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Real Business Cycle Theory: a Guide, an Evaluation, and New Directions

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Introduction

The purpose of real business cycle (RBC) models is to explain aggregate fluctuations in business cycles without reference to monetary policy. Much of the existing RBC analysis also seeks to explain fluctuations without reference to market failures, fiscal policies, or even disturbances to preferences or demographics.

The concentration on technology shocks that characterizes most, though not all, of the current models is not in principle a defining feature of RBC analysis. This concentration indicates both the early state of research and the substantial progress that has been made by considering technology shocks.

This paper summarizes and evaluates in a mostly nontechnical way the state of RBC theory, outlines some useful directions for research in the area, and discusses the implications of this research on economic policy. For space reasons, I will regard sectoral-shift models (Lilien [1982], Abraham and Katz [1986], Loungani [1986], Davis [1987], Hamilton [1987a], and Murphy and Topel [1987]) as a separate topic that deserves its own treatment, though those models clearly form one class of RBC theory.[1]

Real business cycle analysis is important and interesting for several reasons. First, the evidence that monetary policy affects real output is much weaker than most economists had thought. Second, even if monetary policy affects real output, the evidence that it is the dominant influence on business cycles is also much weaker than previously thought. A detailed discussion of the evidence on these topics is beyond the scope of this essay; see, for example, Barro (1987), Eichenbaum and Singleton (1986), Christiano and Ljungqvist (1988), and the references cited in those works.

Third, even if monetary disturbances play a major role in many real-world business cycles, most economists believe that supply shocks and other nonmonetary disturbances, originating from sources such as oil price changes and technical progress, also play important roles in some aggregate fluctuations.

RBC analysis is designed to determine how such "real" shocks affect output, employment, hours, consumption, investment, productivity, and so on. RBC models are also designed to

■ 1 Earlier nontechnical introductoiy essays on RBC models include Walsh (1986) and Rush (1987). Manuelli (1986) summarizes Prescott's arguments, Summers' criticisms, and Prescott's reply. More recent summary papers include McCallum (1989) and Mankiw (1988).

TABLE 1

U.S. Business Cycle Statistics, 1954:IQ-1982:IVQ

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	1.8%	.82	1.00	.82
Consumption				
On services	.6	.66	.72	.61
Nondurables	1.2	.71	.76	.59
Fixed investment	5.3	.78	.89	.78
Nonresidential	5.2	.54	.79	.86
Structures	4.6	.42	.62	.70
Equipment	6.0	.56	.82	.87
Average nonfarm hours worked	1.7	.57	.85	.89
In mfg. only	1.0	.76	.85	.61
GNP/hours	1.0	.51	.34	-.04
Capital stocks:				
Nonfarm inventory	1.7	.15	.48	.68
Nonresidential structures	.4	-.20	-.03	.16
Nonresidential equipment	1.0	.03	.23	.41

NOTE: Corr. = correlation. All data were first detrended with the Hodrick Prescott filter.
SOURCE: Prescott (1986a).

determine how disturbances at a specific time or in one sector of the economy affect the economy later and in other sectors, and to study the dynamics of the transitions.

Fourth, RBC models can be used to determine how any disturbance, even if monetary in origin, spreads through different sectors of the economy over time. While monetary policy, or monetary disturbances, may frequently set business cycles in motion, it is possible that the subsequent dynamics and characteristics of the cycles differ little from those that would have resulted from disturbances to tastes or technology. That could explain the evidence on seasonal cycles without precluding money as a major force in business cycles. Whether or not the more extreme claim that monetary policy is unimportant for business cycles turns out to be correct, RBC analysis is making important contributions for the third and fourth reasons cited above.

I. A Prototype Real Business Cycle Model

What Real Business Cycle Models Try to Explain

The characteristics of business cycles that the RBC models have been designed to explain include the sizes of the variances and covariances in table 1. Among these characteristics are the following:

1. Consumption varies less than output, which varies less than investment; the standard deviation of investment is three to five times that of output. Consumer purchases of durables vary about as much as investment, while purchases of nondurables and services vary less but remain procyclical (defined to mean positively correlated with output).
2. Hours worked are procyclical and vary about as much as output.
3. The average product of labor is procyclical and varies about half as much (in standard deviations) as output; the correlation between productivity and output is smaller than the correlation between hours and output.

Some RBC models attempt to explain other characteristics. For example, Long and Plosser (1983) have a multisector model that attempts to explain why output moves together across most sectors of the economy (including various manufacturing industries, retail and wholesale trade, services, transport, and utilities, with agriculture the main exception) as well as why temporary disturbances have longer-lived effects.

Christiano (1988) adds inventories to an RBC model to try to account for the fact that quarterly changes in inventories are about half the size of changes in GNP, even though inventories are on average only a small fraction, about 0.6 percent, of GNP. Kydland and Prescott (1988) also attempt to explain inventory behavior, particularly inventories of goods in process, through their time-to-build technology.

Real business cycle models have not yet been developed to address still other features of business cycles:

1. Nominal money and real output are highly correlated; most of this correlation is with inside, rather than outside, money (compare with Barro [19871).
2. Prices vary less than quantities.
3. Nominal prices are acyclical.
4. Real wages are acyclical or mildly procyclical.
5. Real exports, imports, and net exports (the balance of trade surplus) are all procyclical.

Backus and Kehoe (1988) and Phillips (1988) have documented the last feature; they have shown that many of the same qualitative features found in U.S. business cycles also characterize business cycles in other countries. I will argue below that *quantitative* differences across countries in business-cycle phenomena and the cyclical behavior of international trade variables can form important new sources of evidence on RBC models. The fourth feature, the acyclical or mildly procyclical behavior of real wages, has been addressed recently by Christiano and Eichenbaum (1988), who conclude that existing models do not adequately explain this fact.

A Description of a Prototype RBC Model

Real business cycle models typically begin with assumptions such as (1) there is a representative household that maximizes the expected discounted value, over an infinite horizon, of a utility function defined over consumption and leisure, or (2) there is a constant-returns technology that transforms labor and capital into output, which may be consumed or invested to augment the capital stock in the next period.

In most RBC models, the production function is subject to random disturbances. Firms are perfectly competitive, and there are no taxes, public goods, externalities, or arbitrary restrictions on the existence of markets. The maximization problems for households and firms imply decisions for consumption, investment, the division of time between labor and leisure, and, thus, output (along with the capital stock, which is predetermined from last period). These decisions are functions of the *state variables:* the capital stock and the exogenous disturbance(s) to the production function.

Given some particular production and utility functions, an initial capital stock, and a stochastic process for the random disturbances, the model can be solved for the decision rules and, therefore, for the probability rules for all of the endogenous variables.[2] These probability rules then yield variances, covariances, and other statistical moments that can be matched against real-world data. A more technical description of a simple RBC model, in a multicountry context, is presented in section VI.

