

REAL BUSINESS CYCLES AND THE ANIMAL SPIRITS HYPOTHESIS

by

Roger E.A. Farmer

and

Jang Ting Guo

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**Address for Correspondence: Department of Economics, UCLA, 405 Hilgard Ave.,
Los Angeles, CA 90024-1477**

ABSTRACT

In this paper, we investigate a quantitative equilibrium macroeconomic model with an aggregate technology that is subject to increasing returns. We show that this model may display fluctuations at business cycle frequencies even when there are no shocks whatsoever to the fundamentals of the economy. These fluctuations are due to the self-fulfilling beliefs of investors which we call 'animal spirits.' We calibrate our model economy using recent evidence on the magnitude of increasing returns from industry studies of the US economy and we find that our calibrated model performs as well or better than the standard RBC model at capturing the contemporaneous properties of the fluctuations in US data. We also compare the impulse response functions predicted by our model, and by two other more standard models, with a four variable vector autoregression on US data. Our animal spirits economy is the most successful of the three at matching broad features of the dynamic responses in the actual data. In addition, the Solow residuals in the animal spirits economy, driven by i.i.d. sunspots, broadly resemble those in the US time series.

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, 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 welfare¹.

Until relatively recently the animal spirits explanation was widely taught in graduate schools as a corner-stone of the Keynesian explanation of recessions. But recently, 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 cycle².

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 time series data, in which there is no fundamental uncertainty

¹Cass and Shell (1983) refer to fluctuations that are unrelated to fundamentals as 'sunspots'. Sunspot fluctuations are not Pareto Optimal (in the standard sense) since they are avoidable and one generally assumes that agents are risk averse. See the Cass and Shell paper 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 (1992). The "self-fulfilling prophecy" is a term that was coined by Robert Merton (1948). It was introduced into economics by Azariadis (1981). In the paper we use the terms animal spirits, sunspots and self-fulfilling prophecies interchangeably.

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 US time series with about the same degree of precision as the standard real business cycle model and that it is more successful at capturing the *dynamics* of US data.

Our work takes off from an observation by Hall who pointed out that the Solow residual, obtained from growth accounting, should be uncorrelated with any variable that is uncorrelated with productivity shifts since, under the assumptions of 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 (1986, 1987, 1988, 1990) has found 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 instruments that could reasonably be expected to be exogenous. He argues 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 fluctuations³.

Following up on Hall's suggestion, several papers have explored the idea that US 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 (1992) have estimated production functions at the two-digit level and found evidence of the presence of external effects and Baxter and King (1991) have studied the implications of an increasing return-to-scale technology for the correlations between variables in a real business cycle environment. The Baxter and King paper uses 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

³ Among others, Domowitz, Hubbard and Petersen (1988) showed that there is a significant difference between price and marginal cost in US manufacturing industries, which supports the presence of market 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 (1982), Weitzman (1982), Mankiw (1985), Akerlof and Yellen (1985), Blanchard and Kiyotaki (1987), Kiyotaki (1988), and Rotemberg and Woodford (1989).

recently Benhabib and Farmer (1992) 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 (1992) 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 (1985) 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 first moments of US time series data, there is some flexibility in calibration that arises from the way that we match theoretical constructs with accounting 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 US 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).

We are primarily interested in the comparison of models 1 and 3 since our objective is to

⁴Peter Klenow (1991) has studied the effect of introducing increasing returns in a framework that is similar to the work of Benhabib and Farmer. Klenow, however, stresses models in which there may be multiple determinate stationary states. The Benhabib-Farmer focus is on a single steady state that is indeterminate.

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

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. 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 find that our sunspot model explains contemporaneous covariances and relative standard deviations as well or better than the standard RBC model but that it performs somewhat better when we compare dynamic responses in all three economies with impulse responses from the postwar US.

