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Monopolistic Competition, Business Cycles, and the Composition of Aggregate Demand*

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We develop a dynamic general equilibrium model with monopolistically competitive firms and endogenous markups and show the possibility of equilibria with persistent fluctuations driven by self-fulfilling revisions of expectations. For some parameter values such fluctuations are characterized by time series properties similar to those observed in U.S. postwar business cycles. In contrast with the existing literature our results do not rely on the presence of increasing returns or nominal rigidities. A key ingredient of the model is the link between markups and the composition of aggregate demand. Some econometric evidence on the latter is also reported. *Journal of Economic Literature* Classification Number: D43, D58, E32.

1. INTRODUCTION

The relevance of imperfect competition for macroeconomic models has been emphasized by several authors in recent years. Growing interest in the subject among macroeconomists is due in part to empirical work providing evidence of substantial deviations from price-taking behavior (e.g., Hall [15] and Domowitz *et al.* [11]). In addition, attempts to provide microfoundations to traditional Keynesian models have typically relied on some departure from the assumption of perfect competition.[1]

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[1] Such departures have been argued to be necessary in order to generate features like sticky prices and consequent monetary non-neutralities (Blanchard and Kiyotaki [5]), underemployment (Hart [16]), multiplier effects (Mankiw [21] and Startz [26]), persistent involuntary unemployment (Mankiw [6] and Weitzman [27]), and multiple equilibria (Heller [17]).

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In the present paper we explore the role that departures from perfect competition may play in generating the possibility of expectations-driven fluctuations. More specifically, we develop a dynamic general equilibrium model with monopolistically competitive firms in which persistent fluctuations may take place even in the absence of shocks to fundamentals, and where changes over time in the degree of market power play a key role in generating those fluctuations.

In our model each firm produces and sells a differential product to two types of customers: households (who derive utility from its consumption) and the remaining firms (that use it to increase their capital stock). Preferences and technology are such that the degree of market power enjoyed by a typical firm—and, consequently, the level of output and employment—is related to the relative weight of consumption and investment in aggregate demand. In equilibrium this phenomenon generates an "accelerator effect" which is at the heart of the resulting dynamics: an upward revision in expected future aggregate demand and output raises the typical firm's expected return to current investment, leading, in the aggregate, to a higher *current* investment share. Through its effect on the optimal markup, that change in the composition of current aggregate demand will in turn affect *current* output, with the direction of the effect depending on the relationship between two parameters determining the substitutability across goods in consumption and production. Under what conditions would the initial revision of expectations be justified? We show the existence, for a range of plausible parameter values, of *stationary sunspot equilibria*, i.e., equilibria along which "coordinated" revisions in expectations are self-fulfilling (i.e., consistent with rational expectations) and become an independent source of economic fluctuations. Under further restrictions on the configuration of parameter values, we show that the sunspot fluctuations generated by the model are characterized by time series properties similar to those observed in actual business cycles.

We end the paper with some evidence concerning the link between the size of markups and the composition of aggregate demand. We attempt to uncover the presence of such a relationship in postwar U.S. data by running both cross-sectional and time series regressions of a constructed markup measure on the investment share (among other variables). The cross-sectional results are rather disappointing: no significant correlation between those two variables can be detected by our regressions. On the other hand, the results that emerge from the aggregate time series regressions are far more encouraging: the investment share systematically shows a significant negative relationship to the size of markups, after controlling for other cyclical factors.

Other authors have examined before the role of monopolistic competition as a source of sunspot equilibria.[2] Peck and Shell [22] show the existence of sunspot equilibria in a pure exchange-economy in which agents have market power in both commodity and security markets, and discuss their connection with the notion of correlated equilibria in market games. Chaterjee *et al.* [9] analyze a two-sector OLG framework with (costly) entry and Cournot behavior and show the possibility of cycles and sunspot equilibria in the presence of sufficiently strong complementarities between the two sectors. Woodford [29] assumes that firms face a kinked demand curve resulting from customers' imperfect information about prices. That feature in itself generates indeterminacy in markups (and thus in prices and output) *for given demand conditions*, an outcome Woodford rules out by assuming that firms follow a particular "price convention" that takes the form of constant and identical prices for all firms, at all times. Countercyclical markups then follow from both an upward sloping labor supply and a decreasing marginal product of labor. Under some parameter configurations Woodford's model economy can experience sunspot fluctuations characterized by an accelerator effect similar to the one found in the present paper.

In a paper in this issue, Farmer and Guo [13] show the possibility of sunspot fluctuations in a stochastic version of the Benhabib–Farmer model [2]. In their model the existence of such equilibria hinges on the presence of sufficiently strong increasing returns. Though they assume the presence of market power in one of the versions of their model, the latter assumption is necessary to sustain increasing returns at the level of the firm, but does not play a role in generating sunspot-driven equilibria.

In the present paper the possibility of sunspot fluctuations does not rely on the presence of increasing returns to scale, kinked demand curves, or nominal rigidities. Instead, it arises once we allow the elasticity of substitution across goods in consumption to differ from that in production. In that case, the effective price elasticity of demand faced by each firm (and thus optimal markups and output) will depend on the composition of aggregate demand, which in turn depends on expectations. In contrast with Woodford's model, sunspot equilibria may exist in our framework even in the limiting case of a fully inelastic labor supply, for in that case expected returns on current investment still depend on future real wages which are in turn a function of (uncertain) future markups.

The plan of the paper is as follows. In Section 2 we introduce the basic

[2] Of course, sunspot equilibria also emerge in models with perfect competition. Early examples of the latter can be found in Shell [24], Azariadis [1], Cass and Shell [8], and Farmer and Woodford [12], among others. Under standard convexity assumptions, some other violation of the assumptions guaranteeing Pareto optimality is necessary if sunspot equilibria are to exist, for the latter will be suboptimal under standard convexity assumptions (Cass and Shell [8]). See Shell [25] for an excellent survey of models with sunspot equilibria.

model and derive the set of equilibrium conditions. In Section 3 we discuss the conditions under which the possibility of stationary sunspot equilibria arises. In that section we also use a calibrated model to study some basic statistical properties of sunspot equilibria, and compare them with their U.S. economy approximate empirical counterparts. Section 4 presents and discusses the results of our markup regressions. Section 5 concludes the paper.

2. The Model

(a) *Consumers*

There is a finite number of identical consumers, indexed by $j = 1, 2, ..., N$. Consumer j's preferences are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t [\sigma(c_t^j) - v(n_t^j)], \tag{1}$$

where $\sigma(\cdot)$ is a "composite consumption" CES index defined by

$$\sigma(c_t^j) \equiv M^{1/(1-\sigma)} \left[\sum_{h=1}^{M} (c_{t,h}^j)^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}, \qquad \sigma > 0,$$

and where $v(\cdot)$ takes the form[3]

$$v(n) = (\tau/(1+\tau))\, n^{(1+\tau)/\tau}, \qquad \tau > 0.$$

M is the number of differentiated goods available, and $c_{t,h}^j$ is the quantity of good h consumed by consumer j in period t. σ is the elasticity of substitution across goods in consumption, which is assumed to be positive. n denotes the amount of labor supplied. β is the discount factor, satisfying $0 < \beta < 1$. E_0 is the usual expectational operator as of time 0.

