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Real Business Cycles and the Animal Spirits Hypothesis*

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We calibrate a quantitative equilibrium macroeconomic model with an aggregate technology that is subject to increasing returns and show that this model may display fluctuations at business cycle frequencies even when there are no shocks to the fundamentals of the economy. These fluctuations are due to the self-fulfilling beliefs of investors which we call "animal spirits." We compare the impulse response functions predicted by our model and by two other more standard models with a four-variable vector autoregression on U.S. data. Our animal spirits economy is the most successful of the three at matching broad features of the dynamic responses in the data. *Journal of Economic Literature* Classification Numbers: E00, E3, E32.

1. INTRODUCTION

Do business cycles represent optimal responses by rational agents to erratic changes in technology, or are they also influenced by the "animal spirits" of investors? This question is important not only from the standpoint of positive economics but also for normative reasons. If business fluctuations represent the delivery of contingent commodities of the kind that occur in finite Arrow–Debreu models of general equilibrium theory,

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then it is difficult to make the case that politicians should be concerned about them since the allocations that occur in such economies are Pareto Optimal. But if economic activity can fluctuate from day to day in a way that is independent of economic fundamentals, then there may be an important role for the policy maker in designing regimes that can reduce fluctuations and increase economic welfare.[1]

Until relatively recently the animal spirits explanation was widely taught in graduate schools as a cornerstone of the Keynesian explanation of recessions. But lately, animal spirits have fallen from grace as a growing number of researchers in the field embrace market clearing and rational expectations as key elements of a theory of economic fluctuations. Although a number of important articles on animal spirits, also referred to as "sunspots" and "self-fulfilling prophecies," have appeared in the economic theory journals, most macroeconomists view the animal spirits hypothesis as a theoretical curiosity that does not have much to add to modern theories of the business cycle.[2]

This paper represents a preliminary attempt to change the perceptions of our colleagues by providing a model of business cycles that is calibrated with the same level of precision as real business cycle (RBC) models. We build a model economy, with parameters that are designed to match the first moments of the U.S. time series data, in which there is no fundamental uncertainty whatsoever. Nevertheless, output, employment, consumption, and investment undergo irregular fluctuations as a direct result of the self-fulfilling beliefs of rational forward looking agents. We show that our economy can explain the contemporaneous correlations of output, employment, investment, and consumption in U.S. time series with about the same degree of precision as the standard real business cycle model and that it is more successfull at capturing the *dynamics* of U.S. data.

Our works takes off from an observation by Hall who pointed out that the Solow residuals, obtained from growth accounting, should be uncorrelated with any variable that is uncorrelated with productivity shifts since, under the assumptions of perfect competition and constant returns-to-scale, the Solow residual should be an unbiased estimate of the "true" shock to the production function. In a series of papers, Hall [13–16] has found

[1] Randomness in the economy that is unrelated to fundamentals is referred to as "sunspots" in the literature. The first work on sunspot equilibrium was reported in Shell [30]. Sunspot fluctuations are not Pareto optimal (in the standard sense) since they are avoidable and one generally assumes that agents are risk averse. See Cass and Shell [7] and Shell [31] for a more detailed discussion of this issue.

[2] "Animal spirits" is a term that was introduced by Keynes and has been resuscitated by Howitt and McAfee [19, 20]. The "self-fulfilling prophecy" is a term that was coined by Merton [25]. It was introduced into economics by Azariadis [2]. In the paper we use the terms animal spirits, sunspots, and self-fulfilling prophecies interchangeably.

empirical evidence against this prediction by showing that there is a positive correlation, in U.S. post-war data, between the Solow residuals and various instrument variables that could reasonably be expected to be exogenous. He argued that *monopolistic competition* and *increasing returns-to-scale* may explain this failure and that these same factors may also play an important role in understanding economic fluctuations.[3]

Following up on Hall's suggestion, several papers have explored the idea that U.S. data may be described by a technology that is subject to the presence of increasing returns-to-scale at the level of the aggregate economy. Caballero and Lyons [6] have estimated production functions at the two-digit level and found evidence of the presence of external effects, and Baxter and King [3] have studied the implications of an increasing return-to-scale technology for the correlations between key macroeconomic variables in a real business cycle environment. The Baxter–King paper used the increasing returns assumption to show that a demand-driven model may capture many of the correlations that are explained by supply disturbances in a more standard framework. More recently, Benhabib and Farmer [4] have pointed out that the increasing returns assumption has potentially more radical implications.[4]

In the standard RBC framework, if there are no shocks to the technology, the underlying economy is described by a two-dimensional dynamical system around a stationary state that is a *saddle point.* Benhabib and Farmer [4] showed that a slight departure from the standard framework leads to a model displaying an indeterminate steady state (i.e., a *sink*) and they pointed out that one may exploit this indeterminacy to generate a model of aggregate fluctuations that is driven by agents' self-fulfilling beliefs. The key feature which changes the stability of the steady state is the assumption that the social technology is characterized by increasing returns-to-scale.

In this paper we compare simulated data from three different economies. Economy 1 is an RBC model with Hansen's [17] modification of *indivisible labor* and Economies 2 and 3 are models with monopolistic competition and increasing returns. Although we calibrate all three economies using the

[3] Among others, Domowitz *et al.* [11] showed that there is a significant difference between price and marginal cost in U.S. manufacturing industries, which supports the presence of marker power in the U.S. economy. A number of authors have looked at business cycle models that include an imperfectly competitive element. For example, Hart [18], Weitzman [33], Mankiw [24], Akerlof and Yellen [1], Blanchard and Kiyotaki [5], Kiyotaki [21], Chatterjee and Cooper [8], Startz [32], Woodford [34], Rotemberg and Woodford [29], and Galí [12].

[4] The paper by Klenow [22] has studied the effect of introducing increasing returns in a framework that is similar to the Benhabib–Farmer article. Klenow, however, stressed models in which there may be multiple determinate stationary states. The focus of the Benhabib–Farmer paper is on a single steady state that is indeterminate.

first moments of U.S. time series data, there is some flexibility in calibration that arises from the way that we match theoretical constructs with actual data. For example, proprietor's income could reasonably be interpreted either as labor income or as profits. Similarly, there is some imprecision in the estimation of the degree of monopoly power in the U.S. economy that is represented by differences in estimates of the average markup of price over marginal cost. This flexibility is the key to understanding the differences between Economies 2 and 3. Economy 2 uses a value for labor's share of 0.63 and a value for the *price-cost-margin*[5] of 0.3; the resulting model exhibits a determinate steady state (a saddle point). Economy 3, on the other hand, sets the labor share parameter equal to 0.7, and the price-cost margin at 0.42; this economy displays an indeterminate steady state (a sink).

Moreover, to obtain artificial time series, Economies 1 and 2 are driven by highly persistent productivity shocks and Economy 3 is driven by i.i.d. sunspots. In all three economies, markets clear and agents optimize and form rational expectations. We are primarily interested in the comparison of models 1 and 3 since our objective is to show that a model that is driven by i.i.d. sunspots can explain the data at least as well as the RBC paradigm. We include model 2, as a control, to distinguish the effects of increasing returns in combination with saddle point dynamics from increasing returns that generate indeterminacy. We find that our sunspot model explains the contemporaneous covariances and relative standard deviations of the actual data as well or better than standard RBC models, and it performs somewhat better when we compare dynamic responses in all three economies with impulse responses from the postwar U.S.

2. The RBC and Increasing Returns Models Compared

2.1. *The Equations of the Benhabib–Farmer Model*

Benhabib and Farmer [4] described two organizational structures that are consistent with the possibility that a competitive economy may be described by an aggregate technology that displays increasing returns-to-scale. They work with a non-stochastic, continuous time economy but the stochastic discrete analog of their model is described by the equations

$$Y_t = Z_t K_t^{\alpha} L_t^{\beta}, \tag{1}$$

$$A \frac{C_t}{L_t^{\gamma}} = b \frac{Y_t}{L_t}, \tag{2}$$

[5] The price–cost margin, defined as the ratio of price-minus-marginal-cost to price is equal to zero in a competitive economy.

$$\frac{1}{C_t} = E_t\left[\frac{\rho}{C_{t+1}}\left(a\frac{Y_{t+1}}{K_{t+1}} + 1 - \delta\right)\right], \tag{3}$$

$$K_{t+1} = (1-\delta)K_t + Y_t - C_t, \tag{4}$$

$$Z_t = Z_{t-1}^{\theta}\eta_t, \qquad Z_0 \text{ is given}, \tag{5}$$

$$\lim_{t\to\infty} \rho^t \frac{K_t}{C_t} = 0, \tag{6}$$

where C_t represents consumption, L_t is labor supply, Y_t is output, K_t is capital, and a is the capital share and b is the labor share in national income respectively. Equation (1) is a Cobb–Douglas technology with a productivity disturbance Z_t, Eq. (4) is the capital accumulation equation and Eq. (5) allows for the productivity disturbance, Z, to be autocorrelated. In two of the models considered below we assume that the innovation, η_t, is an i.i.d. random variable with unit mean and in the other model we assume that Z is a constant equal to unity. Equations (2) and (3) combine the first-order conditions from the problem faced by a representative consumer,

$$\max \sum_{t=0}^{\infty} \rho^t E_0\left[\log C_t - A\frac{L_t^{1-\gamma}}{1-\gamma}\right], \qquad 0<\rho<1, \tag{7}$$

such that

$$K_{t+1} + C_t \leqslant w_t L_t + (1-\delta+r_t)K_t + \Pi_t,\ K_0 \text{ is given}, \tag{8}$$

with the transversality condition (6), and the first-order conditions of a set of representative firms. The notation Π_t in Eq. (8) represents the profits received by a representative household from the ownership of firms, w_t is the real wage, r_t is the rental rate, δ represents depreciation, ρ is the discount factor, γ ($\leqslant 0$) denotes the labor supply elasticity, and A is a positive preference parameter.