2 The key technical papers on which the RBC models are based are Brock (1982) and Donaldson and Mehra (1983).

In principle, with enough freedom to choose arbitrary production and utility parameters and parameters of the stochastic process on the exogenous disturbances, one can always find variants of the model that match any given set of variances and covariances from real-world data. Lawrence Summers has criticized RBC models on this issue, claiming that it is easy to find incorrect models that match any given set of observations.

Obviously, to avoid this kind of criticism, RBC models must use some additional information to limit the arbitrary choices of utility and production parameters and exogenous stochastic processes. In the limit, it would be desirable to eliminate *all* arbitrary choices of parameters by relying solely on other information to parameterize the model, and then by showing that the model necessarily reproduces the kinds and characteristics of aggregate fluctuations that are observed in real-world data. Then there would be little controversy over Prescott's (1986a) assessment that "... it would be puzzling if the economy did not display these large fluctuations in output and employment with little associated fluctuations in the marginal product of labor."

Early RBC models, such as Long and Plosser (1983), made some of their assumptions in order to obtain analytically tractable models, so that the models would actually have closed-form solutions. The assumptions required to obtain analytic solutions to the models, however, are very stringent and, obviously, totally ad hoc. Consequently, RBC theorists have largely abandoned attempts to make their models analytically tractable and have instead turned to numerical solutions. Quantitatively accurate models are ultimately more appealing than analytically tractable models, anyway. The parameter restrictions from outside information used in RBC models are discussed in section II.

Some Variations on the Prototype Model

Kydland and Prescott (1982, 1988) include a number of additional features in their model, including time to build (so that investment cannot be installed instantly but only after a lag), variable utilization of capital, lagged effects (as well as contemporaneous effects) of leisure on utility, and imperfect information about productivity.

Hansen (1985) adds lotteries on employment (Rogerson [1984, 1988]) to the Kydland-Prescott model. People are assumed to be able to work either full time or not at all, rather than part time. If productivity conditions dictate that everyone would work part time if labor were divisible, a

Pareto-optimal allocation may involve ***some*** people working full time and others not working, ***even though people are identical ex ante.*** The choice of who works and who does not is assumed to be determined totally randomly, by an exogenous lottery.

Economies with this random allocation give everyone higher expected utility than economies without it. Hansen's application of Rogerson's theory to the Kydland-Prescott model results in a better match between the model and the data for the variability of hours worked (relative to the variance of GNP), but results in a poorer match for the average product of labor. Hansen's model also requires smaller exogenous productivity disturbances to generate the same variability of GNP.

Greenwood, Hercowitz, and Huffman (1988) investigate a model with shocks to the expected return to current investment that do not affect current output. These shocks raise investment in their model (the substitution effect dominates the wealth effect) and induce intertemporal substitution in labor supply, so that more labor is currently supplied in order to take advantage of the good investment opportunities. In addition, the utilization rate of existing capital rises to increase output and take advantage of these opportunities. The higher utilization rate of existing capital raises the marginal (and average) product of labor. This raises the opportunity cost of current leisure to households and induces them to substitute into greater current consumption. Consumption also increases because of the wealth effect associated with the technology disturbance.

In the Greenwood, et al. model, these two forces tending to raise consumption dominate the intertemporal substitution effect, which tends to reduce consumption so that households can use the goods they otherwise would have consumed in order to augment investment, which the technology shock made more productive. So consumption rises along with labor supply, output, investment, the capacity utilization rate, and the marginal and average products of labor.

It should be noted that in this model, fluctuations in current output do not result directly from assumed changes in current technology, since that technology affects only ***future*** output by augmenting the increase in future capital obtained from one unit of current investment. The entire increase in ***current*** output in the model results from economic forces responding to this productivity shock.

Kydland and Prescott (1988) also added variable utilization of capital to their earlier 1982 model by introducing an endogenous workweek of capital. In contrast to Greenwood, et al., where greater utilization raised depreciation, Kydland and Prescott assume that the cost of greater utilization (that is, a longer workweek) of capital is greater utilization (a longer workweek) of labor. They find that their model, with a variable workweek and with technology shocks measured as in Prescott (1986a), predicts essentially all of the observed variance in U.S. aggregate GNP, substantial variability for inventories (with results somewhat sensitive to the definition of inventories), and greater variation in hours worked than in their original model (but still below measured variation).

Benzivinga (1987) and Christiano (1988) examine models in which shocks to preferences play an important role. Parkin (1988), in contrast, finds little role for preference shocks in his model.

Parkin uses data on labor's share of GNP at each moment in time to obtain a time series on the corresponding parameter in the Cobb-Douglas production function. He assumes, following Solow — and in contrast to Prescott — that this function varies over time. He then uses this time-varying parameter and the production function to measure the multiplicative technology shock at each point in time (one can think of the time-varying parameter representing labor's share as a second productivity shock).

Given measured wages, labor time, consumption, and the rental price of capital (taken as the average payment to capital), Parkin then computes a time series for the utility parameters in his model and the depreciation rate. He describes this procedure as "solving the model backwards," by which he means that he calculates, given the model, what the parameters must (approximately) have been to generate observations on the time series of output, consumption, and so on. Unlike most other business-cycle models, Parkin allows some parameters to vary over time in order to fit the data (almost) exactly.

Parkin then displays these implied time series and argues that they support RBC models in the following senses: (1) none of the parameters except the productivity term varies much over time, and (2) the values of the parameters are not wildly out of line with what would have been expected, based on other information.

Parkin's assumed utility function takes the form of the expected discounted value of $(c_t^{(1-s)} l_t^{s})^f$, where c is consumption, l is leisure, and with the parameter s (the share of leisure) and the discount rate time-varying. Parkin estimates the mean of s at .828, and the percentage change in s has a mean of only .026 with a variance of .007. This parameter is therefore stable over time, implying that shocks to preferences, at least of this form, are unimportant to RBC models, and that people allocate about one-sixth of their total time to working. This estimate is smaller than the one-third value used in some other studies, but is consistent with the value cited by Eichenbaum, Hansen, and Singleton (1986) and is the value preferred by Summers (1986) in his critique of Prescott.

Parkin's estimated discount parameter varies somewhat more over time, and is somewhat higher than expected: its mean is consistent with an average real interest rate of 12 percent per year, which is too high. labor's share is estimated to be 58 percent, as compared to the 64 percent figure used by Prescott based on historical data with the services of consumer durables included as part of output.

Finally, Parkin, after accounting for measurement error in labor and capital, examines the connection between changes in the money supply and variations over time in the parameters of the model, including productivity shocks. He finds little connection, either contemporaneously or at leads or lags, between money and the parameters of the model.