2. The RBC and Increasing Returns Models Compared

2.1 The Equations of the Benhabib-Farmer Model

Benhabib and Farmer describe 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 following equations:

$$(1) \quad Y_t = Z_t K_t^\alpha L_t^\beta,$$

$$(2) \quad A \frac{C_t}{L_t^\gamma} = b \frac{Y_t}{L_t},$$

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

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

$$(5) \quad Z_t = Z_t^\theta ; \eta_t, Z_t \text{ is given,}$$

where C_t represents consumption, L_t is labor supply, Y_t is output and K_t is capital. Equation (1) is a Cobb-Douglas technology with a productivity disturbance Z_t , equation (4) is the capital accumulation equation and equation (5) allows for the productivity disturbance, Z , to be

autocorrelated. In two of the models that we look at we will 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:

$$(6) \quad \max \sum_{t=0}^{\infty} \rho^t E_0 \left[\log C_t - A \frac{L_t^{1-\gamma}}{1-\gamma} \right], \quad 0 < \rho < 1,$$

such that:

$$(7) \quad K_{t+1} + C_t \leq w_t L_t + (1 - \delta + r_t) K_t + \Pi_t, \quad K_0 \text{ is given,}$$

with the first order conditions of a set of representative firms. Equations (6) and (7) use the notation Π_t to represent 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 and A and γ are parameters.

2.2 Externalities and Monopolistic Competition Compared

The key to the Benhabib Farmer paper is the assumption that:

$$(8) \quad \alpha + \beta > 1.$$

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

$$(9) \quad \alpha = a, \quad \text{and,} \quad \beta = b.$$

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

Benhabib and Farmer use 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:

$$(10) \quad a + b = 1,$$

but,

$$(11) \quad \alpha + \beta > 1.$$

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 technology:

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

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. The key difference of the monopolistically competitive model is that it allows for the presence of positive profits. This means that factor shares may sum to *less than one*. In the monopolistically competitive model

$$(13) \quad a + b < 1,$$

and,

$$(14) \quad \alpha + \beta > 1.$$

In our calibration of the model, discussed below, we favor a specification in which $a+b < 1$

3. Dynamics around the Steady State

3.1. Steady State

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

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

where, $g = \alpha(1-d)$, $d = \beta\phi$, $\phi = \frac{1}{\beta+\gamma-1}$, $B = \left(\frac{A}{b}\right)^d$, $D = B\alpha\rho$, and, $\tau = \rho(1-\delta)$.

Employment is determined by the static equation,

$$(16) \quad L_t = \left[A \frac{C_t}{bK_t^\alpha} \right]^\phi,$$

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

In our 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 equation (15) around the stationary state of the non-stochastic economy. This stationary state is defined by the equations:

$$(17) \quad K^* = \left[\frac{\omega}{\nu} \right]^{\frac{1}{\chi-1}}, \quad C^* = \nu(K^*)^\chi,$$

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

3.2 A Linear Approximation

The dynamics of our stochastic economies are described by the non-linear functional equations (15) 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 will 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 , C and Z will never wander far from the neighborhood of the fixed point $\{K^*, C^*, 1\}$ in which the linear approximation is valid. Using the definitions:

$$\hat{K}_t \equiv \frac{K_t - K^*}{K^*} \equiv \log\left(\frac{K_t}{K^*}\right), \quad \hat{C}_t \equiv \frac{C_t - C^*}{C^*} \equiv \log\left(\frac{C_t}{C^*}\right), \quad \hat{Z}_t \equiv \left(\frac{Z_t - 1}{1}\right) \equiv \log(Z_t),$$

and letting the vector:

$$(18) \quad e_{t+1} \equiv \begin{bmatrix} E_t[\hat{K}_{t+1}] - \hat{K}_{t+1} \\ E_t[\hat{C}_{t+1}] - \hat{C}_{t+1} \\ E_t[\hat{Z}_{t+1}] - \hat{Z}_{t+1} \end{bmatrix},$$

represent one-step-ahead forecast errors one can write a linear approximation to equation (15) in the form:

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

where J is the 3×3 Jacobian matrix of partial derivatives of the transformed dynamical system and R is a conformable matrix of co-efficients. Additional linear equations specify how investment, labor hours, output, and productivity are related to the current state vector,

