as the technology shock, consumption and investment fluctuations increase disproportionately more. This fact can be explained by the fact that government expenditures in the model first affect the economy through the household budget, namely consumption and investment opportunities. Note in addition that government expenditure in period t does not affect labor supply and prices in the period. This result follows from the specific specification of the preferences and does not hold in general. However, since government expenditure affects capital accumulation, it has

some effect on fluctuations in the labor market of the model. The expenditure shock from the government sector reduces the correlations among output, consumption, investment, labor and productivity very little, and so there are no significant changes in that respect. However, note that these results depend on the specific way of introducing the public sector in the model. The way of introducing government in the paper is a baseline case which lies on the lower bound in its effect. So the results in the paper do not imply that the expenditure shock always has marginal effects. See Baxter and King (1988) for more discussion.

Table 2 shows the results from the case of the monopoly market. The most notable result is that the size of the fluctuations are overall significantly smaller in the monopoly case than in competitive case. Specifically, output fluctuations decrease more than 32 percent, and if we try to increase the size of fluctuations up to a realistic level, we need a technology shock of size greater than output fluctuations. In terms of fluctuations of components of output, consumption fluctuations decrease more than 60 percent (compared to the competitive case) but there is no change in investment fluctuations. So we can see that almost all of the decrease in output fluctuations associated with a decrease in fluctuations in consumption rather than in investment on the demand side of the model. On the supply side of the model, there are no changes in fluctuations in the capital stock but there are huge changes in labor market fluctuations. Fluctuations in aggregate hours decrease about 77 percent but those in productivity increase more than 70 percent. As a result the ratio of fluctuations in aggregate hours relative to productivity decreases from 2.3 in the case of a competitive market to .3. This is a serious disadvantage of the monopoly market model. The correlation coefficients are smaller in the

monopoly case than in the competitive market case, but the differences are negligible in magnitude.

The effects of introducing government are shown in Table 3 B. The most notable difference in the monopoly case is that introducing government expenditure shocks reduces the size of the fluctuations in output slightly. This can be explained in the following way. First, if government purchases increase, the income available for a household decreases and as a result labor supply increases to compensate for the reduction in income. Second, a persistent increase in government purchases reduces investment and so crowds out capital accumulation, but the decrease in the capital stock lowers the productivity of labor. So labor supply decreases as government purchases increase. It seems that those two opposite factors are more offsetting under monopoly than under competition. This fact is confirmed by the slight decrease in fluctuations in hours. Consumption and investment fluctuate more with government than without it. Note that increases in the fluctuations in the components of output do not necessarily imply the increase in output fluctuations. As in the case of a competitive market, introducing government does not change the correlation coefficients in any significant way. It is worthwhile here to note that the results conflict with Mankiw (1988). In that paper, Mankiw argues that as competition in the goods market becomes less perfect, the fiscal policy multipliers approach the values implied by the Keynesian cross. However, note that the results in table 3 show that introducing serially correlated government purchases, which is independent of the technology shock, stabilizes the output fluctuations (even though the degree is slight). The effects of changes in market structures and of increasing returns in production differ. Kydland and Prescott (1988) show that, even in competitive market, increasing

returns have substantial effects on output fluctuations.

Results from the oligopoly cases are reported in Table 4 and Table 5. Table 4 shows statistics in the case of a two-firm Cournot oligopoly. At a glance we can see that introducing one more firm in the market increases output fluctuations substantially. In fact, output fluctuations increase by 21 percent. If we try to increase the output fluctuations in the monopoly case up to this number, we need to increase the size of the technology shock by far more than 21 percent and so we can argue that increasing competition is a powerful way of increasing responsiveness of the variables involved to the shock. The other key difference is in the behavior of the labor market. In the monopoly case the ratio of aggregate hour fluctuations relative to productivity is .30, but it is 2.3 in two firm oligopoly case. However, we still have a reservation about the fit of the model. Given that the assumed size of the productivity shock is around the upper bound among the estimates by Prescott (1986), the size of the output fluctuations is too small and so two-firm oligopoly can not be a realistic model describing the actual economy. Introducing shocks on government purchases has the same effects in the two-firm oligopoly case as in the monopoly case.

Table 5 contains the simulation results of the ten firm oligopoly case. In every respect the results in table 5 are very close to those in table 2. The only difference is that the sizes of fluctuations in variables are overall slightly smaller than in the competitive case. However, output fluctuations are larger in the model than in the actual U.S. economy, and so the model can mimic this feature in the actual U.S. data with a technology shock within the range of size suggested by Prescott (1986). Introducing government in ten-firm oligopoly case has the same effects as in the competitive market. Note that shocks on government purchases increase the

size of fluctuations of all variables; this was not true in the cases of monopoly and two firm oligopoly.