Christiano and Eichenbaum (1988) add government consumption shocks to an RBC model to induce shifts in labor supply. These shifts, along with shifts in the marginal product of labor due to technology shocks, might induce acyclical or mildly procyclical real wage changes, as in the data. The authors argue that government consumption is insufficiently variable to reduce (by very much) the highly procyclical movements resulting from productivity shocks. Further work with preference shocks or technology shocks, as in Greenwood, et al., may be promising in this regard.

II. Restrictions on Parameters and Functional Forms

Several sources of restrictions have been used to determine the appropriate functional forms and parameter values, aside from the behavior of the macroeconomic variables that the models seek to describe:

1. The fraction of total time spent working (and, consequently, the time spent at leisure, which enters the utility function) enters most of the models as a parameter. Some studies, such as Prescott (1986a), have used the figure of one-third, while others, such as King, Plosser, and Rebelo (1988a), have used one-fifth based on historical measurement of average weekly hours worked in the U.S. in the postwar period. Summers (1986) and Eichenbaum, et al. (1986) suggest one-sixth, which is close to the value found by Parkin (1988).

2. The psychological discount rate enters all of the models as a parameter (or a variable, as in Parkin's model). King, et al. choose this parameter at .988 per quarter to obtain an average real interest rate of 6.5 percent per year. Kydland and Prescott, Hansen, Greenwood et al., and others choose discount factors of .96 percent per year rather arbitrarily.

3. The rate of capital depreciation enters the models as a parameter. Kydland and Prescott assume a depreciation rate of 10 percent per year, on the grounds that the steady-state capital stock would then be about 2.6 times annual output if the real interest rate is 4 percent per year, and this 2.6 figure is close to the historical average in the United States. Most other models also assume 10 percent. Christiano (1988) assumes that capital depreciates at 1.83 percent per quarter, in order to try to match average U.S. data for the change in the public and private capital stock, including consumer durables, as a fraction of output. Greenwood, et al. have a variable depreciation rate depending on the utilization rate of capital. They assume that the elasticity of the depreciation rate with respect to the utilization rate is 1.42, chosen to yield a deterministic steady-state rate of depreciation in their model equal to .10 per year.

4. The marginal rate of substitution over time in consumption, which corresponds to the degree of relative risk aversion (say, r) for intertemporally separable utility functions, enters the models as a parameter. Log utility is frequently assumed, as in Kydland and Prescott (1982), implying that $r = 1$. Greenwood, et al. report results for $r = 1$ and $r = 2$, based on estimates by Hansen and Singleton (1983) and Friend and Blume (1975); Kydland and Prescott (1988) assume $r = 1.5$.

5. The marginal rate of substitution over time in leisure is an important parameter of most of the models. King, et al. (1988a) assume alternately that (a) utility is logarithmic and separable between consumption and leisure, as well as over time, giving a value of unity for the elasticity of the marginal utility of leisure with respect to leisure, or (b) the elasticity of the marginal utility of leisure is -10, based on panel data studies reviewed by Pencavel (1986), or (c) the elasticity is zero, which yields a linear utility function in leisure and so an infinite intertemporal substitutability of leisure, based on theoretical considerations of an economy with indivisible labor and lotteries, examined by Rogerson (1984, 1988) and Cho and Rogerson (1988).

The latter study examines an economy populated by families in which males are primary workers with an elasticity of intertemporal substitution close to zero, and females have the same preferences as males but, because of the fixed costs of having both parents in the labor force, females have a larger (but finite) elasticity of intertemporal substitution of labor. The authors show that, as in Rogerson's earlier work, the aggregate economy behaves as if the elasticity of substitution were infinite. This linear specification based on Rogerson's work is also adopted by Christiano. Greenwood, et al. choose the absolute value of the elasticity of marginal utility of labor supply with respect to labor supply to be .6, based on studies by MaCurdy (1981) and Heckman and MaCurdy (1980, 1982) that give estimates of the inverse of this number that range from .3 for males to 2.2 for females. The .6 figure chosen by Greenwood, et al. corresponds to an intertemporal elasticity of substitution of labor equal to 1.7.

6. labor's share of total GNP is another important parameter in existing RBC models. Prescott estimates the share to be 64 percent, based on historical data with the services of consumer durables included as part of output, and this figure has been adopted in other studies as well. Without treating services of durables in this way, the historical share is higher, around 71 percent since 1950. This higher figure has been used in some other studies, such as Greenwood, et al. Christiano (1988) argues that accounting for measurement error places labor's share in the range of 57 percent to 75 percent; he assumes 66 percent.

7. The variance and autocovariances of productivity shocks play an important role in most RBC models. Prescott (1986a) estimates productivity shocks as the residuals from an aggregate Cobb-Douglas production function, with labor and capital inputs, estimated in first-difference form. He estimates that the standard deviation of these productivity shocks is 1.2 percent per quarter between 1955 and 1984, and that the technology shock is close to a random walk with drift plus serially uncorrelated measurement error. After a downward revision (that he argues is required because of measurement errors in the labor and capital inputs), Prescott ends up with an estimate of the standard deviation of .763 percent per quarter, and a first-order autoregressive coefficient of .95. Hansen also makes this assumption.

In Greenwood, et al., productivity shocks affect only future output from current investment, and not current output directly. Less serial correlation of productivity shocks is required in this model, in order to replicate the first-order autocorrelation of output in the U.S. data. The authors estimate that the first-order autocorrelation of productivity shocks is about .50 per year, while the figure of .95 per quarter would imply .81 per year.

Still other restrictions are specific to particular variations on the prototype RBC model. These include the relative wage of men and women, which appears in Cho and Rogerson and is chosen to be .6 on the basis of evidence from the Current Population Survey from 1979-84. The growth rate of the economy is another parameter that appears in some models. Prescott (1986a) sets the growth rate at zero, after using the Hodrick-Prescott filter, on the grounds that the character of fluctuations does not depend greatly on the growth rate.

The Kydland-Prescott (1988) model requires as parameters the elasticity of substitution between inventories and other factors of production, and a production-function parameter that determines whether variation in total hours occurs through a longer workweek or through more employees per hour; there is currently little evidence on which to base choices of such parameters.

As will be discussed in section VI, there are some quantitative differences between the United States, the United Kingdom, and Japan in features of business cycles. RBC models imply that some of the parameters discussed above should differ across these countries and that these differences should explain the observed differences in business cycles. There has not yet been much research devoted to determining these differences in parameters and examining whether they successfully explain cross-country differences.

III. Business Cycles and Long-Run Growth

A number of economists have recently argued that the traditional distinction between issues involving long-run secular growth on the one hand, and short-term fluctuations in GNP associated with business cycles on the other, is misplaced, and that business cycles and long-run growth are intertwined.