$$s_t \equiv \{\hat{K}_t, \hat{C}_t, \hat{Z}_t\}':$$

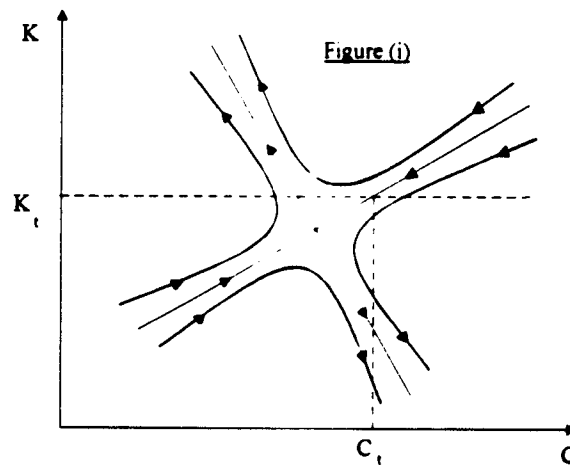
$$(20) \quad X_t \equiv \begin{bmatrix} \hat{I}_t \\ \hat{L}_t \\ \hat{Y}_t \\ \hat{P}_t \end{bmatrix} = M \begin{bmatrix} \hat{K}_t \\ \hat{C}_t \\ \hat{Z}_t \end{bmatrix} \equiv M s_t,$$

where productivity P is defined as Y/L , and M is a (4×3) matrix of co-efficients 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 are going to examine the dynamics of rational expectations equilibria of the linearized model summarized by equations (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. 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.⁶ This situation

⁶ When equation (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:

$$s^*_t = \Lambda s^*_{t+1} + \Pi \begin{bmatrix} \dot{\eta}_{t+1} \\ e_{t+1} \end{bmatrix}$$

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^{*1}_t 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 initial condition:

is depicted in Figure (i).

Benhabib and Farmer (1992) showed 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 labor demand curve will lower wages and employment. The idea is illustrated in

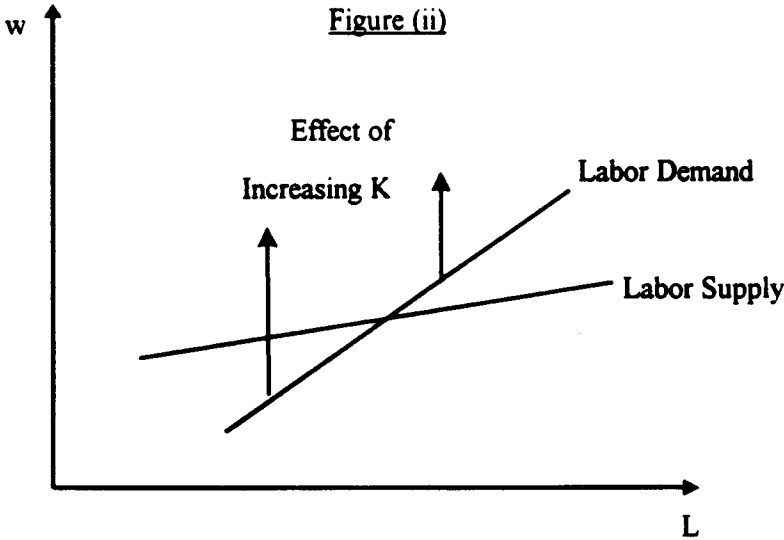


Figure (ii). The implication of an upward sloping labor demand curve is that the steady state of the non-stochastic model may look like either of the two panels of Figure (iii). The left hand panel depicts a situation in which the roots of J are complex and the right hand panel depicts the case in which they are both real. The standard model generates a first order equation in a single state variable 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 suggests that US GNP requires at least a second order representation it is usual, in