Each period's nominal wage rate is normalized to unity, so all remaining prices are in terms of contemporaneous labor. We let p^h denote the price of good h. d^h and q^h are, respectively, the dividend and price of a share in firm h. $s_{t,h}^j$ denotes the number of shares in firm h held by consumer j at the beginning of period t. a_t^j equals total consumption expenditures by consumer j in period t. The representative consumer maximizes (1), subject to the sequence of budget constraints

$$\sum_{h=1}^{M} p_t^h c_{t,h}^j = n_t^j + \sum_{h=1}^{M} (d_t^h + q_t^h)\, s_{t,h}^j - \sum_{h=1}^{M} q_t^h s_{t+1,h}^j \equiv a_t^j, \qquad 0 \leq n_t^j \leq 1,$$

[3] In a previous version of the paper $v(\cdot)$ was taken to be an unspecified convex, twice differentiable function. The functional form chosen here simplifies the algebra substantially, while preserving all the relevant insights of the general case.

for $t = 0, 1, 2, \ldots$, a (symmetric) initial condition $s^j_{0,h} = (1/N)$ (for $h = 1, 2, \ldots, M$), and the solvency condition

$$\liminf_{T \to \infty} E_0 \beta^T \sum_{h=1}^{M} (q^h_T/P_T)\, s^j_{T,h} \geqslant 0,$$

where P is a price index defined by

$$P_t \equiv \left[(1/M) \sum_{h=1}^{M} (p^h_t)^{1-\sigma} \right]^{1/(1-\sigma)}.$$

Henceforth, we restrict our attention to solutions of the consumer's problem for which the time constraint is not binding.[4] An optimal consumption, labor supply, and portfolio plan for consumer j must satisfy the following conditions:

$$c^j_{t,h} = [p^h_t/P_t]^{-\sigma}\, [a^j_t/P_t M], \qquad h = 1, 2, \ldots, M, \tag{2}$$

$$\sigma(c^j_t) = a^j_t/P_t, \tag{3}$$

$$n^j_t = P_t^{-\tau}, \tag{4}$$

$$q^h_t/P_t = \beta E_t (d^h_{t+1} + q^h_{t+1})/P_{t+1}, \qquad h = 1, 2, \ldots, M, \tag{5}$$

for $t = 0, 1, 2, \ldots$, together with a transversality condition $\liminf_{T \to \infty} E_0 \beta^T \sum_{h=1}^{M} (q^h_T/P_T)\, s^j_{T,h} = 0$. Conditions (2) and (3) characterize consumer's demand for each type of good, as well as for composite consumption $\sigma(\cdot)$, as functions of expenditure and prices, in the familiar way arising from the CES assumption. Condition (4) is a labor supply function, with an associated real wage elasticity given by parameter τ. Equation (5) implies that equilibrium expected real returns on all shares must be constant and equal to the discount rate.[5] Combined with the transversality condition, (5) implies that the real value of firm h as of period t (before dividend distribution) will be given by $E_t \sum_{j=0}^{\infty} \beta^j (d^h_{t+j}/P_{t+j})$, i.e., the expected sum of dividends (in terms of composite consumption), discounted at a constant factor β.

(b) *Firms*

There are M firms, indexed by $h = 1, 2, \ldots, M$. Each firm produces a differentiated product, and chooses a price and production plan at each

[4] In our simulations below, we calibrate the model in a way that guarantees that the solution to the consumer's problem will indeed be interior.

[5] That result is a consequence of the linearity of preferences in "composite consumption," and the fact that we measure real returns in terms of the latter.

period in order to maximize its value, taking other firms' prices and the aggregate price index P as given.[6] Each firm uses two types of inputs, labor and capital, which are combined to produce a *differentiated* good. The technology available to a representative firm, say, firm h, is Cobb–Douglas, represented by the production function[7]

$$y_t^h = A(k_t^h)^\alpha (l_t^h)^{1-\alpha}, \tag{6}$$

where y^h, k^h, and l^h respectively denote firm h's output, capital stock, and labor input.

Labor services are hired in a competitive market, in which both firms and workers take the wage as given. We assume that each firm increases its capital stock by purchasing goods produced by all firms. More specifically, the capital accumulation equation for firm h is given by

$$k_{t+1}^h = (1-\delta)\, k_t^h + \eta(i_t^h), \tag{7}$$

where

$$\eta(i_t^h) = (1/M)^{1/(\eta-1)} \left[\sum_{s=1}^{M} (i_{t,s}^h)^{(\eta-1)/\eta} \right]^{\eta/(\eta-1)}, \qquad \eta > 0.$$

Each firm's effective investment is thus a CES function of the goods purchased from other firms.[8] A similar assumption can be found in Kiyotaki [20], though in the latter paper the elasticities of substitution in production and consumption are constrained to be equal.[9] Clearly, there is no *a priori* reason why those elasticities should be equal, since they apply to activities—production and consumption—which are different in nature. As will become clear below, the presence of an elasticity differential plays a central role in generating fluctuations in the economy.

Each period the representative firm will maximize the level of effective investment $\eta(i_t^h)$, conditional on its investment expenditures $z_t^h \equiv \sum_{s=1}^{M} p_t^s i_{t,s}^h$. This yields the set of equations characterizing investment demand by firm h,

[6] We are thus implicitly assuming that M is a "large" number.

[7] The following analysis carries over to the case of a general constant returns technology. The Cobb–Douglas assumption simplifies the algebra considerably, so we adopt it for convenience in our exposition.

[8] Alternatively, we could have introduced an intermediate sector purchasing inputs from the M monopolistically competitive firms and combining them with the constant returns, CES production function $\eta(i)$, in order to produce a homogeneous capital good that is sold competitively to the M original firms. Each of the latter then combines capital and labor in order to produce a differentiated good, sold to both consumers and the intermediate sector. The two structures can be shown to be equivalent.

[9] As in Kiyotaki's paper, and in order to keep the notation simple, we treat a firm's self-purchases in a way symmetric to purchases from other firms.

$$i_{t,s}^h = [p_t^s/\Pi_t]^{-\eta}\,[z_t^h/\Pi_t M], \qquad s \neq h, \tag{8}$$

$$\eta(i_t^h) = z_t^h/\pi_t^h, \tag{9}$$

where Π_t is a price index for the goods purchased by firms defined by

$$\Pi_t \equiv \left[(1/M)\sum_{s=1}^{M}(p_t^s)^{1-\eta}\right]^{1/(1-\eta)}.$$

Note that we are assuming that a given good is sold to both consumers and firms at the same price. In other words, firms are not able to price-discriminate across customer types, an assumption that can be justified by ruling out obvious arbitrage opportunities. Note also that, for a given h, π_t^h will in general differ from P_t, but both indices will take identical values in a symmetric equilibrium.