6. Conclusion

Market structures are introduced in a small dynamic general equilibrium model and the effects of market structures on the fluctuation characteristics are studied. The simulation results show that increasing competition is a powerful tool for increasing the size of fluctuations in quantity variables. The monopoly market structure fits poorly especially in two respects. First, even with the upper bound of the size of the technology shock, the size of output fluctuations is too small. Second, the labor market behaves very badly, namely aggregate hours fluctuates far less than productivity. So we can have a very strong conclusion about the monopoly market structure. If the technology shock is the major shock of the economy and the size of the shock is bounded by the estimates in Prescott (1986), monopoly is not the market structure in the U.S. economy. We can state this in an opposite way. If the market structure of the U.S. economy is of monopoly, then the technology shock cannot be the major shock forcing the business fluctuations in the U.S. economy. However, the latter conclusion seems to be implausible in the sense that the market structure observed in the U.S. economy cannot be economywide monopoly. Increasing competition by increasing the number of firms is a powerful way of increasing the size of the fluctuations in the variables involved. Ten-firm oligopoly seems to mimic the actual economy very closely in many respects, and a government policy shock has a plausible effect as more firms are introduced in the economy.

However, we have to note the following. First, the simulation results

critically depend on the assumed demand for goods and supply of goods, which means that overall specification matters in every respect. Generally a more elastic demand for goods reduces the differences between market structures. So the key question which should be addressed in the future is how elastic the demand for and supply of goods are. Second, noncompetitive market structures are used in many cases to study price setting. Standard price setting environments are completely different from the environment studied in this paper. However, if there are some rigidities in the environment, some modifications of the results are expected. Third, it is desirable to model explicitly the causes of various market structures such as increasing returns, patents and product differentiation etc. Lastly, even though we do not perform the simulation for the case of monopolistically competitive market, we can predict the results. If there are many firms, then the fluctuations will be very close to the competitive case. One feature worthwhile to note is that since the number of firms is procyclical, the fluctuation characteristics are asymmetric in the sense that responsiveness of the variables involved increases in boom times and decreases in depression.

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Figure 1. Perfect Competition and Monopoly

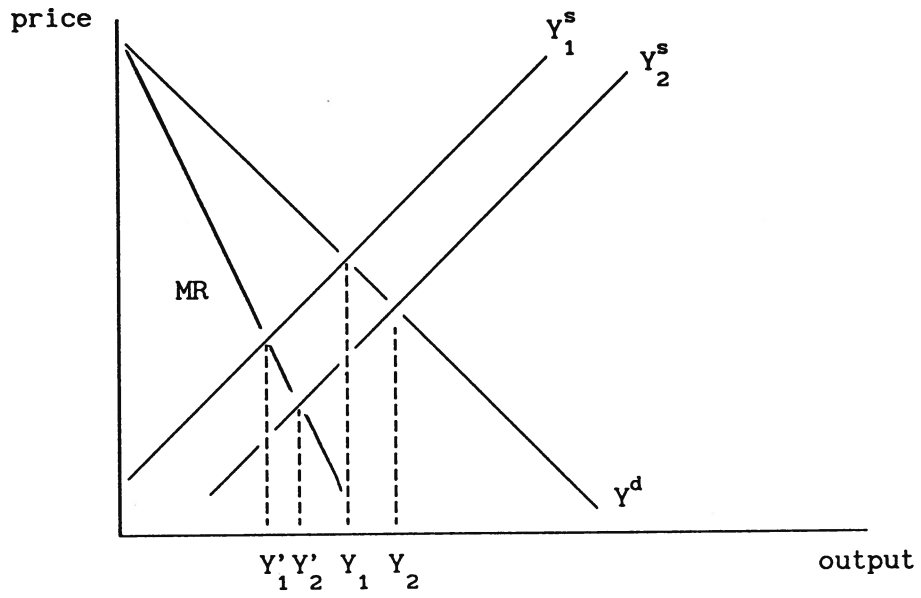


Table 1. Summary Statistics from U.S. Data

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	1.74	1.00					
Consumption (C)	.81	.65	1.00				
Investment (X)	8.45	.91	.42	1.00			
Capital Stock (K)	.63	.05	.17	-.10	1.00		
Hours (N)	1.41	.86	.50	.79	.15	1.00	
Productivity (Pdty)	.89	.59	.47	.54	-.14	.10	1.00
<u>Hours Productivity</u>	1.58						

Note: Y = GNP, C = consumption of nondurables and services plus the flow of services from durables constructed by Lawrence Christiano, X = gross private domestic investment, K = nonresidential equipment and structures, N = total hours per person at work, and Pdty = output divided by hours. All series except consumption were taken from Citibase database. All series are seasonally adjusted, logged and detrended using Hodrick-Prescott filter. The standard deviations are in percentage term. Sample periods: 1955.3 - 1984.1.