2. Externalities and Monopolistic Competition Compared

The key to the Benhabib–Farmer paper is the assumption of increasing returns, $\alpha+\beta>1$. When $\alpha+\beta=1$ the model collapses to a standard real business cycle economy and in this case Eq. (2) equates the slope of the agent's indifference curve to the marginal product of labor. Similarly, Eq. (3) equates the expected ratio of the marginal utilities of consumption in adjacent periods to the marginal product of capital. The special feature in the competitive model is that

$$\alpha = a \quad \text{and} \quad \beta = b. \tag{9}$$

In other words, factor shares of national income are equal to their respective elasticities to production.

Benhabib and Farmer [4] used two separate production structures to achieve competitive models in which the equality restrictions represented by (9) may break down. In one of these environments competitive firms each face constant returns technologies but there are externalities present that cause an increase in output by one firm to simultaneously increase the output of all other firms. In this environment factor shares in national income sum to one, but the rate of return in production may sum to more than one. That is,

$$a + b = 1, \tag{10}$$

but

$$\alpha + \beta > 1. \tag{11}$$

In the second structure a continuum of monopolistically competitive intermediate goods producers, indexed by i, face increasing returns technologies. But a competitive sector combines the intermediate inputs to produce a unique final good using a Dixit–Stiglitz [10] technology,

$$Y = \left(\int_0^1 Y(i)^{\lambda} \, di \right)^{\lambda}, \tag{12}$$

where $0 < \lambda < 1$.

When the parameter λ is less than one, each of the monopolistic competitors faces a downward sloping demand for its product and the solution to its maximization problem may be well defined even when the firm produces subject to increasing returns.[6] From the assumption that factor markets are competitive and the first-order conditions of the representative firm, it can be shown that[7]

$$a = \lambda\alpha \quad \text{and} \quad b = \lambda\beta, \tag{13}$$

which implies that this framework allows for the presence of positive profits and that factor shares in national income may sum to *less than one*. In the monopolistically competitive model,

$$a + b < 1, \tag{14}$$

[6] To be precise, the profit function of the intermediate goods producers is concave as long as $\lambda(\alpha + \beta) \leqslant 1$.

[7] See Benhabib and Farmer [4] for details.

and

$$\alpha + \beta > 1. \tag{15}$$

In our calibration of the model, discussed below, we favor the last specification with increasing returns and monopolistic competition.

3. Dynamics around the Steady State

3.1. *Steady State*

To generate artificial time series from our model economies we have used Eq. (1) to eliminate Y and Eq. (2) to eliminate L from Eqs. (3) and (4), leaving a system of three dynamic equations in K, C, and Z,

$$\begin{aligned} K_{t+1} &= BZ_t^m K_1^g C_t^d + (1-\delta)K_t - C_t, \\ \frac{1}{C_t} &= E_t\left[DZ_{t+1}^m K_{t+1}^{g-1} C_{t+1}^{d-1} + \frac{\tau}{C_{t+1}}\right], \\ Z_t &= Z_{1-t}^{\theta}\eta_t, \end{aligned} \tag{16}$$

where $\phi \equiv 1/(\beta + \gamma - 1)$, $d \equiv \beta\phi$, $m \equiv 1 - d$, $g \equiv \alpha m$, $B \equiv (A/b)^d$, $D \equiv Ba\rho$, and, $\tau \equiv \rho(1-\delta)$. Employment is determined by the static equation

$$L_t = \left[\frac{A}{b}\frac{C_t}{Z_t K_t^{\alpha}}\right]^{\phi}, \tag{17}$$

and throughout the paper we assume that $\phi \neq 0$.

In the following analysis of the high frequency movements predicted by our models we have taken an approach, standard in the literature, of abstracting from growth. To analyze the short run dynamics of alternative models we take a first-order Taylor series approximation to Eq. (16) around the stationary state of the non-stochastic economy. This stationary state is defined by the equations

$$K^* = \left[\frac{\omega}{\nu}\right]^{1/(\chi-1)}, \qquad C^* = \nu(K^*)^{\chi}, \tag{18}$$

where

$$\omega \equiv \frac{B(1-\tau)}{D} - \delta, \qquad \nu \equiv \left[\frac{1-\tau}{D}\right]^{1/d}, \qquad \text{and} \qquad \chi \equiv \frac{1-g}{d}.$$

3. A Linear Approximation

The dynamics of our stochastic economies are described by the nonlinear functional equations (16) for different values of the key parameters. Since these equations cannot be solved analytically we make use of a first-order Taylor series approximation around the point $\{K^*, C^*, 1\}$. To derive the steady-state $\{K^*, C^*, 1\}$ we have set the productivity innovation, η_t, equal to a constant value of 1. In two of our stochastic economies we assume that η_t is a random variable with small bounded support that contains 1, and in the third economy we shut down this disturbance entirely. The assumption of small bounded support ensures that the values of K_t, C_t and Z_t never wander far from the neighborhood of the fixed point $\{K^*, C^*, 1\}$ in which the linear approximation is valid. Using the definitions

$$\hat{K}_t \equiv \frac{K_t - K^*}{K^*} \cong \log\left(\frac{K_t}{K^*}\right), \qquad \hat{C}_t \equiv \frac{C_t - C^*}{C^*} \cong \log\left(\frac{C_t}{C^*}\right),$$

$$\hat{Z}_t \equiv \frac{Z_t - 1}{1} \cong \log(Z_t),$$

and letting the vector

$$e_{t+1} \equiv \begin{bmatrix} E_t[\hat{K}_{t+1}] - \hat{K}_{t+1} \\ E_t[\hat{C}_{t+1}] - \hat{C}_{t+1} \\ E_t[\hat{Z}_{t+1}] - \hat{Z}_{t+1} \end{bmatrix}$$

represent one-step-ahead forecast errors, one can write a linear approximation to Eq. (16) in the form

$$\begin{bmatrix} \hat{K}_t \\ \hat{C}_t \\ \hat{Z}_t \end{bmatrix} = J \begin{bmatrix} \hat{K}_{t+1} \\ \hat{C}_{t+1} \\ \hat{Z}_{t+1} \end{bmatrix} + R \begin{bmatrix} \hat{\eta}_{t+1} \\ e_{t+1} \end{bmatrix}, \tag{19}$$

where J is the 3×3 Jacobian matrix of partial derivatives of the transformed dynamical system and R is a conformable matrix of coefficients. Additional linear equations specify how investment, labor hours, output, and productivity are related to the current state vector, $s_t \equiv [\hat{K}_t, \hat{C}_t, \hat{Z}_t]'$:

$$X_t \equiv \begin{bmatrix} \hat{I}_t \\ \hat{L}_t \\ \hat{Y}_t \\ \hat{P}_t \end{bmatrix} = M \begin{bmatrix} \hat{K}_t \\ \hat{C}_t \\ \hat{Z}_t \end{bmatrix} \equiv M s_t, \tag{20}$$

where productivity P is defined as Y/L and M is a (4×3) matrix of coefficients obtained from linearizing the first-order conditions and the budget constraint. Hats over variables denote deviations from the non-stochastic steady state. In the remaining sections of this paper we examine the dynamics of rational expectations equilibria of the linearized model summarized by Eqs. (19) and (20).

4. The Animal Spirits Hypothesis and Its Implications: Saddles and Sinks

The model that we have described subsumes the standard real business cycle model as a special case with the parameter $\lambda = 1$. The unique rational expectations solution to the standard model determines C_t as a linear function of K_t and Z_t. In the special case of no uncertainty, that is, when Z is identically equal to one, this function places the economy on the stable branch of the saddle.[8] This situation is depicted in Fig. (i).