Let $y_t^h \equiv \sum_{j=1}^{N} c_{t,h}^j + \sum_{s=1}^{M} i_{t,h}^s$ denote total demand for firm h's output in period t. Using (2) and (8), we can derive the demand schedule

$$y^h(p_t^h, t) = [p_t^h/P_t]^{-\sigma}\,[A_t/P_t] + [p_t^h/\Pi_t]^{-\eta}\,[Z_{t,h}/\Pi_t], \tag{10}$$

where $A_t \equiv (1/M)\sum_{j=1}^{N} a_t^j$ and $Z_t \equiv (1/M)\sum_{s=1}^{M} z_t^s$ are the relevant measures of aggregate consumption and investment spending. The argument t in the y^h schedule summarizes the dependence of the demand for good h on P_t, Π_t, A_t, and Z_t. A typical firm h is assumed to take the (possibly random) path for all those variables as given.[10]

Accordingly, the price elasticity of firm h's demand schedule is a weighted average of σ and η given by

$$\xi(\lambda_t^h) = (1-\lambda_t^h)\sigma + \lambda_t^h\eta,$$

where $\lambda_t^h \equiv (\sum_{s=1}^{M} i_{t,h}^s)/y_t^h$, i.e., the fraction of firm h's demand associated with other firms' purchases. If $\sigma = \eta$, that elasticity is constant over time (independently of λ_t^h) and equal to the common elasticity parameter.

[10] In other words, an individual firm's current decisions are assumed to have a negligible effect on the position of the demand schedule faced by the same firm in future periods, so that effect is effectively ignored by each firm. Consequently, and even though a component of each firm's production consists of durable goods, the so-called "durable-good monopolist" problem (e.g., Bulow [7]) does not apply to our model.

Next we proceed to examine the firm's intertemporal problem, i.e., its optimal capital spending policies. Given (9), firm h will choose the investment plan that solves the program

$$\max E_0 \sum_{t=0}^{\infty} \beta^t (d_t^h/P_t)$$

subject to

$$d_t^h = p^h(y_t^h, t)\, y_t^h - l_t^h - z_t^h \tag{11}$$

$$y_t^h = A(k_t^h)^{\alpha} (l_t^h)^{1-\alpha} \tag{12}$$

$$k_{t+1}^h = (1-\delta)\, k_t^h + (z_t^h/\Pi_t) \tag{13}$$

and an initial condition for k_0^h. Note that $p^h(y_t^h, t)$ is the inverse demand function associated with (10) above. An optimal plan for firm h satisfies two conditions. First, it satisfies the familiar static optimal price-setting rule

$$p_t^h = \mu(\lambda_t^h)\, \omega(x_t^h), \tag{14}$$

where $\mu(\lambda_t^h) \equiv \xi(\lambda_t^h)/(\xi(\lambda_t^h) - 1)$ is the optimal markup[11] and where $\omega(x_t^h)$ denotes firm h's marginal cost, which is determined by its output/capital ratio, denoted by $x_t^h \equiv y_t^h/k_t^h$, according to $\omega(x_t^h) \equiv (1-\alpha)^{-1} A^{-1/(1-\alpha)}(x_t^h)^{\alpha/(1-\alpha)}$.

A second optimality condition is given by the Euler equation

$$\Pi_t/P_t = \beta E_t[\theta(x_{t+1}^h) + (1-\delta)\, \pi_{t+1}^h][1/P_{t+1}], \tag{15}$$

where $\theta(x) \equiv \alpha(1-\alpha)^{-1} (x/A)^{1/(1-\alpha)}$ has the interpretation of marginal labor savings from an additional unit of capital, given an output/capital ratio x. The left-hand side of (15) is the price (in terms of the composite consumption good) firm h must pay for an additional unit of capital. The term to the right of the expectational operator is the one-period-ahead payoff from such a marginal investment (again, in terms of composite consumption). Thus, (15) implies that firm h will adjust its level of investment until the expected return to the latter equals the consumer's discount rate.

(c) *Symmetric Equilibrium*

We restrict our analysis to symmetric equilibria in which all firms produce the same quantity of their respective good. We denote that quantity by Y. In a symmetric equilibrium the prices of all goods are identical. Accordingly, $P_t = \Pi_t$ and $t = 0, 1, 2, \ldots$, implying that consumers and firms distribute their consumption and investment expenditures evenly

[11] For the firm's problem to have a solution we need to assume that $\xi(\lambda_t^h) > 1$, for all t.

across the M types of goods. We let C_t and N_t denote, respectively, the value of the CES index $\sigma(c_t^j)$ and the labor supply n_t^h common to all consumers in period t's symmetric equilibrium. I_t denotes each firm's CES investment index $\eta(i_t^h)$, and X_t, L_t, and λ_t (without superscripts) denote the common values of x_t^h, l_t^j, and λ_t^h in the same equilibrium.

Without loss of generality we assume the number of consumers N equals the number of firms M, and normalize all aggregate variables by that number. Thus, equilibrium in the labor market requires $N_t = L_t$. Using (12) we can express labor demand as a function of X_t and K_t, given by $L_t = (X_t/A)^{1/(1-\alpha)} K_t$. Given (4) and the requirement that $N_t = L_t$, the real wage W_t consistent with labor market clearing is given by

$$W_t \equiv 1/P_t = (X_t/A)^{1/\tau(1-\alpha)} K_t^{1/\tau}. \tag{16}$$

Combining (16) with the aggregate version of (14), we can explicitly solve for the output–capital ratio as a function of the aggregate capital stock and the investment share

$$X_t = \Omega_x \mu(\lambda_t)^{-\tau(1-\alpha)/1+\tau\alpha} K_t^{-(1-\alpha)/1+\tau\alpha} \equiv X(K_t, \lambda_t), \tag{17}$$

where $\Omega_x \equiv (1-\alpha)^{\tau(1-\alpha)/1+\tau\alpha} A^{(1+\tau)/1+\tau\alpha}$. Letting D_iX denote the partial derivative of X with respect to i, we see that $D_K X < 0$, whereas $\text{sign}(D_\lambda X) = \text{sign}(\eta - \sigma)$. The intuition for the latter result is straightforward: if $\eta > \sigma$, an increase in the investment share raises the demand elasticity of the representative firm, reducing its optimal markup and leading to a higher level of output in equilibrium. The opposite result obtains when $\eta < \sigma$.

Given (17) it is straightforward to obtain expressions for output, employment, consumption, investent, and the real wage, in terms of the capital stock and the investment share. Thus,

$$Y_t = \Omega_Y \mu(\lambda_t)^{-\tau(1-\alpha)/1+\tau\alpha} K_t^{\alpha(1+\tau)/1+\tau\alpha} \equiv Y(K_t, \lambda_t) \tag{18}$$

$$N_t = \Omega_N \mu(\lambda_t)^{-\tau/1+\tau\alpha} K_t^{\tau\alpha/1+\tau\alpha} \equiv N(K_t, \lambda_t) \tag{19}$$

$$C_t = (1-\lambda_t)\, Y(K_t, \lambda_t) \equiv C(K_t, \lambda_t) \tag{20}$$

$$I_t = \lambda_t Y(K_t, K_{t+1}) \equiv I(K_t, \lambda_t) \tag{21}$$

$$W_t = \Omega_w \mu(\lambda_t)^{-1/1+\tau\alpha} K_t^{\alpha/1+\tau\alpha} \equiv W(K_t, \lambda_t), \tag{22}$$

for $t = 1, 2, \ldots$, where $\Omega_N \equiv [(1-\alpha)A]^{\tau/1+\tau\alpha}$ and $\Omega_w \equiv [(1-\alpha)A]^{1/1+\tau\alpha}$.

Letting $V_t \equiv [K_t, \lambda_t, Y_t, C_t, I_t, N_t, W_t]'$, we can conveniently summarize (18)–(22) by introducing a map $V: \mathbb{R}^2 \to \mathbb{R}^7$ such that $V_t = V(K_t, \lambda_t)$.