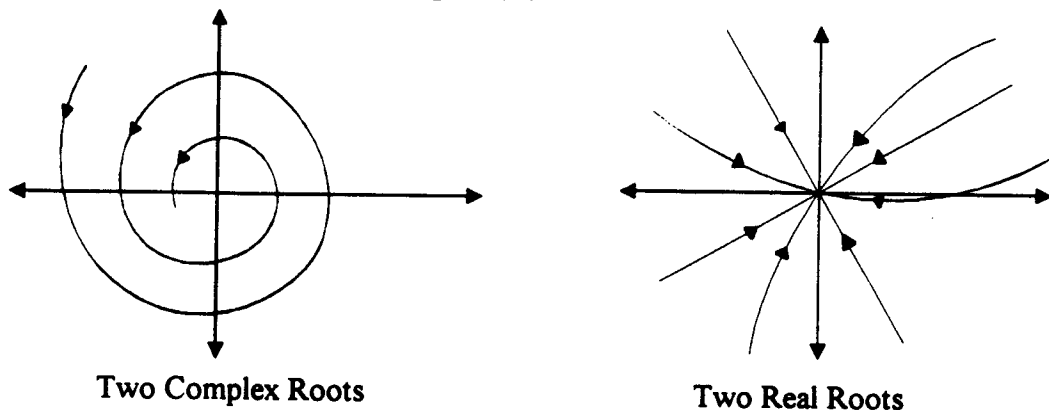
$$s_t^{*1} = 0,$$

which translates into a linear restriction on the vector of state variables $\{K, C, Z\}$. This restriction determines C as a linear function of K_t and Z_t .

the RBC literature, to assume that the disturbance term is autocorrelated. The RBC model has a representation in the form:

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

Figure (iii)



The Benhabib-Farmer (BF) paper (1992) 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 Figure (iii). In the increasing returns economy the data can be described as a third order system of the form:

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

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:

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

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 are 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 are going to investigate the dynamic properties of macroeconomic time series generated by three versions of our model economy. The first of these versions is Rogerson (1988) and Hansen's (1985) *indivisible labor economy* in which the representative agent's utility function (6) is linear in labor hours, but logarithmic in the unique consumption commodity.⁷ 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 for the U.S.

⁷Any 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, Shleifer, and Vishny's (1989) discussion of this issue. Rogerson's (1988) assumption of indivisible labor has been shown by Hansen (1985) to provide a highly effective way of matching the observed variance of hours in US data. The Rogerson-Hansen hypothesis implies that hours are chosen 'as if' a representative agent has a utility function that is linear in leisure.

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 (1991). 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 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 from 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 Richard Rogerson (1988) that was used in a real business cycle study by Gary Hansen (1985). The Rogerson-Hansen assumption implies that the labor supply curve is infinitely elastic with respect to the real wage. We also use a common quarterly discount factor $\rho = 0.99$, across all three models, and a quarterly depreciation rate δ , of 0.025. These figures are standard in the RBC literature.

For model 1 we have chosen the remaining parameters to match Hansen's (1985) paper. Specifically we set the preference parameter $A = 2.8607^8$, and capital's share of national income,

⁸'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

$a=0.36$. In model 1, a is equal to the productive share of capital, α . 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 0.007⁹.

In the competitive model, model 1, the parameters of factor shares in national income, a and b , are equal to their respective shares in production, α and β . In the monopolistically competitive models, however, the parameters may differ since:

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

where λ measures the degree of monopoly power in the markets for intermediate products¹⁰. To get a fix on the value of λ we have made use of the fact that the *Lerner index*, is given by the identity:

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

In a recent study of US manufacturing industries, Domowitz, Hubbard and Peterson (1988) (DHP) have refined an earlier study by Hall (1986) 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 (1986) study implies price-cost margins ranging between .048 and .705, using the DHP definition.¹¹ 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

assumption of a total time endowment 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.

⁹ See Hansen (1985) for details.

¹⁰ See Benhabib and Farmer (1992) for details.

¹¹ Domowitz Hubbard and Peterson (1988) use a methodology that avoids some measurement problems that arise in Hall's (1986) paper. The authors argue that their methodology allows them to attain more precise estimates of markups.

close our model we must also assign values to the share parameters, a and b , and to the marginal products, α and β . To fix the share parameter, b , in our monopolistically competitive models we note that Christiano (1988) finds values of b between 0.57 and 0.75, depending on the treatment of proprietor's income and of the discrepancy in the data between national income and net national product.¹² 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 (1).

Table (1)

	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

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, who ascribe 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. 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 K to get an accurate estimate of α . Point estimates hover around zero with large standard errors¹³.

¹²Earlier studies conform to this proposition. The parameter of labor's share in production is set to 0.64 in Kydland-Prescott (1982), and Hansen (1985), 0.75 in Prescott (1986), 0.66 in Christiano (1988), and 0.58 in Baxter and King (1991).

¹³If 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 to the effects of externalities. In our framework this ratio is interpreted as an estimate of the mark-up parameter since

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 in the economy equal to 7% of national income.¹⁴ 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, sets labor's share to 0.7, leaving 30% of national income as the return to all other factors. In this version we assume 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 assumptions are summarized in Table (2).