The paper by Benhabib and Farmer [4] has shown that a slight modification to the standard framework leads to a model with the dynamics of a sink which may have either real or complex roots. The key feature which causes a change in the stability of the steady state is the fact that increasing returns implies that the labor demand curve may slope up as a function of the wage. If the slope of labor demand is steeper than the slope of labor supply, increases in the stock of capital that shift up the

[8] When Eq. (19) is derived from a representative agent model with competitive markets and a technology that satisfies constant returns-to-scale, the matrix J can be shown to possess three real roots, one of which is less than one in absolute value and two of which are greater than one in absolute value. To find the unique rational expectations solution one decomposes (19) as

$$s_t^* = \Lambda s_{t-1}^* + \Omega \begin{bmatrix} \hat{\eta}_{t+1} \\ e_{t+1} \end{bmatrix},$$

where Λ is a diagonal matrix of eigenvalues of J and s^* is found by premultiplying the state vector by Q^{-1}, the inverse of the matrix of eigenvectors of J,

$$s_t^* = Q^{-1} s_t.$$

Let s_t^{*1} be the transformed variable associated with a root of J that is less than one. The above equation consists of three scalar difference equations since Λ is diagonal. Iterating the first equation of this set and taking expectations leads to the condition

$$s_t^{*1} = 0 \quad \text{for all } t,$$

which translates into a linear restriction on the vector of state variables s_t. This restriction determines $\hat{C}_1$ as a linear function of $\hat{K}_t$ and $\hat{Z}_t$.

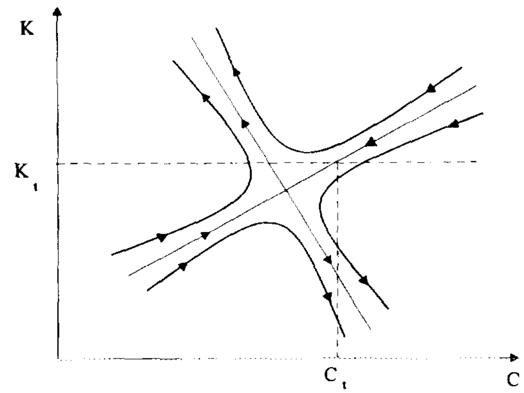

FIG. i. Real business cycle model: A saddle.

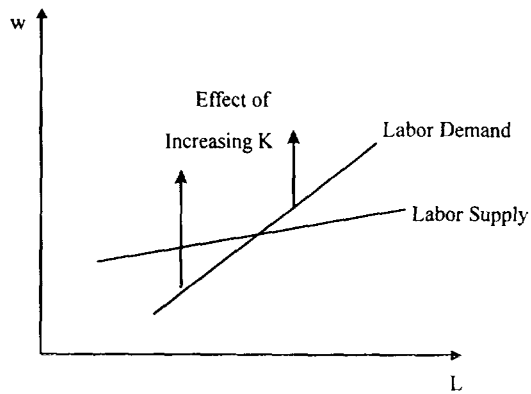

FIG. ii. Labor market in the Benhabib-Farmer economy.

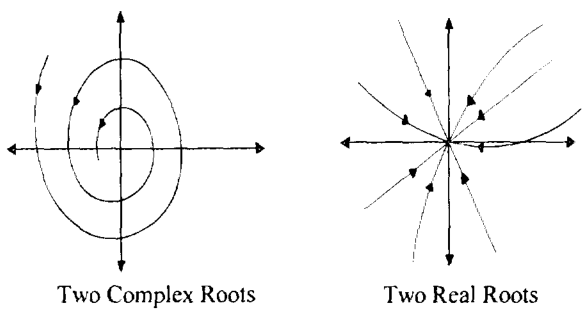

FIG. iii. Animal spirits economy: A sink.

labor demand curve will *lower* wages and employment.[9] This idea is illustrated in Fig. ii. The implication of an upward sloping labor demand curve is that the steady state of the non-stochastic model may look like either of the two panels in Fig. iii. The left-hand panel depicts a situation in which the roots of J are complex conjugates and the right-hand panel depicts the case in which they are both real.

As a result, the standard model generates a first-order equation in single state variable, capital, driven by the stochastic disturbance Z_t. This equation is derived by substituting the solution for C_t as a function of K_t and Z_t into the linearized capital accumulation equation. Since the data suggest that U.S. GNP requires at least a scond-order representation, it is usual, in the RBC literature, to assume that the disturbance term is autocorrelated. Thus, the RBC model has a representation in the form

$$\begin{aligned} \hat{K}_t &= a_{11}\hat{K}_{t-1} + a_{12}\hat{Z}_t, \\ \hat{Z}_t &= \theta \hat{Z}_{t-1} + \hat{\eta}_t. \end{aligned} \tag{21}$$

On the other hand, the Benhabib–Farmer paper showed that, if increasing returns are strong enough, the equilibrium may be represented by an equation of the same form as (19), with the difference that the roots of J may *all* be outside the unit circle. This implies that the picture which represents the non-stochastic model may look like Fig. iii. In the increasing returns economy the data can be described as a third-order system of the form

$$\begin{aligned} \hat{K}_t &= a_{11}\hat{K}_{t-1} + a_{12}\hat{C}_{t-1} + a_{13}\hat{Z}_t, \\ \hat{C}_t &= a_{21}\hat{K}_{t-1} + a_{22}\hat{C}_{t-1} + a_{23}\hat{Z}_t + b_2\hat{V}_t, \\ \hat{Z}_t &= a_{33}\hat{Z}_{t-1} + b_3\hat{\eta}_t, \end{aligned} \tag{22}$$

where the term V_t represents *any* random variable that has zero conditional mean at date $t-1$. In the special case in which there is no shock to fundamentals, these equations have a second-order representation in the form

$$\begin{aligned} \hat{K}_t &= a_{11}\hat{K}_{t-1} + a_{12}\hat{C}_{t-1}, \\ \hat{C}_t &= a_{21}\hat{K}_{t-1} + a_{22}\hat{C}_{t-1} + b_2\hat{V}_t. \end{aligned} \tag{23}$$

[9] After breaking down the first-order condition for labor supply, Eq. (2), it is straightforward to show that the slope of the labor demand curve is equal to $\beta - 1$, and the slope of the labor supply curve is given by $-\gamma$. Consequently, the necessary conditions for indeterminacy are $\beta - 1 > 0$, and $\beta - 1 + \gamma > 0$.

In a standard RBC model the error term to the consumption equation is linked to the *fundamentals* of the economy by the cross-equation restrictions that place the economy on the stable branch of the saddle. When the strength of increasing returns in the economy is sufficient to change the properties of the steady state dynamics from a saddle to a sink, it is no longer possible to uniquely pin down beliefs as a function of fundamentals. It becomes possible to interpret the disturbance term V_t as an independent source of fluctuations that can magnify the effects of the productivity shock Z_t. In the extreme case it is possible for an economy with increasing returns to display belief driven cycles *in the absence of any underlying fundamental uncertainty.*

5. Calibrating the Model

5.1. *Three Economies*

In this section of the paper we investigate the dynamic properties of macroeconomic time series generated by three versions of our model economy. The first of these versions is Rogerson [28] and Hansen's [17] *indivisible labor economy* in which the representative agent's utility function (7) is linear in labor hours, but logarithmic in the unique consumption commodity.[10] Our second and third models maintain the Rogerson–Hansen utility function but they introduce a technology that displays increasing returns to scale produced by monopolistically competitive firms. Model 2 exhibits a determinate steady state with saddle point dynamics, whereas model 3 possesses an indeterminate steady state. We examine whether the model-generated time series broadly resemble the business cycle fluctuations of the U.S. economy in the post-Korean War period (1954–1991) by investigating (i) contemporaneous moments, (ii) persistence, (iii) impulse response functions, and (iv) Solow residuals.

Our first increasing returns economy, model 2, is similar to the model studied by Baxter and King [3]. But whereas Baxter and King use externalities to reconcile social increasing returns with competitive factor markets, in model 2 we assume that output is produced from a continuum of intermediate inputs, each of which is produced by a monopolistic competitor. This difference means that our economy may display positive profits, in the presence of free entry, since each entrant into the market for

[10] Any equilibrium business cycle model that fits the observed fluctuations of labor input requires the assumption that labor supply is highly elastic. See, for example, Murphy, *et al.*'s [26] discussion of this issue. Rogerson's [28] assumption of indivisible labor has been shown by Hansen [17] to provide a highly effective way of matching the observed variance of hours in U.S. data. The Rogerson–Hansen hypothesis implies that hours are chosen "as if" a representative agent has a utility function that is linear in leisure.

intermediate factor inputs is assumed to produce a differentiated product. Model 3 also uses monopolistically competitive input markets but it takes a different stand on the calibration of certain key parameters. This difference implies that the dynamics of the linearized model no longer provide enough restrictions to uniquely determine a rational expectations equilibrium in terms of fundamentals.