Finally, note that real aggregate dividends in the symmetric equilibrium are given by $D_t/P_t = C(K_t, \lambda_t) - N(K_t, \lambda_t)\, W(K_t, \lambda_t) \equiv D_R(K_t, \lambda_t)$. It follows that equilibrium real stock prices $q_t^h/P_t = Q_t/P_t$ $(h = 1, ..., M)$ will be given by

$$Q_t/P_t = E_t \sum_{j=1}^{\infty} \beta^j D_R(K_{t+j}, \lambda_{t+j}). \tag{23}$$

The consumer's transversality condition in a symmetric equilibrium can be written as $\liminf_{T \to \infty} \beta^T E_0(Q_t/P_t) = 0$. That condition will hold whenever the sequence $\{K_t, \lambda_t\}_{t=0}^{\infty}$ is bounded, for (23) implies $\{Q_t/P_t\}_{t=0}^{\infty}$ will also be bounded in that case.

Let us turn next to the symmetric equilibrium version of the Euler equation (15), which takes the form

$$E_t[\theta(X_{t+1})/P_{t+1}] = \delta + \rho,$$

where $\rho \equiv \beta^{-1} - 1$ is the [consumer's] discount rate. As discussed above, $\theta(X_{t+1})/P_{t+1}$ can be interpreted as the marginal labor cost savings (in terms of the composite good) associated with a unit investment in period t. Using (17), (22), and the definition of $\theta(\cdot)$, and realizing that K_{t+1} is known as of period t, we can rewrite the Euler equation as

$$K_{t+1} = K_c E_t \mu(\lambda_{t+1})^{-(1+\tau)/(1-\alpha)} \tag{24}$$

for $t = 1, 2, ...,$ where $K_c \equiv [\alpha/(\delta + \rho)]^{(1+\tau\alpha)/(1-\alpha)} (1-\alpha)^{\tau} A^{(1+\tau)/(1-\alpha)}$. Equation (24) underscores the role of both expectations and endogenous markups in determining the dynamic behavior [of the economy] under analysis: as long as $\mu'(\cdot) \neq 0$, the desired one-period-ahead capital stock depends on the "perceived" probability distribution of λ_{t+1}. The mechanism underlying that dependence can be grasped by thinking of the effect as of period t of an increase in the expected investment share for period $t+1$. Assume, for the sake of concreteness, that $\eta > \sigma$, implying $\mu'(\cdot) < 0$, $D_\lambda X > 0$, $D_\lambda N > 0$, and $D_\lambda P < 0$. In that case an upward revision in the expected investment share will lead, *given* K_t, to a higher expected output–capital ratio X_{t+1} and real wages $W_t \equiv 1/P_{t+1}$ for the following period, thus raising the anticipated labor savings $\theta(\cdot)/P$ that would result from having an additional unit of capital available in period $t+1$, i.e., the expected marginal return to *current* investment. As a result, firms will revise upward their desired K_{t+1} and thus increase their current level of investment. As is formally shown below, that response will raise the current aggregate investment share λ_t, which will in turn result in a higher elasticity of demand and higher current output and employment (by (18) and (19)). An analogous mechanism, not discussed here, is at work in the case of $\eta < \sigma$. Of course, it still remains to be shown under what conditions revisions in expectations of the sort considered above are consistent with a rational expectations equilibrium, but this is left for the following section.

An additional equilibrium condition is given by the capital accumulation equation

$$J(K_t, K_{t+1}, \lambda_t) \equiv K_{t+1} - [(1-\delta) + \lambda_t X(K_t, \lambda_t)]\, K_t = 0. \tag{25}$$

Two remaining conditions need to be imposed, namely, an aggregate version of the consumer's time constraint and a non-negativity constraint on consumption and investment. Formally,

$$0 \leqslant N_t \leqslant 1; \quad C_t \geqslant 0; \quad I_t \geqslant 0. \tag{26}$$

An equilibrium in our model economy can now be defined as a sequence of quantities $\{K_t, N_t, Y_t, C_t, I_t\}_{t=0}^{\infty}$ and prices $\{P_t, Q_t\}_{t=0}^{\infty}$ satisfying conditions (18) to (26) for $t = 0, 1, 2, \ldots$, as well as an initial condition for K_0 and the consumer's transversality condition.

We define a stationary perfect foresight equilibrium (or, in short, a *steady state*) as a sequence $\{V_t\}_{t=0}^{\infty}$ such that $V_t = V = V(K, \lambda)$, for all t, and where (K, λ), $0 \leqslant \lambda \leqslant 1$, $K \geqslant 0$, satisfy

$$K = K_c \mu(\lambda)^{-(1+\tau)/(1-\alpha)} \tag{27}$$

$$\lambda X(K, \lambda) = \delta. \tag{28}$$

Note that K_c has a simple interpretation: it is the steady state capital stock that would obtain under perfect competition ($\mu \equiv 1$).

Using (27) to substitute for K in (17), plugging the resulting expression for X in (28), and using the definitions of Ω_x and K_c, we obtain

$$\lambda \mu(\lambda) = \delta\alpha/(\delta + \rho). \tag{29}$$

Any $\lambda \in [0, 1]$ that solves this equation defines a steady state of our model economy. The corresponding capital stock $K \geqslant 0$ is then given by (27). Under appropriate assumptions on preferences and technology at least one such steady state exists and is (generically) locally unique.[12]

Our interest lies in the possibility of stochastic equilibria characterized by a stationary sequence $\{V_t\}_{t=0}^{\infty}$ that remains arbitrarily close to a steady state V. That class of equilibria, referred to in the literature as *stationary sunspot equilibria*, were originally introduced in Woodford [28]. Before we study the existence of such equilibria, we briefly mention two "degenerate"

[12] Note that under $\sigma \geqslant \eta$ the left-hand side of (29) is strictly increasing, so there can be at most one steady state. This is not necessarily true when $\sigma < \eta$. See Gali [14] for an analysis of the implications of multiple steady states in a version of the present model.

cases for which sunspot equilibria can be ruled out *a priori*, since equilibrium in those cases can be shown to be nonstochastic: (i) the *symmetric case* ($\sigma = \eta$), and (ii) the *perfectly competitive case* ($\mu = 1$). In both cases the markup μ is independent of the investment share, so (27) implies $K_{t+1} = K_c \mu^{-(1+\tau)/(1-\alpha)} \equiv K$, the steady state capital stock. Since $D_\lambda Y = 0$ in this case, we can write $\lambda_0 = [K - (1-\delta) K_0]/Y(K_0)$, which will belong to $[0, 1]$ under the assumption that K_0 is close enough to K. The associated equilibrium will thus be given by $V_0 = V(K_0, \lambda_0)$, $V_t = V(K, \lambda)$ for $t = 1, 2, ..., \infty$; i.e., the economy will reach the steady state in one period.[13] Interestingly, and in contrast with Woodford [29], we cannot rule out sunspot equilibria in our model when the labor supply is perfectly inelastic ($\tau = 0$). In that case, current investment still depends on future real wages which are in turn a function of future markups. Changes in expectations on the future investment share will affect, through their impact on expected returns, current investment (and current markups).

Given the above discussion, variable nontrivial markups are a *necessary*—but not sufficient—ingredient for stochastic equilibria to exist in our model, given the absence of shocks to fundamentals. We focus on versions of the model in which that ingredient is present in the remainder of the paper.