Table (2)

	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	0.4

5.4 Assumptions About the Driving Process in Each Economy

The properties of the dynamic equations that describe our model economy depend on how many roots of the matrix J 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 $1/\theta$. Since we will maintain the hypothesis that the productivity disturbance is stationary, this root will be greater than one in absolute value. 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

$$\frac{\alpha + \beta}{a + b} = \frac{1}{\lambda}$$

¹⁴The 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

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.¹⁵ This is reflected in the fact that the parameter, β , in economy 3 is greater than 1. In Table (3) we report the values of the roots of J that are implied each of our three parametric specifications:

Table (3)

	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)	$1.07+.11i$	$1.07-0.11i$	N/A

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

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

with an autocorrelation parameter, $\theta=0.95$. We have chosen the standard deviation of $\hat{\eta}$ in each economy in a way that causes the standard deviation of output to match the volatility of GNP in time series data. The fact that economy 2 is subject to increasing returns means that we can match the volatility of output in US data using an innovation to the technology that is approximately half as variable as the Hansen RBC economy. Since rational expectations equilibrium is unique in each 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 substitute for the technology shock as the driving force behind the business cycle. With this end in mind, we have set the standard deviation of η_t equal to zero in model 3, that is, we assume that $Z_t = 1$. Unlike models 1 and 2,

¹⁵Since 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.

consumption in model 3 is not constrained to move one for one with capital and with the technology shock. We drive business cycles in model 3 with an i.i.d. 'sunspot' and we set the standard deviation of our sunspot disturbance in a way that causes the volatility of output to match the US data. The assumptions about the driving uncertainty in all three economies are summarized below in Table (4).

Table (4)

	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

6. Simulating the Model

6.1 Pictures of the Data

In this section of the paper we present a set of simulated time series from each of model economies and we compare this simulated data with time series from the post Korean war period in the US. For each simulation we have generated a sequence of technology and sunspot shocks using a random number generator in GAUSS. Shock variances were set to match the standard deviation of the simulated output series with the detrended US 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. In Figures (1), (2) and (3) we 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 actual U.S. time series.