5.2. *Parameters Suggested by Other Studies*

To derive the linear approximation, solve for an equilibrium, and generate artificial time series, we assign specific numerical values to the parameters of the model based on evidence from growth observations, panel studies of individual households, and empirical studies in the industrial organization literature.

For all three model economies, we set γ equal to zero. This parameterization draws on an argument by Rogerson [28] that was used in a real business cycle study by Hansen [17]. The Rogerson–Hansen assumption implies that the labor supply curve is infinitely elastic with respect to the real wage. We also use a common quaterly discount factor $\rho = 0.99$ and a quarterly depreciation rate $\delta = 0.025$ across all three models. All these figures are standard in the RBC literature.

For model 1 we have chosen the remaining parameters to match Hansen's [17] paper. Specifically we set the preference parameter $A = 2.86$[11] and the capital share of national income, $a = 0.36$. The persistence parameter for the technology shock $\theta = 0.95$, and the standard deviation of the innovation to this shock, which we denote σ_η, is set to 0.007.[12]

In the competitive model (model 1), the parameters of factor shares in national income, a and b, are equal to respective elasticities in production, α and β. In the monopolistically competitive models, however, the parameters may differ since $a = \lambda\alpha$ and $b = \lambda\beta$, where λ measures the degree of monopoly power in the markets for intermediate products.[13] To get a fix on the value of λ, we have made use of the *Lerner index* that is given by the identity

$$1 - \lambda \equiv \frac{p - mc}{p}.$$

[11] A is set to this value to match the share of leisure as a fraction of total hours supplied to the labor force given the assumption of a total time indowment of 1. An alternative normalization, which we use for models 2 and 3, is to set $A = 1$ and pick the total leisure endowment to match this feature of the data.

[12] See Hansen [17] for details.

[13] The first-order condition of an intermediate good producer leads to a negatively sloped demand curve for its product with elasticity equal to $1/(1 - \lambda)$.

TABLE I

	λ	b	β
M1 (Hansen RBC Model)	1	0.64	0.64
M2 (Baxter–King MC Model)	0.7	0.63	0.9
M3 (Benhabib–Farmer MC Model)	0.58	0.7	1.21

In a recent study of U.S. manufacturing industries, Domowitz *et al.* (DHP) [11] have refined an earlier study by Hall [13] to attain estimates of this index from a panel data set of 284 four-digit S.I.C. industries. The DHP study finds an estimated value of the price–cost margin that ranges from 0.198, for tobacco products, to 0.513, for printing and publishing. The Hall [13] study implies price–cost margins ranging between 0.048 and 0.705, using the DHP definition.[14] Drawing on these studies, our monopolistically competitive models, 2 and 3, use values of the price-cost margin of 0.3 for model 2 and 0.42 for model 3. These values in turn imply that $\lambda = 0.7$ in model 2 and $\lambda = 0.58$ in model 3.

5.3. *An Important Assumption about Monopoly Profits*

We have described evidence from existing studies that gives a fix on λ. But in order to close our model we must also assign values to the share parameters in national income, a and b, and thus α and β. To fix the labor share parameter, b, in our monopolistically competitive models, we note that Christiano [9] found values of b between 0.57 and 0.75 in the U.S. economy, depending on the treatment of proprietor's income and of the discrepancy in the data between national income and net national product.[15] In model 2 we choose $b = 0.63$, and for model 3 we set $b = 0.70$. These values, given our assumptions about λ, imply values for β in each economy that are summarized in Table I.

To fix the share of capital, represented by a, most studies make the assumption that $a + b = 1$. This is true of standard RBC approaches and it is also true of the work of Baxter and King [3] that ascribed increasing returns to the effects of externalities. We find that a key ingredient of our animal spirits economy, model 3, is the assumption that $a + b < 1$. If one had accurate measures of capital then it might be possible to fix this parameter more accurately by taking capital's share of national income.

[14] Domowitz *et al.* [11] use a methodology that avoids some measurement problems that arise in Hall's [13] paper. The authors argued that their methodology allows them to attain more precise estimates of markups.

[15] Earlier studies conform to this proposition. The parameter of labor's share in national income is set to 0.58 in Baxter and King [3], 0.64 in Kydland and Prescott [23] and Hansen [17], 0.66 in Christiano [9], and 0.75 in Prescott [27].

TABLE II

	λ	a	α
M1 (Hansen RBC Model)	1	0.36	0.36
M2 (Baxter–King MC Model)	0.7	0.3	0.43
M3 (Benhabib–Farmer MC Model)	0.58	0.23	1.4

Alternatively, one might try to estimate α directly with instrumental variable estimates of the technology. We did try this approach, but found that there is not enough independent movement in capital to get an accurate estimate of α. Point estimates hover around zero with large standard errors.[16]

For the purposes of simulating our model economies we have made the arbitrary decision to set the return to the capitalized value of monopoly profits to 7% of national income.[17] In model 2, which sets labor's share to 0.63, the total share in national income of all other factors is equal to 37%, of which we ascribe 30% to physical capital and 7% to the capitalized value of monopoly profits. Model 3, setting labor's share to 0.7, leaves 30% of national income as the return to all other factors. In this version we postulate that 23% of national income represents a return to physical capital and the remaining 7% represents monopoly rents. The values of a and α implied by these formulations are summarized in Table II.

5.4. *Assumptions about the Driving Process in Each Economy*

The properties of the dynamic equations that describe our three model economies depend on how many roots of the Jacobian matrix J in Eq. (19) lie inside the unit circle. Since the process that drives the technology disturbance is uncoupled from the other two equations, one of the roots of J will always be equal to $1/\theta$. This root will be greater than one in absolute value

[16] If one maintains the assumption that $a+b=1$, it is possible to estimate the ratio of $\alpha+\beta$ to $a+b$ by applying an instrumental variables estimator to a regression of output growth on a weighted index of input growth. This technique leads to a value of

$$\frac{\alpha+\beta}{a+b} \cong 1.5,$$

which is attributed by Baxter and King [3] to the effects of externalities. In our framework this ratio is interpreted as an estimate of the price–cost markup parameter since $(\alpha+\beta)/(a+b)=1/\lambda$.

[17] The results described in the following sections are not very sensitive to the choice of $a+b$ and one may obtain similar results over a range of parameter values. We explored values from several alternative parameterizations in which we chose values of monopoly profits between 2 and 7%. We obtained similar results in all cases.

TABLE III

	Root 1	Root 2	Root 3 ($1/\theta$)
M1 (Hansen RBC Model)	0.93	1.06	1.05
M2 (Baxter–King MC Model)	0.83	1.07	1.05
M3 (Benhabib–Farmer MC Model)	1.07 + 0.11i	1.07 − 0.11i	N/A

because of the hypothesis that the productivity disturbance is stationary. In the standard RBC model, our model 1, the other two roots of J can be shown to split around unity; that is, the steady state is a saddle point.

In the case when the technology is subject to increasing returns, it is no longer *necessarily* true that the steady state of the model is a saddle. However, we have chosen the parameters of model 2 in such a way that the saddle point property is preserved. Model 3 differs from our first two economies since the degree of increasing returns to labor is large enough to cause the demand curve for labor to become upward sloping.[18] This is reflected in the fact that the parameter, β, in economy 3 is greater than 1. In Table III we report the values of the roots of J that are implied by each of our three parametric specifications.

To simulate economies 1 and 2 we have solved the stable root of J *forward* to derive $\hat{C}$ as a linear function of $\hat{K}$ and $\hat{Z}$. Each of these two economies is driven by a stochastic process

$$\hat{Z}_t = \theta \hat{Z}_{t-1} + \hat{\eta}_t, \tag{24}$$

with an autocorrelation parameter, $\theta = 0.95$. We have chosen the standard deviation of $\hat{\eta}_t$ in each economy in a way that causes the standard deviation of simulated output series to match the GNP volatility in the actual data. The fact that economy 2 is subject to increasing returns means that we can match the volatility of output in U.S. data using an innovation to the technology that is approximately half as variable as the Hansen RBC model. Since the rational expectations equilibrium is unique in both of our economies 1 and 2, the volatility of the sunspot process, V_t, must be set to zero.