3. Equilibria with Sunspot Fluctuations

The plan of this section is as follows. First we use a key result in Woodford [28] to determine the conditions under which the economy can experience stationary sunspot fluctuations near a steady state. Second, we calibrate the model in a way consistent with some long-run features of the postwar U.S. economy. Then we compute some simple statistics characterizing the time series generated by the calibrated model in the presence of sunspot fluctuations, and compare them to similar statistics for actual postwar U.S. time series.

(a) *Existence of Stationary Sunspot Equilibria*

The analysis of existence of stationary sunspot equilibria (hereafter, SSE) follows closely the approach in Woodford [28].

We characterize the conditions under which our model economy can experience SSE, i.e., equilibria characterized by a nontrivial stationary stochastic process $\{V_t\}_{t=0}^{\infty}$, such that $V_t = V(K_t, \lambda_t)$, with $\{K_t, \lambda_t\}_{t=0}^{\infty}$

[13] If K_0 is sufficiently far from the steady state, the economy will reach the latter after several periods with "corner" allocations with either zero investment or zero consumption. The lack of "richer" transitional dynamics in the cases described is a consequence of linearity of preferences in consumption.

satisfying (24) and (25) while remaining in an open ball (of arbitrarily small radius) with center at an interior steady state.

Consider thus a steady state of the economy described in Section 2, defined by $V = H(K, \lambda) \in R$, where (K, λ) satisfy (27) and (28). Applying the implicit function theorem to (25) we can write[14]

$$\lambda_t = \lambda(K_t, K_{t+1}), \tag{30}$$

where $D_1\lambda(K, K) = -(D_1J/D_\lambda J)(K, K, \lambda)$, and $D_2\lambda(K, K) = -(D_2J/D_\lambda J)$ (K, K, λ).

Thus we can substitute for λ_{t+1} in (24) to obtain

$$E_t G(K_{t+1}, K_{t+2}) = 0, \tag{31}$$

where

$$G(K_{t+1}, K_{t+2}) \equiv K_{t+1} - K_c \mu(\lambda(K_{t+1}, K_{t+2}))^{-(1+\tau)/(1-\alpha)}.$$

Using the implicit function theorem we can rewrite (31) (lagged one period) as $K_{t+1} = H(K_t, \varepsilon_t)$ where ε_t is the realization at time t of a sunspot variable satisfying $E_{t-1}\varepsilon_t = 0$. Recursively, $K_{t+1} = H(H(K_{t-1}, \varepsilon_{t-1}), \varepsilon_t) = \cdots = H^*(\varepsilon_t, \varepsilon_{t-1}, \varepsilon_{t-2}, ...)$; i.e., the capital stock depends on the entire history of the sunspot variable ε.[15]

The following proposition provides a necessary and sufficient condition for the existence of SSE.

PROPOSITION. *Let $V(K, \lambda)$ define a (interior) steady state of the economy described in Section 2. Let $\phi \equiv -D_1G(K, K)/D_2G(K, K)$. Then SSE exist in a (arbitrarily small) neighborhood of $V(K, \lambda)$ if and only if*

$$|\phi| < 1. \tag{32}$$

Proof. The above proposition is a straightforward application to the present model of Theorem 1 in Woodford [28].[16]

[14] More precisely, as long as $D_\lambda J(K, K, \lambda) \neq 0$ (which will hold generically), the implicit function theorem implies the existence of a open sets $U \subset \mathbb{R}^3$ and $W \subset \mathbb{R}^2$, where $(K, K, \lambda) \in U$ and $(K, K) \in W$, such that to every pair $(K_{t+1}, K_t) \in W$ there corresponds a unique λ_t such that $(K_t, K_{t+1}, \lambda_t) \in U$ and $J(K_t, K_{t+1}, \lambda_t) = 0$. Since we are restricting our analysis to equilibria arbitrarily close to the steady state the "local" nature of the above result is not constraining.

[15] This is the type of equilibria analyzed in Woodford [28]. It contrasts with the finite-state sunspot equilibria found in Chiappori *et al.* [10], among others. For a related application of the formalism used here see Woodford [29].

[16] Woodford's theorem applies to a more general model of the form $E_tG(K_{t+1}, K_{t+2}, K_t) = 0$, where K_t is predetermined as of period t. Our model can be seen as a particular case with $D_3G = 0$. That feature allows one to show that (32) is also a necessary and sufficient condition for existence of sunspot equilibria of the kind examined by Chiappori *et al.* [10]; i.e., equilibria in which K is a function of the contemporaneous realization of a sunspot variable that follows a finite state Markov process.

It is not difficult to find an expression for ϕ in terms of interpretable parameters,

$$\phi = 1 - [\delta(1-\alpha)/(1+\tau)][1 + (1/\varepsilon_\mu)], \tag{33}$$

where $\varepsilon_\mu \equiv \mu'(\lambda)\,\lambda/\mu(\lambda) = (\sigma - \eta)\,\lambda/[\xi(\lambda)(\xi(\lambda) - 1)]$, i.e., the elasticity of markups with respect to the investment share, evaluated at the steady state value λ. Clearly, if ε_μ is very small (as it will be for σ sufficiently close to η) condition (32) will be violated. Thus, the existence of SSE requires a "sufficiently large" deviation from the symmetric case ($\sigma = \eta$).

(b) *Welfare*

Before we attempt to assess the plausibility of (32) using a calibrated version of our model, we say a word about welfare. Clearly, and because of the presence of market power, equilibria in the economy above will always be Pareto suboptimal, even in the absence of sunspot fluctuations. Sunspot fluctuations, however, will unambiguously reduce the level of expected utility attained by the representative consumer relative to the perfect foresight case. To see this, note that the consumer's expected utility in a neighborhood of the steady state can be approximated by

$$(1-\beta)^{-1}\,[\mathrm{SSW} - (1/2\tau)\,N^{(1-\tau)/\tau}\,\mathrm{var}(\hat{N}_t)]$$

where $\hat{N}_t \equiv N(K_t, \lambda_t) - N(K, K)$, $\mathrm{SSW} \equiv [C - v(N)]$ is the (one-period) level of utility attained in the steady state, and var$(\cdot)$ denotes the variance conditional on period zero's information set. As long as τ is positive and finite (i.e., as long as the disutility of work is strictly convex), expected utility will be unambiguously reduced by the presence of sunspot fluctuations (i.e., whenever $E\hat{N}_t^2 > 0$).[17]

(c) *Calibration*

In this section we calibrate preferences and technology parameters, so that some basic features of the model's steady state roughly match postwar U.S. data.

We set specific values for four parameters: (i) $\lambda = 0.20$, the average share of gross investment in private domestic spending in postwar U.S. data,[18]

[17] Such a conclusion cannot be generalized to all sunspot models. In Woodford [29], for instance, the existence of sunspot fluctuations does not affect the representative consumer's welfare.

[18] Based on the statistics reported in Kydland and Prescott [19] for the 1954–1989 period.