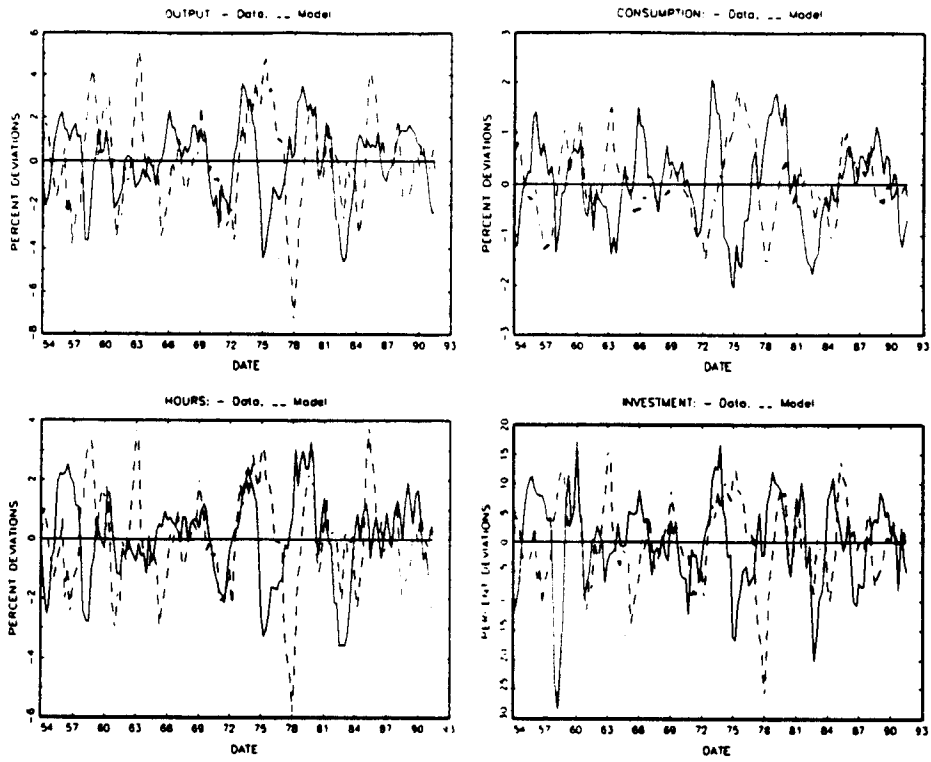


Figure (1): The Hansen RBC Economy

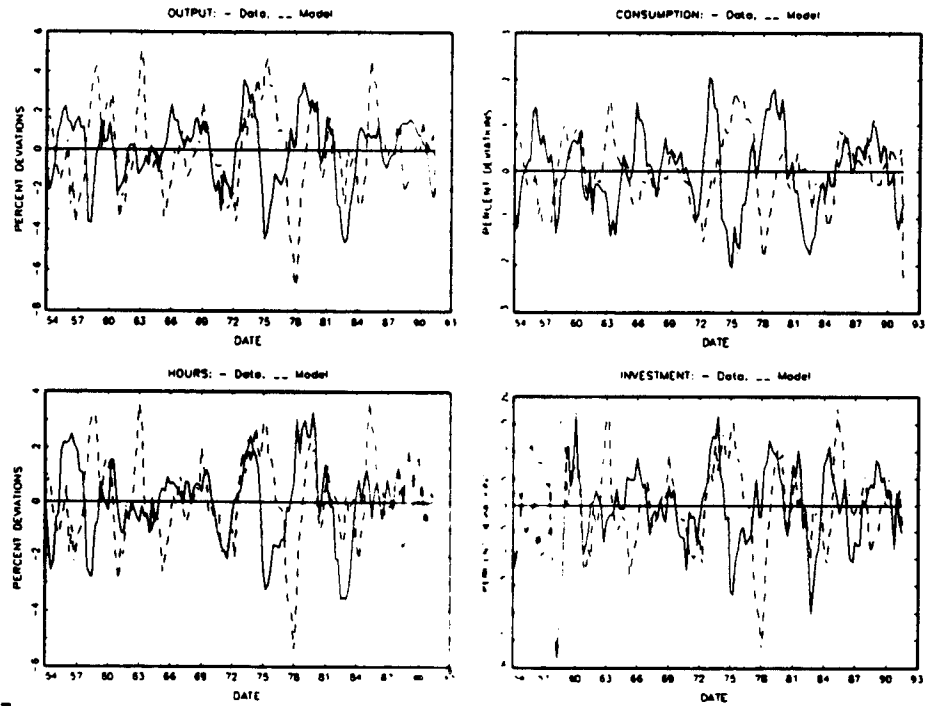


Figure (2): The Baxter-King Increasing Returns Economy

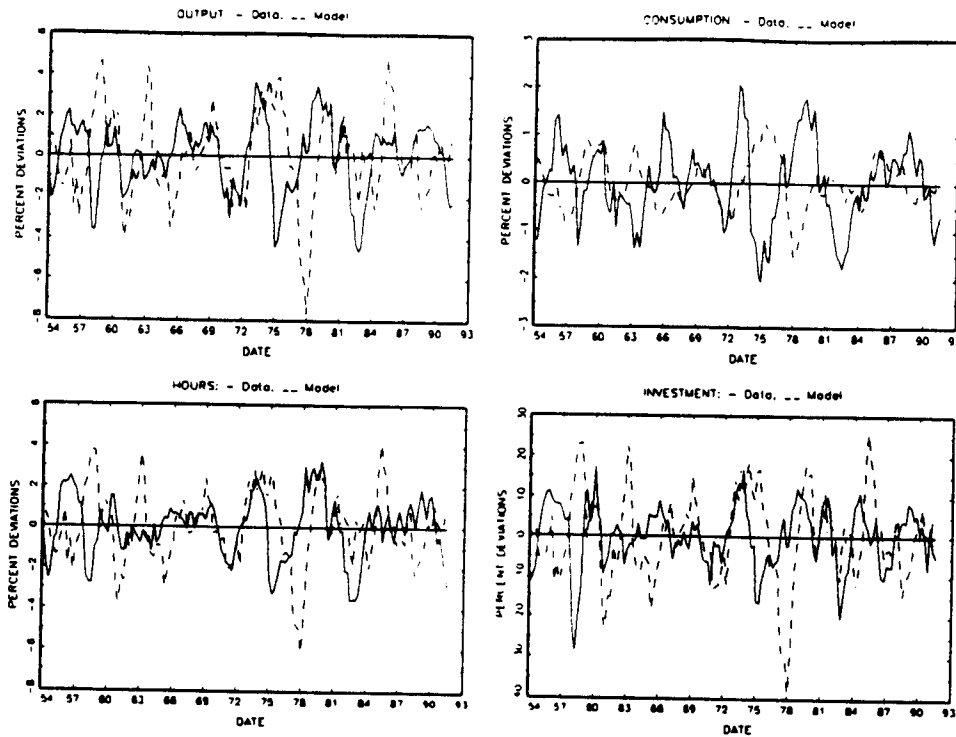


Figure (3): The Benhabib-Farmer Increasing Returns Economy

The data in Figures (1) - (3) has been seasonally adjusted and logged and all series have been passed through the Hodrick-Prescott filter.¹⁶

6.2 Contemporaneous Moments

Notice from the figures that all three models do a reasonably good job of matching the relative variances of the US 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 (5).

¹⁶We 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 cycle: $d_t = x_t - \tau_t$ by finding the trend that solves

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

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.

Table (5)

Variables	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 the column 2, 3, and 4 are sample means computed for 100 simulations. Each simulation consists of 151 periods, the same number of as the U.S. sample.

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

d. Shock variance 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.

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

Table (6) presents contemporaneous correlation co-efficients:

Table (6)

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. Quarterly data, 1954.1-1991.3.

b. For total consumption expenditure, the number is 0.83.

c. For fixed investment, the number is 0.91.

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.

We conclude from this rather imprecise comparison, that the sunspot model performs no worse than the RBC model at matching contemporaneous standard deviations. 