Table 2. Summary Statistics from Perfect Competition

A. Without Government

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	1.99 (.30)	1.00					
Consumption (C)	1.36 (.21)	1.00	1.00				
Investment (X)	3.81 (.57)	1.00	.99	1.00			
Capital Stock (K)	.33 (.08)	.01	.07	-.05	1.00		
Hours (N)	1.38 (.21)	1.00	.99	.99	.01	1.00	
Productivity (Pdty)	.60 (.09)	1.00	.99	.99	.01	1.00	1.00

B. With Government

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	2.08 (.29)	1.00					
Consumption (C)	1.57 (.22)	1.00	1.00				
Investment (X)	5.33 (.71)	.99	.98	1.00			
Capital Stock (K)	.48 (.09)	.05	.13	-.05	1.00		
Hours (N)	1.45 (.20)	1.00	.99	.99	.05	1.00	
Productivity (Pdty)	.62 (.09)	1.00	.99	.99	.05	1.00	1.00

Note: The statistics reported are the sample means of statistics from each of fifty simulations of 115 observations. The sample standard deviations are reported in parentheses. Each simulated series was logged and detrended by the same filter applied to the U.S. data. Standard deviations are in percentage term.

Table 3. Statistics from Monopoly

A. Without Government

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	1.35 (.19)	1.00					
Consumption (C)	.53 (.08)	.96 (.01)	1.00				
Investment (X)	3.80 (.53)	.99 (.00)	.92 (.02)	1.00			
Capital Stock (K)	.33 (.08)	.05 (.09)	.31 (.10)	-.06 (.09)	1.00		
Hours (N)	.31 (.04)	1.00 (.00)	.96 (.01)	.99 (.00)	.05 (.09)	1.00	
Productivity (Pdty)	1.03 (.14)	1.00 (.00)	.96 (.01)	.99 (.00)	.05 (.09)	1.00 (.00)	1.00

B. With Government

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	1.33 (.16)	1.00					
Consumption (C)	.74 (.09)	.98 (.00)	1.00				
Investment (X)	4.58 (.52)	.99 (.00)	.95 (.01)	1.00			
Capital Stock (K)	.38 (.08)	.06 (.05)	.26 (.07)	-.06 (.04)	1.00		
Hours (N)	.29 (.03)	1.00 (.00)	.98 (.00)	.99 (.00)	.06 (.05)	1.00	
Productivity (Pdty)	1.04 (.12)	1.00 (.00)	.98 (.00)	.99 (.00)	.06 (.05)	1.00 (.00)	1.00

Note: See the note for Table 2.

Table 4. Statistics from Oligopoly (2 Firms)

A. Without Government

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	1.61 (.23)	1.00					
Consumption (C)	.81 (.11)	.99 (.00)	1.00				
Investment (X)	3.97 (.57)	1.00 (.00)	.97 (.01)	1.00			
Capital Stock (K)	.33 (.07)	.02 (.06)	.16 (.07)	-.06 (.06)	1.00		
Hours (N)	.75 (.11)	1.00 (.00)	.99 (.00)	1.00 (.00)	.02 (.06)	1.00	
Productivity (Pdty)	.32 (.05)	1.00 (.00)	.99 (.00)	1.00 (.00)	.02 (.06)	1.00 (.00)	1.00

B. With Government

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	1.60 (.23)	1.00					
Consumption (C)	1.01 (.15)	.99 (.00)	1.00				
Investment (X)	4.92 (.68)	.99 (.00)	.97 (.01)	1.00			
Capital Stock (K)	.41 (.11)	.04 (.06)	.17 (.07)	-.07 (.04)	1.00		
Hours (N)	.73 (.10)	1.00 (.00)	.99 (.00)	.99 (.00)	.04 (.06)	1.00	
Productivity (Pdty)	.32 (.05)	1.00 (.00)	.99 (.00)	.99 (.00)	.04 (.06)	1.00 (.00)	1.00

Note: See the note for Table 2.

Table 5. Statistics from Oligopoly (10 Firms)

A. Without Government

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	1.86 (.24)	1.00					
Consumption (C)	1.20 (.15)	1.00 (.00)	1.00				
Investment (X)	3.80 (.48)	1.00 (.00)	.99 (.00)	1.00			
Capital Stock (K)	.35 (.07)	.01 (.06)	.08 (.06)	-.06 (.05)	1.00		
Hours (N)	1.22 (.16)	1.00 (.00)	.99 (.00)	1.00 (.00)	.01 (.06)	1.00	
Productivity (Pdty)	.52 (.07)	1.00 (.00)	.99 (.00)	1.00 (.00)	.01 (.06)	1.00 (.00)	1.00

B. With Government

<u>Series</u>	<u>Standard Deviation</u>	<u>Cross Correlation</u>					
		Y	C	X	K	N	Pdty
Output (Y)	1.97 (.22)	1.00					
Consumption (C)	1.43 (.17)	1.00 (.00)	1.00				
Investment (X)	5.28 (.61)	.99 (.00)	.98 (.00)	1.00			
Capital Stock (K)	.47 (.09)	.06 (.06)	.16 (.06)	-.04 (.05)	1.00		
Hours (N)	1.28 (.15)	1.00 (.00)	.99 (.00)	.99 (.00)	.06 (.06)	1.00	
Productivity (Pdty)	.69 (.08)	1.00 (.00)	.99 (.00)	.99 (.00)	.06 (.06)	1.00 (.00)	1.00

Note: See the note for Table 2.