Nelson and Plosser (1982) argue that there is a secular or growth component to real GNP that is nonstationary, and another component that is stationary. They find that, empirically, the variance of the innovations to the nonstationary component is larger—the standard deviations are from one to six times as large—than the variance of the innovations to the stationary component. Given the assumption that monetary disturbances have only temporary effects on real output, Nelson and Plosser argue that "... real (nonmonetary) disturbances are likely to be a much more important source of output fluctua-

TABLE 2

U.S. Business Cycle Statistics, 1954:IQ-1982:IVQ Classified by Hamilton's "Normal States" and "Recession States" First-Difference Filter

	Normal States (103 observations)		Recession States (36 observations)	
Variable	Standard Deviation	Corr. with GNP	Standard Deviation	Corr. with GNP
GNP	.7%	1.00	.9	1.00
Consumption				
Total	.6	.50	.7	.45
On services	.4	.09	.5	.21
Nondurables	.7	.26	.7	.27
Fixed investment	2.3	.48	2.7	.68
Nonresidential	2.6	.28	2.4	.74
Structures	2.7	.28	2.7	.41
Equipment	3.5	.23	3.2	.76
Average nonfarm hours worked	.4	.26	.4	.12
In mfg. only	.8	.32	.8	.21
Employment	.6	.29	.7	.45
Productivity = GNP/total hours	.9	.56	1.0	.68

NOTE: Corr. = correlation. Hamilton's recession states during this period are (dates are inclusive) 1957:IQ-1958:IQ, 1960:IIQ-1960:IVQ, 1969:IIIQ-1970:IVQ, 1974:IQ-1975:IQ, 1979:IIQ-1980:IIIQ, and 1981:IIQ-1982:IVQ. Other dates in this period are normal states.
SOURCES: Hamilton (1987b) and Citibase.

tions than monetary disturbances." They also note that their conclusion "... is strengthened if monetary disturbances are viewed as only one of several sources of cyclical disturbances."

Subsequent work by Campbell and Mankiw (1987b), Clark (1987), Cochrane (1986), Evans (1986), Stock and Watson (1986), and Watson (1986) has generally corroborated the finding that real GNP has either a unit root (a nonstationary component) or a root that is close to unity (the power of the test for a unit root versus a root of .96 is small). However, measures of the relative sizes of the nonstationary (if it exists) and stationary components vary depending on the methods used. Cochrane, for example, finds that there may be a random walk component to GNP, but that its innovation variance is small relative to the variance of the transitory component. The difference between his finding and that of Nelson and Plosser results largely from his use of information from autocorrelations at long lags. Cochrane finds that the in-sample behavior of real GNP is represented well by a second-order autoregressive process around a deterministic trend.

Hamilton (1987b) estimates a simple nonlinear model of real GNP in which the economy shifts periodically from its "normal growth states" into "recession states" associated with negative average growth rates. Hamilton's model is an alternative to the assumption made in most previous work, that the first-difference of GNP is a linear stationary process (either white noise or purely deterministic). He uses a time-series model for real GNP that involves a stochastic trend: a random walk with drift in which the drift term takes one of two values, depending on the state of the economy. The state itself is a stationary Markov process. GNP is the sum of this stochastic trend component and a zero-mean ARIMA(4,1,0) process.

Hamilton's nonlinear model implies that a term is missing from an AR(4) model of the growth rate of GNP (a standard linear representation), and that addition of the extra term yields a large and significant coefficient, indicating that the nonlinear model is a better predictive model than the linear model.

He finds that, first, the dynamics of GNP during recessions are considerably different from the dynamics during normal, nonrecession periods. In particular, the economy is expected to grow at a rate of 1.2 percent per quarter during normal times and at a negative rate, -0.4 percent, during recessions. If the economy is in a normal state, there is a 90 percent chance that it will remain in the normal state next quarter; if the economy is in a recession, there is a 75 percent chance it will remain in that state next quarter. This suggests that there may be differences in the "facts" regarding business cycles across those states, and that these facts should be included in tables that RBC models seek to replicate. Table 2 shows that the main difference in correlations with GNP between normal states and recessions occurs in nonresidential investment, which is much more highly correlated with GNP during recession states.

Second, Hamilton finds that business cycles are associated with large *permanent* effects on the level of output. When the economy enters a recession, current output falls on average by 1.5 percent, while the permanent level of output falls by 3 percent. When the economy is in a normal state, a 1 percent fall in output reduces permanent output by two-thirds of 1 percent. In fact, Hamilton's results imply that most of the dynamics of GNP result from switches in the state of the economy generating the stochastic growth component rather than from the ARIMA process added to this component.

Finally, he finds that the dating of recessions estimated by the nonlinear model closely replicates the NBER dating. Hamilton's results suggest that while business cycles and long-term growth are subtly related, they are also separable in that one can study the switches between states of the economy, and characteristics of the recession states, separately from the characteristics of the normal growth state.

King, Plosser, and Rebelo (1988b) argue that it is inappropriate to study business cycles and long-term growth separately for two reasons. First, business cycles may *be* changes in the long-run growth path. Using models based on Romer (1986) and Lucas (1988), the authors construct examples of economies in which purely temporary shocks permanently affect the level of output. Similarly, permanent shocks (or policies) can change the economy's long-term rate of growth. While Hamilton's nonlinear model suggests that temporary shocks have permanent effects, it also suggests that business cycles differ substantially from "normal" changes in the long-run growth path.

Second, the authors argue that the characteristics of long-term growth—such as constancy of growth rates (although see Romer [1986]), rapidly rising consumption per capita with constant or only slowly rising leisure per capita, and the absence of a strong secular trend in the average real interest rate—imply restrictions on forms of production and utility functions and on their parameter values, and that RBC models must be made consistent with these restrictions. As McCallum (1989) argues, "... if technical change were exogenous, then there would be little necessary relation between the magnitude of growth and the extent of cycles, as they depend on two different aspects of the technical-progress process..." (that is, the mean and the short-term variations from this mean). However, even with exogenous growth, there are restrictions on the model that are required to produce steady-state growth, or large secular increases in real wages with a small reduction in hours worked, and so on.

IV. Seasonal Fluctuations and Business Cycles

Barsky and Miron (1988) have shown that deterministic seasonal fluctuations in macroeconomic variables exhibit the same characteristics (discussed above) as fluctuations at business-cycle frequencies. In addition, the seasonal fluctuations are large relative to the business-cycle fluctuations.