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 US 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, (model 3) will generate highly persistent movements in output even when driven by i.i.d. disturbances. In the sunspot model, persistence is endogenous. In Table (7) we document a measure of persistence for each of the three models by estimating a first order AR(1) model from data generated by each model economy and comparing the AR co-efficient with US data.

Table (7)^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 (8) 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 i.i.d. sunspot model to mimic the highly persistent features of the detrended data without building this persistence into the driving process.

Table (8) a

Variable	Data			Model 1			Model 2			Model 3		
	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	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.

6.4 Impulse Response Functions

To check another dimension on the dynamic properties of the three model economies we have estimated a four variable, five lag, autoregression on simulated data and compared the resulting impulse response functions with the US data. The first panel of 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.

Roughly speaking¹⁷ these pictures measure the dynamic response of the US data to a unit disturbance in one of the variables, output. At date $t = 1$ when the shock takes place, investment is more responsive to the output innovation than other variables. Subsequently, all four variables display a similar cyclical pattern and converge to the stationary state at about the same rate. The

¹⁷A complication arise from the fact that the innovations in the data are contemporaneously correlated. A unit shock to output will, therefore, typically be associated with a disturbance to each of the other variables.

other three panels in Figure (4) plot the impulse response functions from the three model economies. Notice 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 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.