To simulate economy 3 we make a very different set of assumptions since we are interested in the hypothesis that animal spirits may subsitute for the technology shock as the driving force behind the business cycle. With this end in mind, we have set the standard deviation of $\hat{\eta}_t$ equal to zero in model 3; that is, we assume that $Z_t = 1$ for all t. Unlike models 1 and 2, consumption in model 3 is not constrainted to move one for one with capital and

[18] Since the utility function is linear in leisure, the labor supply curve in all three economies is horizontal. An upward sloping labor demand curve implies, therefore, that labor demand slopes up *more steeply* than labor supply.

TABLE IV

	θ	σ_η	σ_v
M1 (Hansen RBC Model)	0.95	0.007	N/A
M2 (Baxter–King MC Model)	0.95	0.00465	N/A
M3 (Benhabib–Farmer MC Model)	N/A	N/A	0.00217

the technology shock. We drive business cycles in model 3 with i.i.d. sunspots and we set the standard deviation of our sunspot disturbance in a way that causes the volatility of output to match the U.S. data. The assumptions about the driving uncertainty in all three economies are summarized below in Table IV.

6. Simulating the Model

6.1. *Pictures of the Data*

In this section we present a set of simulated time series from each of the model economies and compare them with the post-Korean War U.S. data. For each simulation we use a random number generator in GAUSS386 to draw realizations of $\hat{\eta}_t$ and V_t. The same set of random numbers are used as innovations to technology shocks in economies 1 and 2 and as sunspot shocks in model 3. Shock variances are set to match the standard deviation of the simulated output series with the detrended U.S. data. Each model was simulated by feeding in the appropriate sequence of shocks and generating artificial time series for the economy from the calibrated linear approximation. Figures 1–3 present the responses of output, consumption, labor hours, and investment in these model economies for a single simulation experiment and we plot the series for each model alongside the actual U.S. time series. The data in Figs. 1–3 has been seasonally adjusted and logged and all series have been passed through the Hodrick–Prescott filter.[19]

[19] We have detrended with the HP filter mainly for ease of comparison with other papers in the RBC literature. The HP filter decomposes a series $\{x_t\}$ into a trend $\{\tau_t\}$ and a cycle $d_t = x_t - \tau_t$ by finding the trend that solves

$$\mathrm{Min}_{\{T_t\}} \frac{T}{T} \sum_{t=1}^{T} (x_t - \tau_t)^2 + \frac{\lambda}{T} \sum_{t=2}^{T-1} [(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2,$$

where $\lambda > 0$ is the penalty on variations in the growth rate of the trend component. A larger λ means the resulting $\{\tau_t\}$ is smoother. Following the literature, we set λ equal to 1600 for quarterly data.

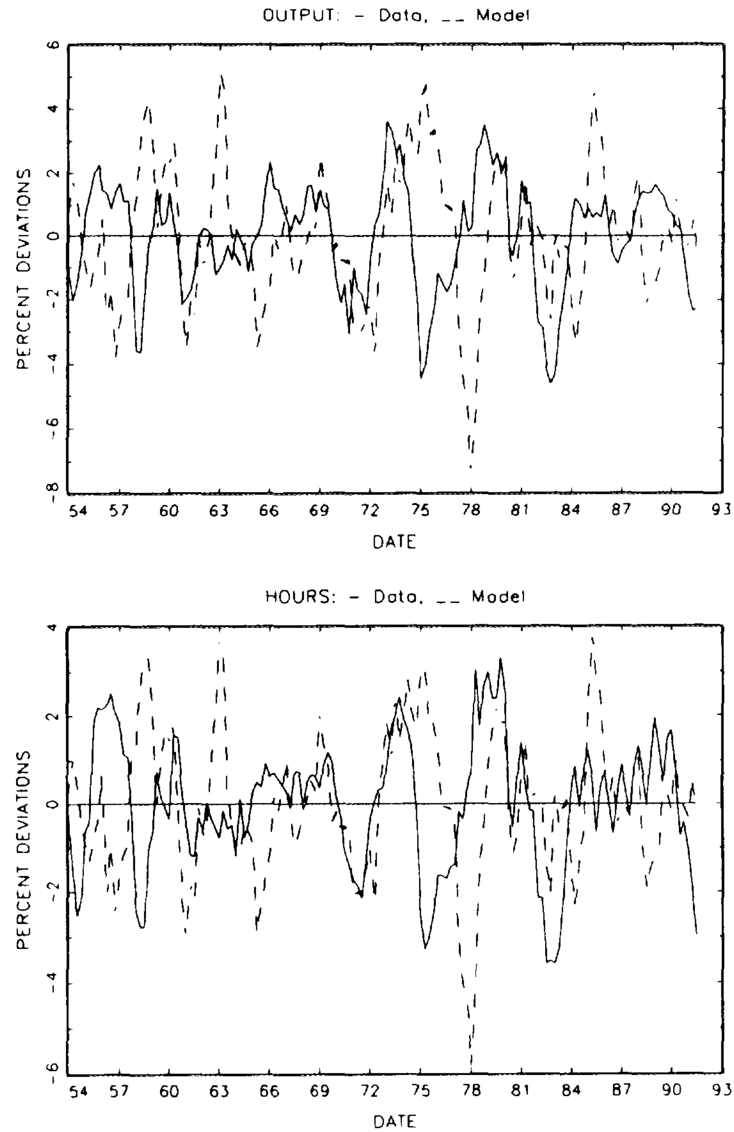

FIG. 1. The Hansen RBC economy.