Using quarterly data, the authors find that deterministic seasonal fluctuations account for more than 85 percent of fluctuations in the growth rate of real GNP and over half of the fluctuations in real GNP relative to trend. Similar measures of the quantitative importance of seasonal fluctuations relative to business-cycle fluctuations apply to other macroeconomic time series, such as consumption, investment, the labor force, hours worked, and so on.

More important, they find that the *comovements* and *relative sizes* of movements in various macroeconomic variables are similar for seasonal and business-cycle fluctuations. This similarity also applies to the positive comovements of monetary aggregates and real output. As Barsky and Miron conclude, this "...suggests the possibility of a unified explanation of both business cycles and seasonal cycles." Miron (1988) has shown that the same qualitative conclusions also apply to seasonal and business-cycle fluctuations in many other countries.

If one accepts the view that business cycles and seasonal cycles have the same explanation—and are the results of the same types of disturbances as well as the same propagation mechanisms—then these results cast doubt on some popular theories of business cycles. Such theories include those based on unperceived monetary disturbances and confusion of sellers about changes in nominal and relative prices (as in Lucas [1975, 1982] and Barro [1976, 1980]) and those based on unanticipated changes in economic conditions in the face of predetermined nominal wages or prices. The seasonal changes in average weather and seasonal occurrence of holidays, such as Christmas, are clearly both perceived and anticipated.

An alternative, weaker, interpretation of the Barsky-Miron results is that business cycles and seasonal fluctuations are the results of different underlying disturbances (with the former unanticipated and the latter anticipated), but that most of the key features of business cycles are driven by the propagation of these disturbances through the economy and are largely independent of the source of the disturbance. Under this interpretation, monetary, rather than real, disturbances might play an important role in instigating business cycles. But RBC analysis would be extremely important in trying to understand the characteristics of business cycles, because the propagation mechanism studied in these models would be responsible for generating the particular comovements and relative sizes of movements of economic variables that are observed. In this sense, the focus on RBC analysis as a means of determining how disturbances affect the economy and how they spread through different sectors of the economy over time (the third and fourth reasons for RBC analysis mentioned in the introduction) would be very important.

V. Criticisms of Real Business Cycle Models

Several popular criticisms that have been levied against RBC models are presented here, along with some responses to those criticisms. For further arguments, see Summers (1986) and Prescott (1986b).

What Are These Technology Shocks?

An additional question, posed by Robert Hall (1988), is how to interpret periods in which real output actually falls: what are the negative technology shocks? Summers, having suggested that oil price changes could constitute such a shock, cites a study by Berndt (1981) which concludes that energy shocks had little role in the fall in manufacturing labor productivity from 1973 to 1977. Summers also asks, "What are the sources of technical regress? Between 1973 and 1977, for example, both mining and construction displayed negative rates of productivity growth. For smaller sectors of the economy, negative productivity growth is commonly observed."

Our inability to document the changes in technology that produced business cycles may not be important, however. We can *measure* the technical change—up to problems associated with measuring inputs—by estimating production functions. Further, much of the technical change may occur in forms not easy to understand without specialized knowledge of a particular industry, and, as Prescott stresses, the sum of many (nonindependent) technical changes is the aggregate technical change.

As for reductions in output, there are many possibilities for technical changes that *temporarily* cause reductions in measured aggregate output, and some that cause permanent reductions in *measured* output but increases in true total output (which includes unmeasured or poorly measured components, such as household production). In addition, it may be unnecessary to *explain* the sources of technical regress in an industry in order to use the *measured facts* of that regress to account for economic fluctuations. As Summers notes, for smaller sectors of the economy, negative productivity growth is commonly observed. Are all of these individual experiences of negative productivity growth to be attributed to monetary policy or macroeconomic coordination failures? Would such a traditional macroeconomic explanation of these negative productivity shocks—providing such a *quantitative* model could even be built—be a better explanation than an RBC explanation?

There Is Some Evidence that Money Affects Real Output

Christiano and Ljungqvist (1988) present simulation evidence about the failure of monetary aggregates to Granger-cause real output in systems that have been first-differenced to achieve stationarity. They find that this phenomenon results from a lack of power caused by first-differencing the data and by inducing specification error. In contrast, this Granger-causality does typically show up in systems estimated in levels or with deviations from deterministic linear trends.

These results are important because most reasonably specified models in which money affects real output imply Granger causality from money to output (though it is possible to construct examples—perhaps unrealistic ones—in which such Granger causality is absent). The estimates presented by Christiano and Ljungqvist are, as they argue, economically as well as statistically significant: about 18 percent of the conditional variance in the log of industrial production 12 months into the future is accounted for by lagged values in (the log of) M1, and this figure rises to nearly 30 percent at the 48-month horizon.

Other, less formal, evidence suggests that money affects real output, real interest rates, and other real variables in the short run. In addition, McCallum (1985, 1986) has argued that monetary policy has been implemented through interest-rate instruments and that, consequently, innovations in monetary aggregates may have no explanatory power for output once nominal interest rates are controlled for, as in Sims (1980, 1982). McCallum also contends that the explanatory power of nominal-interest-rate innovations may reflect the real effects of money on output.

A statistical association between money and output, however, does not imply that exogenous changes in money affect output, rather than vice versa (or both resulting from some other disturbance). As was noted in the introduction, the major component of the money supply that changes with real output is not high-powered money, but bank deposits.

These changes in deposits may be endogenous reponses to changes in output or may be a joint result of another underlying change. Alternatively, RBC models may not account for all fluctuations in output, but only a major part of them, with monetary disturbances accounting for the remainder. Clearly, RBC models are better equipped than monetary models to study the seasonal fluctuations in aggregate variables that mimic business-cycle behavior.

There Is Evidence that Nominal Prices Are Sluggish

The implication is that traditional, sluggish-price macroeconomic models are good models of aggregate fluctuations. But that implication does not necessarily follow. Even if nominal prices are sluggish (and there is some evidence to that effect), RBC models might explain most aggregate fluctuations for two reasons.

First, in the presence of price sluggishness, there are incentives to develop alternative allocation mechanisms, associated with long-term contracts or other devices, that bypass or supplement the use of prices in the resource allocation mechanism. The competitive equilibrium may closely approximate the solution to an RBC model if the alternative market mechanisms are sufficiently well developed.

Second, even if sluggish nominal-price adjustment affects resource allocation in important ways, it may play a subsidiary role to the features emphasized in RBCs for explaining aggregate fluctuations, either because the effects of monetary disturbances are not large relative to the effects of real disturbances or because, as discussed in the introduction, the characteristics of business cycles (once they have begun) are largely independent of the source of disturbance.

While some evidence supports nominal price sluggishness, it is largely concentrated on a few commodities such as newspapers. Moreover, much of the evidence from microeconomic data is weak because all characteristics of goods (including delivery lags, warranties, and quality control) are not held fixed. In any case, long-term contracts can involve ex-post settling up that occurs in ways that do not show up in the current price.