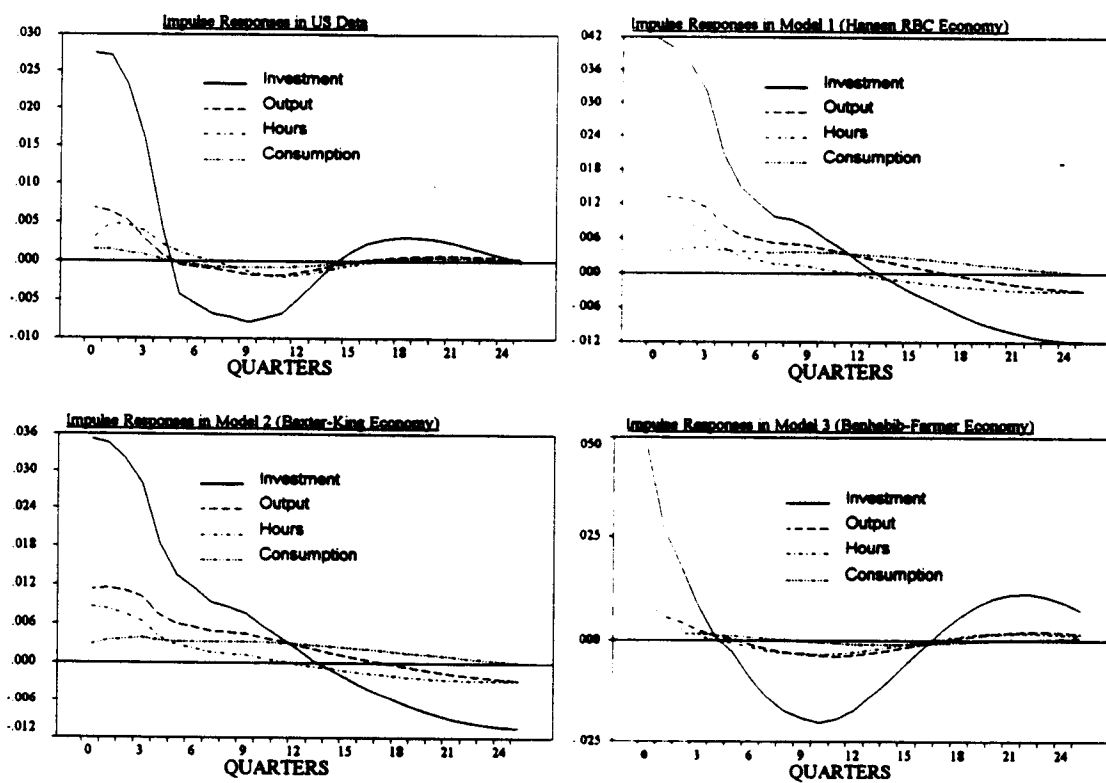


Figure (4): Impulse Response Functions

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 residual.

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 are different in production and national income in models 2 and 3. However, as an independent check of the model performance, we derived the Solow residuals from actual data and the Benhabib-Farmer economy using the following identity:

$$(25) \quad SR_t \equiv \log(Y_t) - 0.7\log(L_t) - 0.3\log(K_t),$$

where 0.7 and 0.3 are the labor and capital shares respectively¹⁸.

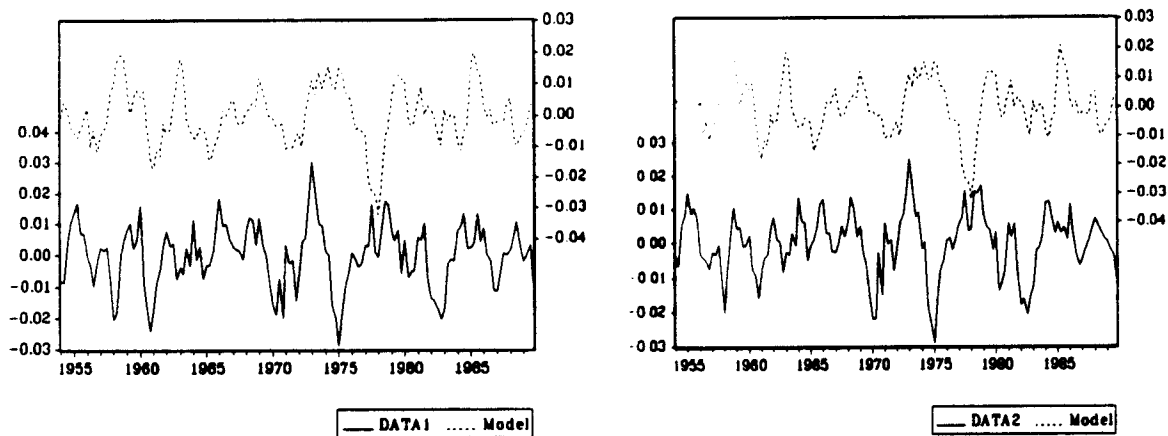


Figure (5): Solow Residuals in Benhabib-Farmer Economy

In Figure (5), we have graphed the detrended Solow residuals computed from two sets of US data together with the artificial residual series generated by the model 3. Notice 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 (9) Although the model 3 is driven by i.i.d. sunspots, it nevertheless generates Solow residuals that broadly resemble those in the US time series

¹⁸Here we treated the data and model-generated time series in the same way; 'as if there were no monopoly profits

Table (9)

	S.D.(%)	AR(1) coeff.	AC 1	AC 2	AC 3
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 U.S. 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 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 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 time series data.

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