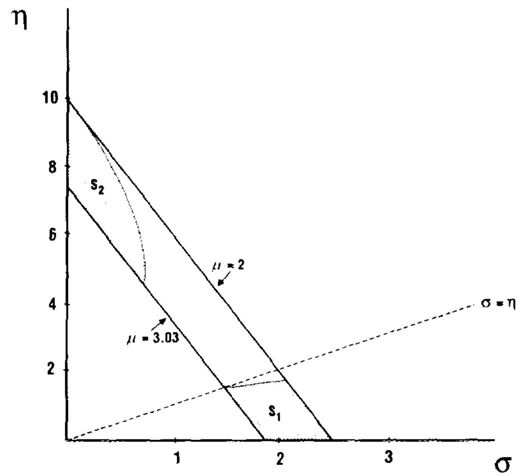

FIG. 1. Existence of SSE.

(ii) $\delta = (0.10)/4 = 0.025$, (iii) $\rho = (0.065)/4 = 0.01625$ (the average return to equity in the postwar period),[18] and (iv) $\tau = 1$, a "benchmark" value for the elasticity of labor supply used by other researchers.[19]

Figure 1 represents the set of (σ, η) pairs consistent with the existence of SSE for some $\mu(\lambda) > 1$ and $0 < \alpha < 1$, and given the above settings for λ, ρ, δ, and τ. In particular, the two straight, downward-sloping lines represented in the figure correspond to the extreme values for the steady state markup $\mu(\lambda)$ consistent with such equilibria, namely, 2 and 3.03. As the figure illustrates, within the set of (σ, η) values that are consistent with the existence of a steady state under our calibration—i.e., the (σ, η) that fall between the two lines—there are two large subsets S_1 and S_2 for which sunspot fluctuations are possible. Note that such fluctuations are possible in both economies with $\sigma > \eta$ and those with $\sigma < \eta$, which correspond to subsets S_1 and S_2, respectively.

(d) *Properties of Stationary Sunspot Equilibria*

Needless to say, the potential for sunspot equilibria in our model would be of limited interest if it was associated with fluctuations in aggregate

[18] Based on King *et al.* [18].

[19] We view the settings for λ, ρ, and δ as (relatively) uncontroversial. Our setting for τ is more questionable, but none of the results below were qualitatively affected when we experimented with other reasonable values for that parameter. As mentioned above, and as can be seen in (32), a zero value for τ is also consistent with SSE.

TABLE I

U.S. Data, 1947:1–1989:4[a]

Variable (x)	Relative std. dev.	Correlation of GNP with $x(t-1)$	$x(t)$	$x(t+1)$
GNP	1.00	0.85	1.00	0.85
Consumption	0.73	0.81	0.82	0.66
Investment	3.14	0.83	0.90	0.81
Hours	0.85	0.69	0.86	0.86
Real wage	0.53	0.40	0.35	0.26
Investment share	0.32	0.74	0.81	0.77

[a] Source, Kydland and Prescott (1990). "Consumption" includes durables, nondurables and services. "Hours" correspond to the household survey measure. "Investment" and "investment share" refer to fixed investment.

variables that failed to replicate some basic features of actual aggregate fluctuations. Some of those features are summarized in Table I, which reports a variety of statistics for HP filtered output, consumption, investment, hours, the real wage, and the investment share, all of them taken from the Kydland and Prescott [19] study.

Tables II and III report a set of statistics generated by two calibrated versions of the model. In each case we set σ and η at values consistent with a steady state markup equal to 2.8 (given $\lambda = 0.20$), this being the average of Hall's estimated markups for seven one-digit U.S. industries (Hall [15]). Note that $\mu \in (2, 3.03)$ and is thus consistent with the existence of a steady state given settings for the remaining parameters. In all cases the

TABLE II

Baseline Model, $\sigma = 1.75$, $\eta = 0.79$

Variable (x)	Relative std. dev.	Correlation of GNP with $x(t-1)$	$x(t)$	$x(t+1)$
GNP	1.00	0.98	1.00	0.98
Consumption	1.55	0.59	0.70	0.66
Investment	4.62	0.15	0.29	0.25
Hours	0.14	0.64	0.74	0.71
Real wage	0.72	0.64	0.74	0.71
Investment share	0.88	0.06	−0.08	−0.04

TABLE III

Baseline Model, $\sigma = 0.6$, $\eta = 5.37$

Variable (x)	Relative std. dev.	Correlation of GNP with $x(t-1)$	$x(t)$	$x(t+1)$
GNP	1.00	0.99	1.00	0.99
Consumption	0.99	0.99	0.99	0.99
Investment	1.08	0.87	0.87	0.88
Hours	0.12	0.86	0.87	0.86
Real wage	0.60	0.86	0.87	0.86
Investment share	0.10	0.08	0.09	0.07

technology parameter A was set at a value consistent with $N = 0.2$ in the steady state, the average work week as a fraction of total weekly hours in postwar U.S. data.[21] The statistics reported correspond to logarithmic deviations from steady state values in the case of output, consumption, investment, and the real wage, but to absolute deviations for both labor input and the investment share.

The results in Table II correspond to the setting ($\sigma = 1.75$ and $\eta = 0.79$). Since $\sigma > \eta$, the investment share is positively related to markups in this case. As a result the former shows a (contemporaneous) negative correlation with output, a clearly counterfactual prediction since the investment share is known to have a strongly procyclical behavior (see Table I). That feature does not prevent the level of investment from being procyclical, though its correlations with output are clearly too low. Note also that both consumption and investment appear to be more volatile than output, another result at odds with the evidence.[22] Those anomalies notwithstanding, the remainder of statistics are not far off their empirical counterparts, at least qualitatively. Similar results obtain for other parameter configurations for which $\sigma > \eta$.

Table III reports the statistics obtained by setting $\eta = 5.4$ and $\sigma = 0.6$. Those parameter values imply a procyclical investment share, in a way consistent with the evidence, though the correlation coefficients seem excessively low. In addition, consumption now appears to be less variable than output, and investment is more so, though the difference in standard deviations is substantially smaller than in the data. Several other

[21] See King *et al.* [18].

[22] Of course, that result is only possible if consumption and investment are negatively correlated in equilibrium.

qualititative features of U.S. time series are matched by our model's predictions (e.g., consumption, investment, employment, and the real wage are procyclical, both hours and the real wage are less volatile than output, etc.). Even though the magnitudes of the generated statistics differ substantially from the sample ones in several cases, we find the qualitative similarities encouraging.[23]

Interestingly, there is a specific dimension of the data which our model seems to capture better than the standard real business cycle (RBC) model. As discussed in Benhabib and Farmer [2], hours devoted to the production of consumption goods appear to be procyclical in the data, a feature that is at odds with the predictions of RBC models. Under both calibrations above our model predicts that consumption is procyclical; given that technology is stationary, hours devoted to consumption goods production must also be procyclical, thus matching the existing evidence.

4. Markups and Aggregate Demand Composition: Some Econometric Evidence

In this section we provide some cross-sectional and time series evidence on the size of markups in the U.S. economy that may shed some light on the empirical relevance of the model above.

We start by constructing a measure of markups, under the assumption of a Cobb–Douglas production function

$$Y_t = A_t K_t^{\alpha} N_t^{\gamma},$$

which generalizes (6) by allowing for nonconstant returns to scale and technical progress. The markup is thus given by

$$\mu_t = (\partial Y_t / \partial N_t)/W_t = \gamma / \xi_t, \tag{34}$$

where $\xi_t \equiv W_t N_t / Y_t$ is the labor income share.