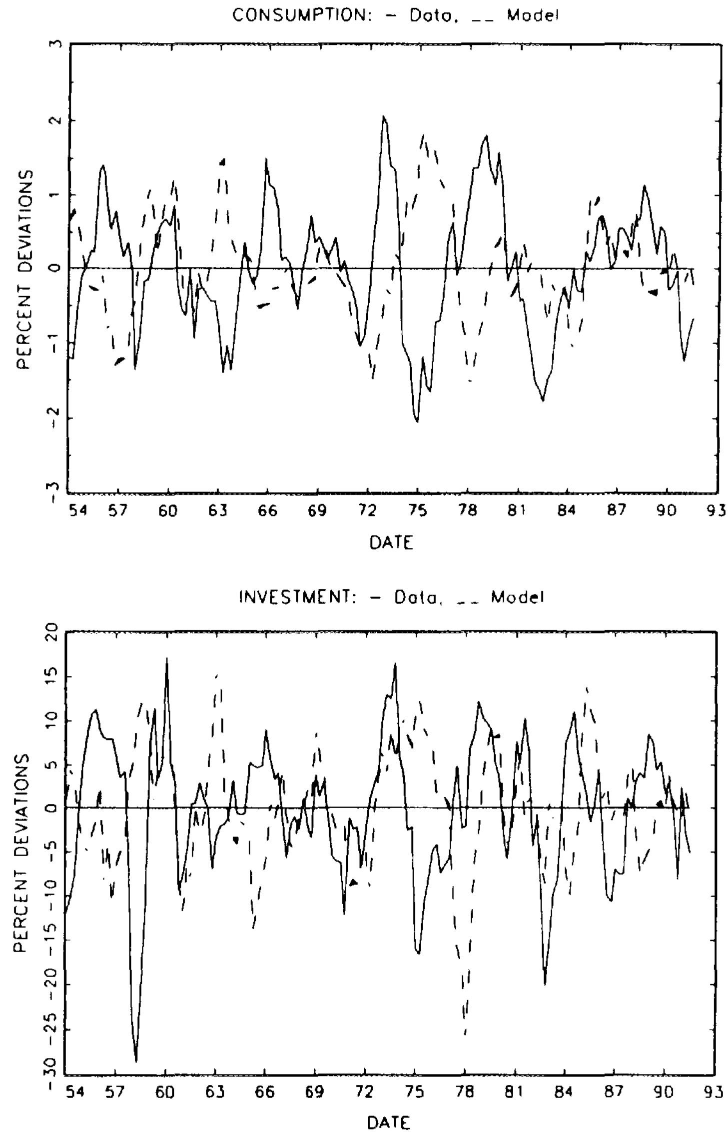

FIG. 1—*Continued*

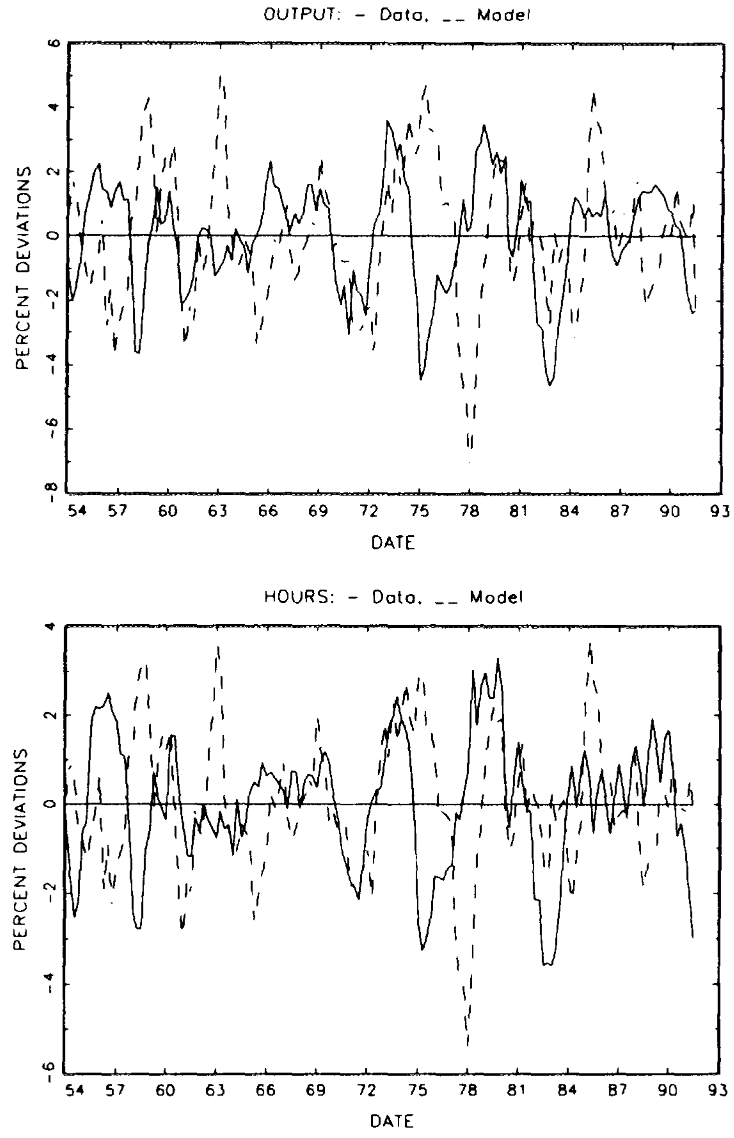

FIG. 2. The Baxter–King increasing returns economy.

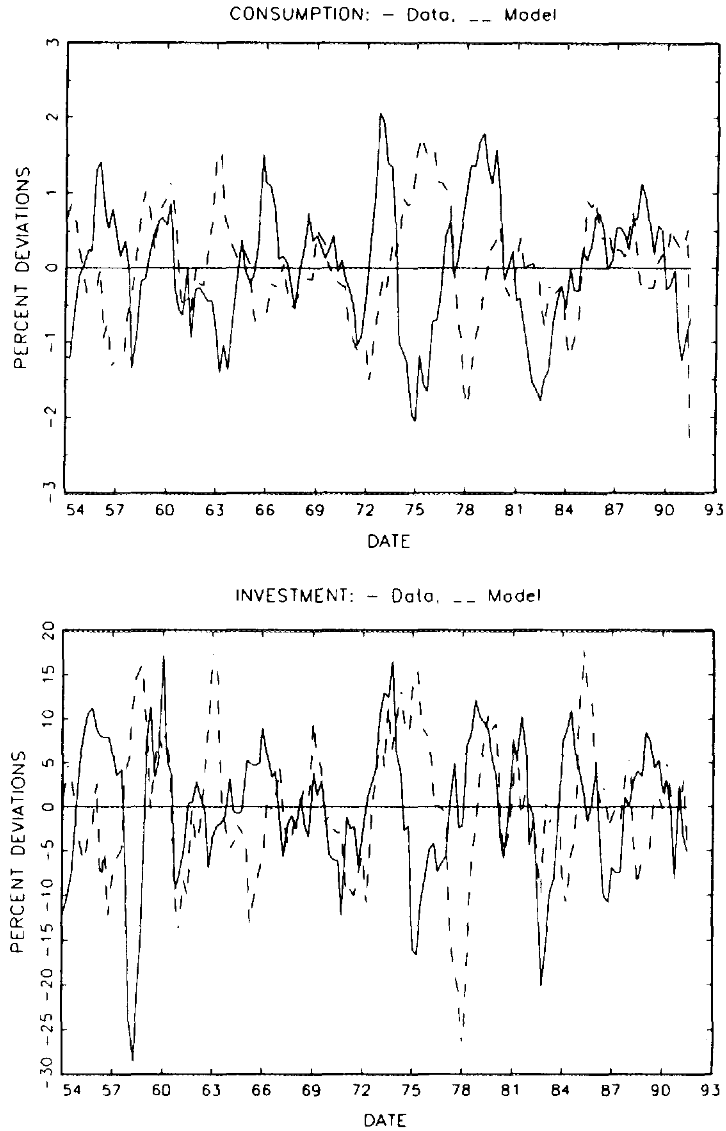

FIG. 2—*Continued*

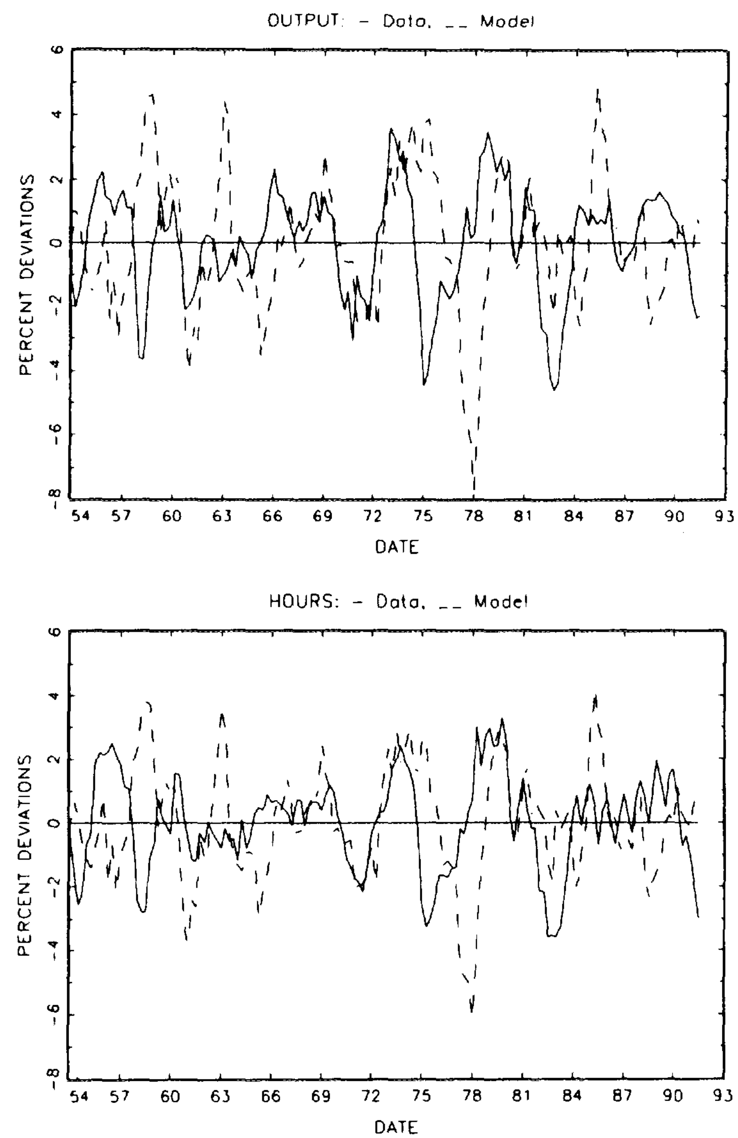

FIG. 3. The Benhabib–Farmer increasing returns economy.