The Success of RBC Models Rests on Incorrect Parameter Values

Summers argues that RBC models have not explained the data as well as they seem to have, because the parameters they have chosen are incorrect. For example, he argues that the degree of intertemporal substitution is smaller than that assumed in most RBC studies. While Prescott chooses parameters to make the average real interest rate 4 percent per year, and King et al. choose them so that the rate is 6.5 percent per year, Summers argues that, based on historical data, the average real interest rate is closer to 1 percent per year. Similarly, Summers argues that Prescott's calculation of the fraction of time spent working, one-third, is much too large, and should be closer to one-sixth.

Prescott (1986b) has defended his choice (and the Kydland-Prescott choice) of parameters. He cites Rogerson's work (see above) to rationalize a high degree of intertemporal substitution in labor at the aggregate level, regardless of its magnitude at the individual level. The fraction of time spent working in his model is the fraction of time not devoted to sleep or personal care, so that the figure one-third would be close to that found from micro data. Finally, Prescott's real interest rate is intended to represent the real rate of return on capital, which can be measured approximately from GNP accounts and is about 4 percent per year, rather than a riskless real interest rate.

Technical Change Is Overstated by Prescott's Measurement

The residuals from the production functions that Prescott has estimated are not, according to this argument, correctly interpreted as mainly involving technical change.[3] There are both neglected factors and mismeasured factors.

One argument, made by Summers (1986) and McCallum (1989), involves labor-hoarding. When output is lower than normal (for example, due to a fall in aggregate demand), firms continue to employ workers who do not actually work much. The employees are measured as working, however, so the labor input is overstated when output

■ 3 Actually, Prescott calculates the production functions using a fixed value of the share parameter, rather than estimating by ordinary least squares.

is low. Similarly, it is understated when output is high. Calculation of residuals from a production function will then yield residuals that are too low when output is low, and too high when output is high. If the residuals are incorrectly interpreted as productivity shocks, these "shocks" will seem to explain the level of output, when they actually result from measurement error.

Summers cites a study by Fay and Medoff (1985) to argue that this labor-hoarding (employment of people who do not really work during recessions) is quantitatively important. McCallum points out that the growth literature following Solow (1957) typically found modifications of his procedure that would reduce the contribution of the disturbances (interpreted as technical progress in total factor productivity) to the overall growth in output. McCallum cites a study by Jorgenson and Griliches that used corrections for "aggregation errors" and changes in utilization rates of capital and labor to reduce the contribution of the residuals from nearly half of the variance of output to only **3** percent.

Prescott (1986b) notes that the Fay-Medoff study asked plant managers how many extra workers they employed in a recent downturn, rather than how many ***more*** extra workers they employed in the downturn than in the upturn. The latter question would be required to determine the quantitative significance of labor-hoarding. In addition, Prescott points out that labor-hoarding may ***fall*** in recessions: firms would be less reluctant to lay off workers in recessions because it is less likely that those workers would find alternative jobs. If so, the measurement error in the labor input would make measured technical change too small rather than, as Summers argues, too large.

Horning (1988) examines a model in which heterogeneous industries experience industry-specific as well as aggregate shocks, and shows that the number of firms hoarding labor is procyclical while the amount of labor hoarded per firm is countercyclical. Labor-hoarding will result in overstatement of the size of technology shocks only if the first effect dominates the second. Similarly, Kydland (1984) shows that measured technical change will be too small if workers are heterogeneous in skills and that highly skilled workers have less variability in weekly hours worked than do low-skilled workers. More generally, it would be desirable to have better estimates of technical change from production function studies, and these could be incorporated into RBC models.

The RBC Models Fail Formal Econometric Tests

The implication is that the RBC models should be rejected. The question is, in favor of what? Rogerson and Rupert (1988) have shown that very small measurement errors can lead to rejection of such models, even if the models are good approximations to reality.

If models are to be used for policy purposes, a formal policy decision problem should be analyzed to determine whether policymakers are better off in terms of expected utility when they make use of RBC models. The models may, for example, be wrong but give better advice than the other incorrect theories. If models are to be used for additional scientific research, then clearly the models should not be dismissed entirely when they fail, until they have been examined for the source of failure and, perhaps, changed accordingly.

The Models' Implications for Prices Fail

An example cited by Summers is the "equity premium" studied by Mehra and Prescott (1985). McCallum (1989) notes that the observed procyclical movements in real wages (see, for example, Bils [1985]) are smaller than the procyclical wage movements implied by RBC models such as that of Kydland and Prescott. Similarly, models such as the ones developed by Greenwood, Hercowitz, and Huffman presumably imply larger procyclical movements in ex ante real interest rates than those calculated from ex post data, as in Mishkin (1981) or based on survey data for inflationary expectations.

Prescott (1986b) replies that his representative-agent RBC model may be poorly designed to explain the equity premium but is well designed for aggregate fluctuations. Nevertheless, a business cycle theory that is also consistent with observations on prices would be better than having different models for different purposes.

Kydland and Prescott (1988) report implications of their model for the cyclical behavior of the real interest rate. The behavior of real interest rates is, of course, difficult to measure because inflationary expectations are not well measured. Similarly, there are notorious problems with treating measured average pecuniary compensation at a point in time as a measure of the marginal product of labor. Thus, Bils' (and the other) evidence may understate the true procyclical behavior of the marginal product of labor.

The Models Do Not Explain Involuntary Unemployment

Involuntary unemployment is generally asserted to be a "fact" of business cycles. Perhaps it is, but one can check the truth of this claim only after the term has been precisely defined. Rogerson's model with indivisible labor is promising in this regard. Because everyone is alike ex ante, yet some people find work and others do not, models like this may eventually be able to explain involuntary unemployment in the sense that a person without a job is no different in tastes, experiences, and other characteristics from someone else with a job. Alternatively, RBC models may have to be modified to include some market failures in order to account adequately for such phenomena.

There Are Large Nation-Specific Components to GNP Fluctuations

I have argued (Stockman, 1988a) that RBC models based solely on technology shocks seem unable to account for the empirical finding (documented in that paper) that there are large changes in output across all industries that occur in one country but not in another. Technology shocks would be more likely to affect a particular group of industries, irrespective of nation (at least in developed, OECD countries) than to affect a particular country, irrespective of industry. Instead, the evidence in my paper suggests that while technology shocks are important, some nation-specific disturbances play at least as large a role in output fluctuations.

Whether these nation-specific disturbances are monetary or "real" (for example, resulting from fiscal policy) remains unclear. It is possible, of course, that technology is more specific to nations than to industries, though that seems unlikely. These conclusions may also result from international transmission of aggregate disturbances. I discuss these issues briefly in the context of the formal two-country model in section VI, which illustrates one of the important reasons for developing multicountry, multisector RBC models, as outlined in that section.