We introduce m_t, defined by

$$m_t \equiv -\log \xi_t, \tag{35}$$

as our basic markup measure. Given (34) it is clear that $m_t \equiv \log \mu_t - \log \gamma$.

(a) *Some Cross-Sectional Evidence*

We construct measures of *average* markups for each of 18 two-digit U.S. manufacturing sectors. Using (34), combined with the assumption of a

[23] This observation is reinforced by the fact that the endogenous nature of fluctuations in our model leaves the "calibrator" without an exogenous driving process (describing technology or preferences, say) whose parameters can be manipulated more or less at will in order to match additional sample moments.

constant, sector-specific γ^i, the average markup in sector i can be written as $(\gamma^i/T)\sum_{t=1}^{T} 1/\xi_t^i$, where ξ_t^i is the share of labor income in sector i's value added in period t. We accordingly define $m^i \equiv \log[(1/T)\sum_{t=1}^{T} 1/\xi_t^i]$, and estimate the regression

$$m^i = a + b\lambda^i + u^i,$$

where λ^i is the fraction of sector i's total output sold to firms and u^i is a sector-specific error term containing γ^i. We obtained our λ^i's from the input–output table, as the sum of sector i's intermediate demand and the fixed investment component of its final demand.

Given our discussion of the properties of sunspot equilibria, one would expect to find a significant, and presumably negative, correlation between our markup measure and the investment share. The results are, however, somewhat disappointing: the point estimate of b in the regression above turned out negative, but insignificant ($\hat{b} = -0.062$, s.e. $= 0.17$). That result carries over to an augmented regression including the $C4$ concentration measure as an explanatory variable.

(b) *Some Time Series Evidence*

Several attempts to describe and quantify the cyclical behavior of markups in the U.S. economy can be found in the literature. Bils [4] examines the cyclical behavior of markups over marginal costs that explicitly account for overtime pay and finds those measures to be countercyclical in almost all two-digit industries.

Domowitz *et al.* [11] attack the same issue by allowing markups to depend on capacity utilization (among other variables) in a Hall-type regression. Their results point toward procyclical markups in U.S. manufacturing, with the exception of highly concentrated durables good industries.

Rotemberg and Woodford [23] construct both aggregate and sectoral time series for markups, under the assumptions of overhead labor and a technology exhibiting constant returns in capital and variable labor. They regress their markup measures on output and alternative proxies for the expected discounted value of future profits. Their results imply that, in most cases, low markups are associated with high current output and low future profits. They interpret this evidence as suggesting that markup variations at cyclical frequencies may be due to changes over time in the ability to collude, as implied by implicit-collusion models.

We construct a time series of markup variations using U.S. quarterly data on hours, real wages, and output corresponding to the sample period 1964:1–1988:4.[24] All our data were drawn from the Citibase tape.

[24] The coverage of the data is not completely uniform. Hours and wage data correspond to the private, non-agricultural sector, whereas value added is the difference between GNP and value added by the Federal, state, and local governments.

TABLE IV

Time Series Markup Regressions[a]

	Regressors			
Row no.	h	y	λ	R^2
1	−0.221* (0.111)			0.97
2		−0.201* (0.092)		0.97
3	0.089 (0.170)		−1.067* (0.396)	0.97
4		0.304* (0.137)	−1.611* (0.286)	0.98
5	−0.149 (0.204)	0.428* (0.177)	−1.602* (0.281)	0.98

[a] Estimated coefficients of an OLS regression of m_t on the listed regressors, a time trend, and an intercept. Standard errors were computed using the Newey–West correction with four lags.

Rows 1 and 2 in Table IV report the estimates of simple regressions of m_t on HP filtered GNP and hours, respectively denoted by $\hat{Y}_t$ and $\hat{N}_t$. The significantly negative coefficient estimates imply our markup time series is countercyclical, in a way that is consistent with previous evidence by Bils [4] and Rotemberg and Woodford [23]. Of course, that negative correlation does not necessarily have a causal interpretation: (detrended) output and hours could be a proxy for the "true" factor driving fluctuations in markups. Our model implies that the share of investment in output could be that causal factor, for its variations could affect the effective demand elasticity faced by the average firm. This leads us to consider a more general regression of the form

$$m_t = a + b\lambda_t + c\hat{Y}_t + d\hat{N}_t + u_t,$$

where λ_t is the share of fixed investment in aggregate private spending,[25] and u_t is meant to capture the effects on markup variations of factors ignored by the model and which we assume to be uncorrelated with the regressors. Our model implies $b \neq 0$ and $c = d = 0$; i.e., all the cyclical variations in markups should reflect variations in the investment share. Of course, the sign of b implied by the model depends on whether the elasticity

[25] We construct that time series as the ratio of gross fixed capital formation to the sum of the latter and total private consumption.

of substitution in consumption is greater or smaller than that in production, though the results of the previous section would tend to favor a negative value for b.

The corresponding estimates are reported in rows 3–5. In all cases, and as predicted by our model under the $\eta > \sigma$ assumption, the estimated investment share coefficients are significantly negative, and have a similar size (between -1 and -1.62).

Note that in regressions 3 and 5 the detrended hours coefficient becomes insignificant, while the estimated output coefficient is still significant (though with a switched sign). The latter result is at odds with our model's prediction that the size of markups should depend only on the composition of aggregate demand. We can think of two explanations for that result. First, and given that both hours and output enter the formula used to construct the dependent variable, it is likely that any measurement error in that variable—resulting, for instance, from the inappropriateness of some of the assumptions underlying those formulas—would be correlated with them, thus explaining their significance. Second, the investment share may not be the *only* determinant of markups; mechanisms of the kind found in other models of endogenous markup determination—e.g., the customer market or the implicit collusion models described in Rotemberg and Woodford [23]—may also be at work. In any event, and though further work will clearly be necessary to assess the relative merits of the alternative explanations, we find the explanatory power of the investment share in the markup regression an interesting result that, in addition to verifying some of the predictions of our model, sheds some light on the potentially important role of the composition of aggregate demand as a source of markup movements. In particular, and as illustrated in Table III if the elasticity of substitution in production is sufficiently higher than that in consumption, the economy can experience sunspot fluctuations characterized by a countercyclical markup and a procyclical investment share. Under that model one can interpret the evidence of countercyclical markups found in the literature (and in regressions 1 and 2) as resulting from the positive correlation between the cyclical indicators used as regressors and the (omitted) investment share.

5. Conclusions

We have developed a dynamic, general equilibrium model with monopolistically competitive firms in which the possibility of persistent fluctuations in the absence of shocks to fundamentals arises for a wide range of parameter values. That possibility arises once we allow the elasticity of substitution across goods in consumption to differ from that in production. In that case, the effective price-elasticity of demand faced by each firm (and thus optimal markups and output) will depend on the composition of aggregate demand. For some plausible parameter values, sunspot equilibria have been shown to exist and to be characterized by time series properties for different aggregate variables which qualitatively match those observed in actual business cycles.

Though the model developed and analyzed in this paper is highly stylized and characterized by an extreme symmetry, we believe it provides an interesting example of a fully specified general equilibrium model in which the presence of market power, in addition to its well known role as a source of suboptimal allocation, plays a key role in allowing for endogenous, random fluctuations resembling business cycles. We see the assumption of monopolistic competition (and, more generally, that of price-setting agents) as a natural/relevant departure from the Arrow–Debreu paradigm, and thus as a more interesting source of suboptimality and (potential) sunspot fluctuations than that of, say, an infinite number of agents (as found in OLG settings). Accordingly, we believe more effort should be devoted to a further understanding of the link between imperfect competition, multiple equilibria, and sunspot fluctuations, a research line that we plan to pursue in the future.