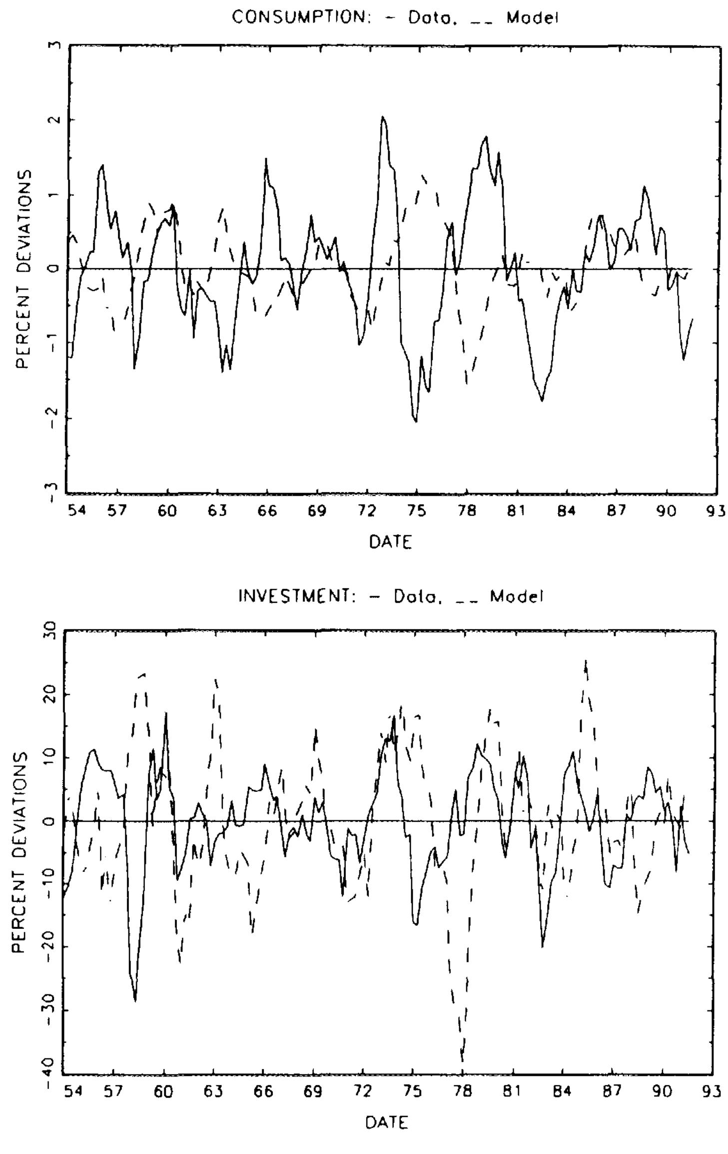

FIG. 3—*Continued*

TABLE V

Variable	U.S. data[a]	Model 1[b]	Model 2[b]	Model 3[b]
Output	1.73(1.00)[c]	1.76[d](1.00)	1.74[d](1.00)	1.74[d](1.00)
Consumption	0.86[e](0.50)	0.51(0.29)	0.56(0.32)	0.41(0.24)
Investment	7.78[f](4.50)	5.73(3.26)	6.31(3.64)	8.91(5.13)
Hours 1	1.50(0.87)	1.34(0.76)	1.26(0.73)	1.44(0.83)
Hours 2	1.67(0.97)			
Productivity 1	0.88(0.51)	0.51(0.28)	0.56(0.32)	0.41(0.24)
Productivity 2	0.82(0.47)			

[a] Quarterly data, 1954.1–1991.3. The U.S. time series used are real GNP, consumption expenditure on nondurable goods and services, and gross private investment (all in 1982 dollars). The Hours 1 series is total manhours of employed labor force in all industries derived from the Household Survey. The Hours 2 series, which is obtained from the establishment survey, includes total employee hours in the non-agricultural industries. Productivity is output divided by labor hours. All series are taken from the CITIBASE data bank. All data and model-generated time series have been Hodrick–Prescott filtered.

[b] The statistics reported in columns 2, 3, and 4 are sample means computed for 100 simulations. Each simulation consists of 151 periods, the same number as the U.S. sample.

[c] For variable x, the number reported in parentheses is its relative standard deviation to output.

[d] Shock variances are adjusted to match with output variation of actual data.

[e] For total consumption expenditure, the number is 1.26.

[f] For fixed investment, the number is 5.41.

6.2. *Contemporaneous Moments*

From the above figures we find that all three models do a reasonably good job of matching the relative variances of the U.S. data. A summary of the standard deviations of the variables generated by each model and of standard deviations relative to GNP (the figures in brackets) is presented in Table V.

Note that all three models understate the volatilities of consumption and productivity, but the sunspot model (model 3) is worse in both dimensions than either of the technology shock driven economies. The volatilities of investment and hours, on the other hand, are more closely matched by the sunspot model.

Table VI presents contemporaneous correlation coefficients of consumption, labor hour, investment, and investment with output. On this dimension all three models display contemporaneous correlations between investment and output and between hours and output that are too high. The sunspot model comes closer to capturing the correlations of output with consumption and productivity.

TABLE VI

Variable	U.S. data[a]	Model 1	Model 2	Model 3
Consumption	0.77[b]	0.86	0.89	0.78
Investment	0.84[c]	0.99	0.99	0.99
Hours 1	0.86	0.98	0.98	0.98
Hours 2	0.88			
Productivity 1	0.50	0.87	0.89	0.78
Productivity 2	0.32			

[a] Quaterly data, 1954.1–1991.3.
[b] For total consumption expenditure, the number is 0.83.
[c] For fixed investment, the number is 0.91.

We conclude from this rather imprecise comparison that the sunspot model performs no worse than the RBC model at matching contemporaneous covariances in the data. Since there is reason to be skeptical of *any* single shock model, we view this exercise as encouragement to investigate the sunspot model in more depth.

6.3. *Persistence*

The real business cycle model has been criticized by a number of authors for its inability to *endogenously* explain persistence. In order to capture the high degree of autocorrelation that exists in U.S. data, the RBC model must be driven by a highly autocorrelated disturbance. Although we do not view this as a shortcoming of the RBC model, it is worth pointing out that the sunspot model will generate highly persistent movements in output that are endogenous, even when driven by i.i.d. disturbances. In Table VII we document a measure of persistence for each of the three models by estimating an AR(1) model from artificial data generated by each model economy and compare the AR coefficient with U.S. data.

TABLE VII[a]

Variable	U.S. Data[b]	Model 1	Model 2	Model 3
Output	0.86	0.78	0.78	0.80
Consumption	0.84	0.86	0.84	0.90
Investment	0.76	0.77	0.77	0.79
Hours[c]	0.85	0.77	0.77	0.79
Productivity[c]	0.53	0.86	0.84	0.90

[a] For variable x, the figure reported in the table is its AR(1) coefficient.
[b] Quarterly data, 1954.1–1991.3.
[c] The hours/productivity series used here is from the Household Survey. For the establishment data, the figures are 0.90 for hours and 0.67 for productivity.

TABLE VIII[a]

	Data			Model 1			Model 2			Model 3		
Variable	AC1	AC2	AC3	AC1	AC2	AC3	AC1	AC2	AC3	AC1	AC2	AC3
Output	0.85	0.63	0.38	0.78	0.54	0.30	0.77	0.54	0.29	0.80	0.57	0.33
Consumption	0.84	0.65	0.48	0.86	0.67	0.47	0.84	0.61	0.42	0.90	0.74	0.55
Investment	0.76	0.47	0.20	0.77	0.52	0.26	0.77	0.53	0.28	0.79	0.56	0.31
Hours[b]	0.83	0.62	0.42	0.77	0.53	0.28	0.77	0.53	0.27	0.79	0.56	0.31
Productivity[b]	0.53	0.25	−0.06	0.86	0.68	0.48	0.84	0.61	0.42	0.89	0.74	0.55

[a] Quarterly data, 1954.1–1991.3.

[b] The hours/productivity series used here is from the Household Survey. For the establishment data, the numbers are 0.89, 0.66, 0.42 for hours and 0.67, 0.45, 0.10 for productivity.

Table VIII presents the correlation coefficients of the current value of output, consumption, investment, hours, and productivity with the series lagged from one to three periods. The feature of the tables that we wish to emphasize is the ability of the sunspot driven model to mimic the highly persistent characteristics of the detrended data without building this persistence into the driving process.

6.4. *Impulse Response Functions*

To check another dimension of the dynamic properties of the three model economies, we examine the impulse response functions that trace out how a dynamical system reacts to an initial shock. Figure 4 shows the responses of output, employment, consumption, and investment to an innovation to output computed from an estimated vector autoregression consisting of a linear time trend and five lags of the real GNP, labor hours (from the Household Survey), real consumption of goods and services, and real private gross investment, 1954.1–1991.3. In each panel, the solid line displays the point estimates of responses, whereas the dashed lines present the two standard error bounds derived from bootstrapping with 1,000 replications. At date $t = 1$ when the shock takes place, investment is more responsive to the output innovation than other variables. Subsequently, all four variables exhibit a similar *cyclical* pattern and converge to the stationary state at about the same rate.