It is Easy to Produce Models to Mimic Facts

Summers cites Ptolemaic astronomy as an example of how "...many theories can approximately mimic any given set of facts; that one theory can does not mean that it is even close to right." The assertion is clearly correct in general, but it is beside the point. While it is possible that many theories could replicate the facts of business cycles and meet the other criteria of being consistent with basic economic theory, the fact that a theory is consistent with the facts ***raises*** (and certainly does not lower) the conditional probability that it is a good and useful theory.

In any case, RBC models such as those developed by Kydland and Prescott have set a standard to which alternative models, including those with sluggish price adjustments and coordination failures, should aspire: to present a prima facie case that the model is ***quantitatively*** accurate. The alternative models favored by Summers and by other critics of RBC analysis may prove to be better models of aggregate fluctuations, but those models as yet have not been developed sufficiently to even enter the race against RBC models in mimicking the quantitative as well as qualitative aspects of business cycles.[4]

VI. Outline of a Stripped-Down Two-Country ABC Model

This section outlines a two-country version of a simple RBC model. It illustrates formally the setup of a prototype model, describes one method of solving the models (as in King, Plosser, and Rebelo [1988a]), and discusses the reasons for an international extension of the RBC model. Frequently, international extensions of closed-economy macroeconomic models have little motivation (except, perhaps, to turn one idea into two papers); there are better reasons for an international extension in this case.

The first reason is that RBC models have been calibrated with a single set of parameters to explain a single set of standard errors and covariances of macroeconomic variables. One way to improve on the models is to add additional variables, but this requires adding more equations and more parameters to obtain additional implications from the models.

A second way to check an RBC model is to apply the same model to a ***different*** set of

■ 4 The large econometric models do not qualify because they are not true structural models in the sense of the Lucas critique of econometric policy evaluation.

macroeconomic facts (standard errors, correlations, and so on), using the *same* criteria for choosing parameter values. The different sets of macroeconomic facts can be obtained by using data from different countries. Application of the models to data from other countries will therefore provide a valuable check on the models, as Rogoff (1986) also suggested. Differences in the characteristics of business cycles across countries are substantial enough to provide powerful checks on the models, as I will discuss below.

The second reason for an international extension is that the RBC models have implications, in an international setting, for additional variables such as exports, imports, and the balance of trade. RBC models with multiple sectors can also be shown to have implications for relative prices, such as the terms of trade or the relative price of nontradeables. These additional implications can be checked against the data.

In addition, the models can be used to examine issues associated with the international transmission of real disturbances, and the effects on aggregate fluctuations of various government policies toward international trade. Finally, equilibrium models of exchange rates imply that changes in real and nominal exchange rates result from "real" shocks; in this sense they are closely linked to RBC models.5

Also, like RBC models, equilibrium models of exchange rates are based on simple dynamic, stochastic, general-equilibrium models. But the RBC models have been quantitatively developed (in closed economies) in ways that the equilibrium models of exchange rates have not; application of the RBC models to open economies therefore has the potential of advancing the equilibrium exchange-rate models and furthering our understanding of exchange rates.

There are two categories of differences between countries: differences in parameters and differences in exogenous disturbances. To keep the issues associated with international extensions clear, consider a simple model similar to that in King, Plosser, and Rebelo with exogenous growth. There is a representative individual in each country who maximizes the expected discounted utility of consumption of two goods—one produced in each country—and leisure, $1-N$, where N is labor supply and total time is normalized to one,

$$(1) \quad U = \Sigma_{t=0}^{\infty} \beta^t u(C_{1t}, C_{2t}, 1-N_t),$$

and the foreign representative individual maximizes

$$(1^*) \quad U^* = \Sigma_{t=0}^{\infty} \beta^t u(C^*_{1t}, C^*_{2t}, 1-N^*_t).$$

Each country produces only one good, and its production is described by constant-returns-to-scale production functions

$$(2) \quad Y_t = A_t F(K_t, N_t X_t)$$

and

$$(2^*) \quad Y^*_t = A^*_t F^*(K^*_t, N^*_t X^*_t),$$

where K_t and K^*_t are chosen at date $t-1$, and investment in each country utilizes only that country's good, that is,

$$(3) \quad K_{t+1} = (1-\delta)K_t + I_t$$

and

$$(3^*) \quad K^*_{t+1} = (1-\delta^*)K^*_t + I^*_t,$$

where K and K^* are the foreign and domestic capital stocks, 6 and δ^* are depreciation rates, and I and I^* are investments using domestic and foreign goods.

This model includes some assumptions that should be relaxed in further work but are made here for simplicity: that utility functions are identical across countries, that countries are completely specialized in production, and that all goods are internationally traded. Also, the production functions do not allow one good to be used as an input into the other, which precludes certain types of sectoral interactions as in the model of Long and Plosser (1983).

The resource constraints differ from those of a closed economy due to international trade:

$$(4) \quad C_{1t} + C^*_{1t} + I_t = Y_t$$

and

$$(4^*) \quad C_{2t} + C^*_{2t} + I^*_t = Y^*_t$$

5 See Stockman (1980, 1987, 1988b), Lucas (1982), Stockman and Svensson (1987), Salyer (1988), and Stockman and Dellas (1988).

Given initial conditions on the capital stock in each country and weights on domestic versus foreign utilities (which correspond to relative wealth positions in competitive equilibrium), equations (1) through (4) and nonnegativity constraints on consumption, leisure, labor supply, and capital stocks can be solved for time paths of consumption, labor, and capital for given time paths of the exogenous productivity disturbances 4 A*, X, and X*.

Suppose we adopt the restrictions on preferences that King, Plosser, and Rebelo argue are implied by the observation of steady-state growth, and we assume that the degree of relative risk-aversion is unity. Then, for the three-argument utility function postulated here,

$$(5)\quad u(C_1, C_2, 1-N) = \log(C_1) + \log(C_2) + v(1-N),$$

where $v' > 0$ and $v'' < 0$. The production functions are assumed to be Cobb-Douglas,

$$(6)\quad Y_{1t} = A_t K_t^{1-a} (N_t X_t)^a$$

and

$$(6^*)\quad Y_{2t} = A^*_t K^{*\,1-a^*}_t (N_t X_t)^{a^*},$$

all variations in A are assumed to be temporary, and all variations in X are assumed to be permanent (explained below).