Appendix

For a given calibration, computation of model-generated statistics involves three steps. First we use (30) to substitute for λ_t in (18)–(22), and define a new map $H: \mathbb{R}^2 \to \mathbb{R}^7$, by setting $H(K_t, K_{t+1}) \equiv V(K_t, \lambda(K_t, K_{t+1}))$. Second, we define $\hat{V}_t \equiv [\hat{K}_t, \hat{\lambda}_t, \hat{Y}_t, \hat{C}_t, \hat{I}_t, \hat{N}_t, \hat{W}_t]'$, where $\hat{K}_t \equiv \log(K_t/K)$, $\hat{Y}_t \equiv \log(Y_t/Y)$, $\hat{C}_t \equiv \log(C_t/C)$, $\hat{I}_t \equiv \log(I_t/I)$, $\hat{N}_t \equiv N_t - N$, $\hat{\lambda}_t \equiv \lambda_t - \lambda$, and $\hat{W}_t \equiv \log(W_t/W)$, and linearize the H map around the steady state capital stock K implied by the calibrated parameters, yielding an expression of the form $\hat{V}_t = B\hat{U}_t$, where $\hat{U}_t \equiv [\hat{K}_t, \hat{K}_{t+1}]'$, and where B is a (7×2) matrix. Third, we linearize (31) around K, which yields a simple AR(1) process for $\hat{K}_t$

$$\hat{K}_{t+1} = \phi \hat{K}_t + \varepsilon_t,$$

where $E_{t-1}\varepsilon_t = 0$, all t, and where ϕ is determined by the model's parameters, as in (33). Given $|\phi| < 1$ we can easily compute $\Sigma_k \equiv E\hat{U}_t\hat{U}'_{t-k}$, $k = 0, \pm 1, \pm 2, \ldots$, i.e., the autocovariance of $\{\hat{U}_t\}$. Finally, we can recover all the statistics reported in Tables II and III by computing the autocovariogram of $\{\hat{V}_t\}$, using the formula $E\hat{V}_t\hat{V}'_{t-k} = B\Sigma_k B'$.

REFERENCES

1. C. AZARIADIS, Self-fulfilling prophecies, *J. Econ. Theory* **25** (1981), 380–396.
2. J. BENHABIB AND R. E. A. FARMER, Indeterminacy and increasing returns, *J. Econ. Theory* **62** (1994).
3. J. BENHABIB, R. ROGERSON, AND R. WRIGHT, Homework in macroeconomics: Household production and aggregate fluctuations, *J. Polit. Econ.* **99** (1991), 1166–1187.
4. M. BILS, The cyclical behavior of marginal cost and price, *Amer. Econ. Rev.* **77** (1987), 838–857.
5. O. BLANCHARD AND N. KIYOTAKI, Monopolistic competition and the effects of aggregate demand, *Amer. Econ. Rev.* **77** (1987), 647–666.
6. O. BLANCHARD AND L. H. SUMMERS, Hysteresis in unemployment, *Europ. Econ. Rev.* **31** (1987), 288–295.
7. J. I. BULOW, Durable goods monopolists, *J. Polit. Econ.* **90** (1982), 314–332.
8. D. CASS AND K. SHELL, Do sunspots matter?, *J. Polit. Econ.* **91**, 193–227.
9. S. CHATTERJEE, R. COOPER, AND B. RAVIKUMAR, Participation dynamics: Sunspots and cycles, *Rev. Econ. Stud.*, in press.
10. P. A. CHIAPPORI, P. I. GEOFFARD, AND R. GUESNERIE, Sunspot fluctuations around the steady state: The case of multidimensional, one-step forward looking economic models, *Econometrica* **60** (1992), 1097–1126.
11. I. R. DOMOWITZ, R. G. HUBBARD, AND B. C. PETERSEN, Market structure and cyclical fluctuations in U.S. manufacturing, *Rev. Econ. Statist.* (1988), 55–66.
12. R. E. A. FARMER AND M. WOODFORD, Self-fulfilling prophecies and the business cycle, CARESS working paper, 1984.
13. R. E. A. FARMER AND J. GUO, Real business cycles and the animal spirits hypothesis, *J. Econ. Theory* **62** (1994).
14. J. GALÍ, Multiple equilibria in a growth model with monopolistic competition, unpublished manuscript, Columbia University, 1992.
15. R. E. HALL, The relation between price and marginal cost in U.S. industry, *J. Polit. Econ.* **96** (1988), 921–948.
16. O. HART, A model of imperfect competition with Keynesian features, *Quart. J. Econ.* **97** (1982), 109–138.
17. W. P. HELLER, Coordination failure under complete markets with applications to effective demand, *in* "Equilibrium Analysis: Essays in Honor of Kenneth J. Arrow" (W. Heller, R. M. Starr, and D. Starret, Eds.), Cambridge Univ. Press, Cambridge, 1986.
18. R. G. KING, C. I. PLOSSER, AND S. T. REBELO, Production, growth, and business cycles. I. The basic neoclassical model, *J. Monet. Econ.* **21** (1988), 195–232.
19. F. E. KYDLAND AND E. C. PRESCOTT, Business cycles: Real facts and a monetary myth, *Quart. Rev.* (1990), 3–18.
20. N. KIYOTAKI, Multiple equilibria under monopolistic competition, *Quart. J. Econ.* **103** (1988), 695–713.
21. N. G. MANKIW, Imperfect competition and the Keynesian cross, *Econ. Lett.* **26** (1988), 7–14.
22. J. PECK AND K. SHELL, Market uncertainty: Correlated and sunspot equilibria in imperfectly competitive economies, *Rev. Econ. Stud.* **58** (1991), 1011–1029.
23. J. ROTEMBERG AND M. WOODFORD, Markups and the business cycle, *in* "NBER Macroeconomics Annual 1991" (O. J. Blanchard and S. Fischer, Eds.), pp. 63–129, MIT Press, Cambridge, MA, 1991.
24. K. SHELL, "Monnaie et Allocation Intertemporelle", mimeo., Séminaire d'Econométrie Roy–Malinvaud, Centre Nationale de la Recherche Scientifique, Paris, November 21, 1977. [title and abstract in French, text in English]

25. K. Shell, Sunspot equilibrium, *in* "The New Palgrave: A Dictionary of Economics" (J. Eatwell, M. Milgate, and P. Newman, Eds.), Vol. 4, pp. 549–551, MacMillan, New York, 1987.
26. R. Startz, Monopolistic competition as a foundation for Keynesian macroeconomic models, *Quart. J. Econ.* **104** (1989), 737–752.
27. M. Weitzman, Increasing returns and the foundations of unemployment theory, *Econ. J.* **92** (1982), 787–804.
28. M. Woodford, Stationary sunspot equilibria: The case of small fluctuations around a deterinistic steady state, unpublished manuscript, University of Chicago, 1986.
29. M. Woodford, Self-fulfilling expectations and fluctuations in aggregate demand, *in* "New Keynesian Economics" (N. G. Mankiw and D. Romer, Eds.), Vol. 2, MIT Press, Cambridge, MA, 1991.