Figure 5 plots the impulse response functions from the same VAR estimation of the simulated time series from three model economies along with the actual data. Note that all of the models correctly predict the relative magnitude of immediate responses: investment is the most responsive, followed by output, hours, and consumption. But when we compare the dynamic elements of the response to a unit innovation to output, the

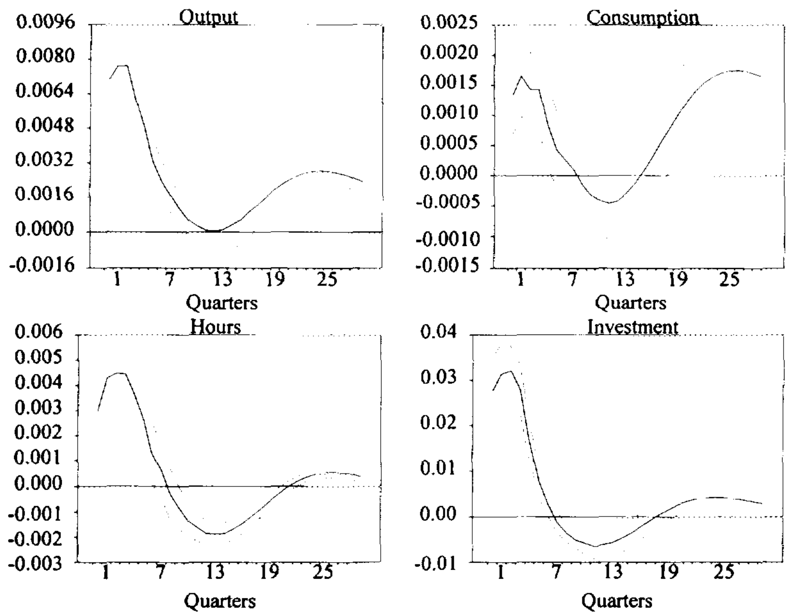

FIG. 4. Responses of output, hours, consumption, and investment to an output shock, 1954.1–1991.3.

differences across the three models are quite striking. Models 1 and 2 predict very similar monotonic return patterns which differ markedly from the cyclical response favored by the data. Model 3, however, is qualitatively similar to the cyclical response of the post-Korean War data.

The cyclical responses arise from the fact that the data favors a model in which there is one or more pairs of complex roots. This shows up as a damped cyclical response to a unit innovation. The saddle-point economies, models 1 and 2, are not capable of generating this pattern since they are described by an *uncoupled* second-order system. The productivity disturbance can feed into the capital accumulation equation, but there is no channel by which the accumulation of capital can feed back into the Solow residuals.

6.5. *Solow Residuals*

In model 1, the Solow residuals represent the observations on the driving disturbance $\{Z_t\}$. This statement does not hold in the monopolistically competitive economy since factor shares in national income are different from their productive elasticities in models 2 and 3. However, as an independent

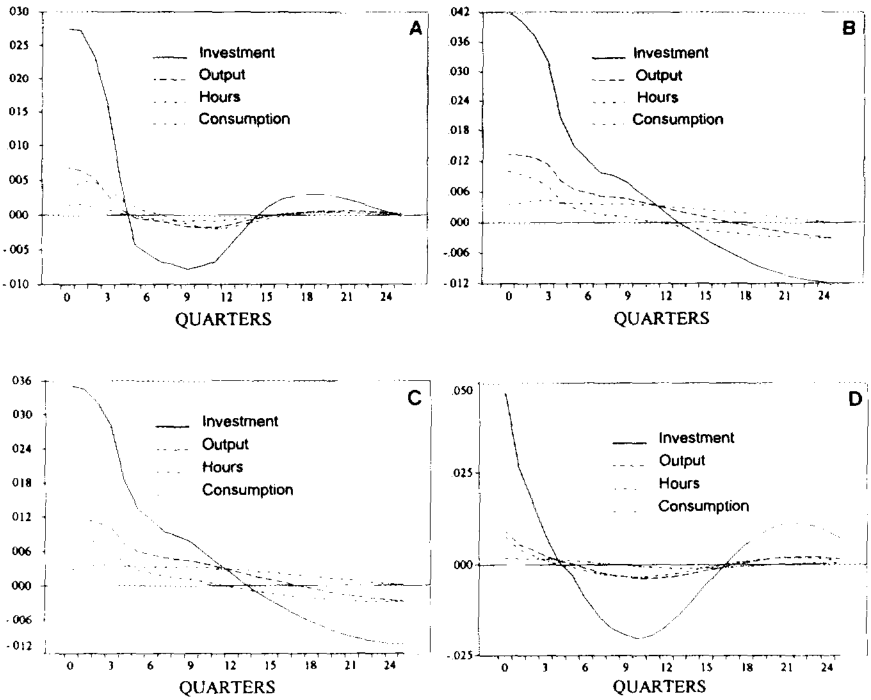

FIG. 5. Impulse response functions: (A) Impulse responses in U.S. data, (B) impulse responses in Hansen's model, (C) impulse responses in the Baxter–King model, and, (D) impulse responses in the Benhabib–Farmer Model.

check of the model performance, we derive the Solow residuals from actual data and the Benhabib–Farmer economy using the identity

$$SR_t \equiv \log(Y_t) - 0.7\log(L_t) - 0.3\log(K_t), \tag{25}$$

where 0.7 and 0.3 are the labor and capital shares, respectively.[20]

Figure 6 depicts the detrended Solow residuals computed from two sets of U.S. data together with the artificial residual series generated by model 3. Note that the model does a fairly good job of matching the volatility and persistence of the actual data. A summary of their standard deviation, AR(1) coefficient, and autocorrelations are presented in Table IX. Although model 3 is driven by i.i.d. sunspots, it nevertheless generates Solow residuals that broadly resemble those in the U.S. time series.

[20] Here we treat the data and model-generated time series in the same way; "as if" there were no monopoly profits.

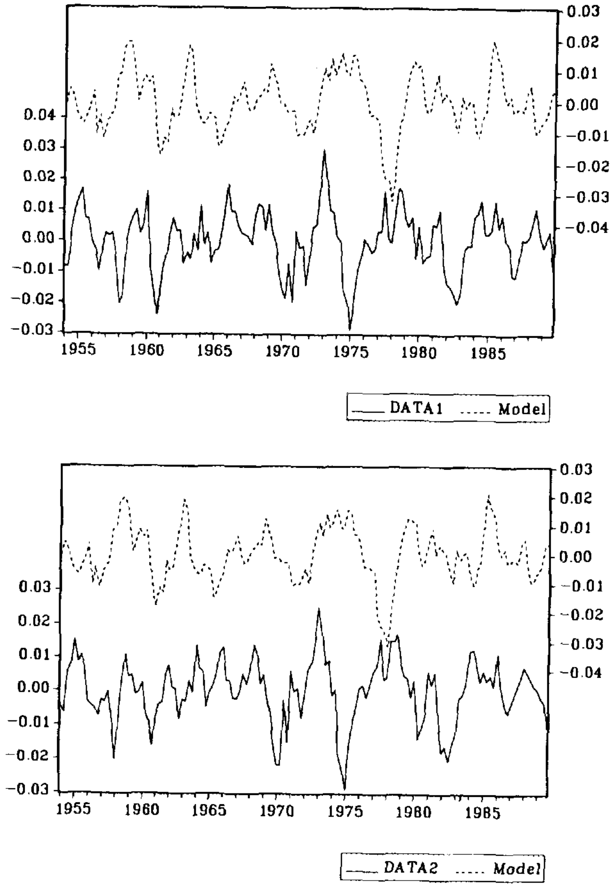

FIG. 6. Solow residuals in the Benhabib–Farmer economy.

TABLE IX

	SD (%)	AR(1) coeff.	AC1	AC2	AC3
Data 1[a]	1.00	0.68	0.68	0.43	0.11
Data 2[a]	0.93	0.72	0.72	0.49	0.19
B–F Economy	0.93	0.80	0.80	0.56	0.32

[a] Quarterly data, 1954.1–1989.4. The US time series used are real GNP and real private fixed capital stock (in 1982 dollars). The labor hours series is drawn from the Household Survey in Data 1, and from the establishment data in Data 2. All data and model-generated time series have been Hodrick–Prescott filtered.

7. Concluding Remarks

This paper is not the first to argue that animal spirits should be taken seriously. But, in our experience, many of our colleagues have been reluctant to accept the idea that the animal spirits hypothesis deserves more than a footnote as a passing curiosity. We believe that this reluctance has been fueled by the refusal of economic theorists to state the hypothesis in terms that are comparable with other more standard explanations of economic fluctuations. For example, much of the work on endogenous fluctuations relies on strong income effects, backward bending offer curves, or other parameterizations of preferences or technologies that are difficult to take seriously as models of the data generation process.

Our innovation in this paper has been to show not only that animal spirits *can* drive business cycles, but that the phenomenon can occur in a model that is close enough to be compared *quantitatively* with the real business cycle paradigm. Although the work that we have presented is in its early stages, we have some confidence that a more formal econometric investigation of increasing returns economies may overcome many of the shortcomings of the standard RBC model at capturing the dynamic features of the U.S. time series data.

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