Define the transformed variables $c_1 = C_1/X$, $c^*_1 = C^*_1/X$, $c_2 = C_2/X^*$, $c^*_2 = C^*_2/X^*$, $i = I/X$, $i^* = I^*/X^*$, $k = K/X$, $k^* = K^*/X^*$, $g = X'/X$, and $g^* = X^{*\prime}/X^*$. Then a social planning problem for this economy can be expressed as

$$(7)\quad \text{Maximize } \Sigma_{t=0}^{\infty} \beta^t [w \{\log(c_{1t}) + \log(c_{2t}) + v(1-N_t)\} + (1-w)\{\log(c^*_{1t}) + \log(c^*_{2t}) + v(1-N^*_t)\}]$$

with respect to the sequence $\{c_{1t}, c_{2t}, c^*_{1t}, c^*_{2t}, k_{t+1}, k^*_{t+1}, N_t, N^*_t;\ t = 0, \ldots \infty\}$ for given utility-weight w, and subject to the sequence of constraints (with multipliers Φ and Φ^*),

$$(8a)\quad A_t K_t^{1-a} N_t^a - c_{1t} - c^*_{1t} - [g_x k_{t+1} - (1-\delta) k_t],$$

$$(8b)\quad A^*_t k^{*\,1-a^*}_t N_t^{a^*} - c_{2t} - c^*_{2t} - [g_{x^*} k^*_{t+1} - (1-\delta) k^*_t],$$

and the inequality constraints listed above.

Necessary conditions for this problem include the resource constraints (8), the inequality constraints listed above, and

$$(9a)\quad w/c_{1t} = \Phi_t = (1-w)/c^*_{1t}$$

$$(9b)\quad w/c_{2t} = \Phi^*_t = (1-w)/c^*_{2t}$$

$$(9c)\quad \beta \Phi_{t+1} [A_t (N_t/k_t)^a + (1-\delta)] = \Phi_t g_x$$

$$(9d)\quad \beta \Phi^*_{t+1} [A^*_t (N^*_t/k^*_t)^{a^*} + (1-\delta)] = \Phi^*_t g_{x^*}$$

$$(9e)\quad \Phi_t A_t k_t^{1-a} N_t^a / N_t = v'(1-N_t)$$

$$(9f)\quad \Phi^*_t A^*_t k^{*\,1-a}_t N^{*\,a}_t / N^*_t = v'(1-N^*_t)$$

$$(9g)\quad \lim_{t\to\infty} \beta^t \Phi_t k_{t+1} = 0$$

$$(9h)\quad \lim_{t\to\infty} \beta^t \Phi^*_t k^*_{t+1} = 0.$$

One undesirable characteristic of the solution is evident from these conditions: consumption of each good is perfectly correlated across countries. This prediction is not borne out by **data.** One way to modify the model would be to include nontraded goods, as in Stockman and Dellas (1988). Because numerical methods are required to solve the model anyway, it is feasible to relax the special assumption imposed in that paper that utility is separable between traded and nontraded goods.

In fact, traded goods may have to be processed in each country before they are bought and consumed by a production technology that includes nontraded goods (such as retailing, transportation to markets, and storage). This feature of traded goods has been emphasized in work by Kravis and Lipsey (1983) and explains their strong empirical finding that countries with higher wealth have higher prices of nontraded goods and higher prices of traded goods at the retail level. With this modification, trade would take place in intermediate goods rather than final goods, and final goods production would occur in each country with the use of a nontraded factor, as in Jones and Purvis (1983).

Next, define the operator D so that Dc, is the log-deviation of c, from its stationary steady-state value, c , that is $Dc_t = \log(c_t/c)$. Then take linear approximations of (9) around these stationary values,

$$\text{(10a)}\quad Dc_{1t} = Dc^*_{1t} = -D\Phi_t$$

$$\text{(10b)}\quad Dc_{2t} = Dc^*_{2t} = -D\Phi^*_t$$

$$\text{(10c)}\quad D\Phi_t = D\Phi_{t+1} + [1-\beta(1-\delta)/g_x][DA_{t+1} + a(DN_{t+1} - Dk_{t+1})]$$

$$\text{(10d)}\quad D\Phi^*_t = D\Phi^*_{t+1} + [1-\beta(1-\delta)/g_{x^*}][DA^*_{t+1} + a^*(DN^*_{t+1} - Dk^*_{t+1})]$$

$$\text{(10e)}\quad DA_t + (1-a)Dk_t - (1-a)DN_t + D\Phi_t = -(1-N)(v''/v')[N/(1-N)]DN_t$$

$$\text{(10f)}\quad DA^*_t + (1-a^*)Dk^*_t - (1-a^*)DN^*_t + D\Phi^*_t = -(1-N^*)(v^{*\prime\prime}/v^{*\prime})[N^*/(1-N^*)]DN^*_t$$

$$\text{(log)}\quad DA_t + (1-a)Dk_t + aDN_t = s_{c1}Dc_{1t} + s_{c1^*}Dc_{*1t} + [1-s_{c1}-s_{c^*1}][g_x/(g_x-1+\delta)]Dk_{t+1} + [1-s_{c1}-s_{c^*1}][1-g_x/(g_x-1+\delta)]Dk_t$$

$$\text{(10h)}\quad DA^*_t + (1-a^*)Dk^*_t + a^*DN^*_t = s_{c2}Dc_{2t} + s_{c2^*}Dc_{*2t} + [1-s_{c1}-s_{c^*1}][g_{x^*}/(g_{x^*}-1+\delta)]Dk^*_{t+1} + [1-s_{c1}-s_{c^*1}][1-g_{x^*}/(g_{x^*}-1+\delta)]Dk^*_t.$$

Next, solve (10a), (10b), (10e), and (10f) for the optimal decisions $\{Dc_1, Dc_2, Dc^*_1, Dc^*_2, DN, DN^*\}_t$ as functions of the state variables $\{Dk_t, Dk^*_t, DA_t, DA^*_t\}$ and $\{D\Phi_t, D\Phi^*_t\}$. Then substitute these solutions into (10c), (10d), (10g), and (10h) to obtain the difference equations

$$\begin{pmatrix} Dk_{t+1} \\ \\ \end{pmatrix} = G \begin{pmatrix} Dk_t \\ \\ \end{pmatrix} + HDA_{t+1} + J.$$

and

$$\begin{pmatrix} Dk^*_{t+1} \\ D1^*_{t+1} \end{pmatrix} = G^* \begin{pmatrix} Dk^*_t \\ D1^*_t \end{pmatrix}$$

$$D1^*_{t+1}$$

$$+ H^*DA^*_{t+1} + J^*DA^*_t,$$

each of which is analogous to the system in King, Plosser, and Rebelo (1988a), shown there as having a solution of the form

$$\begin{pmatrix} Dk_t \\ D1_t \end{pmatrix} = G^t \begin{pmatrix} Dk_0 \\ D1_0 \end{pmatrix} + \Sigma_{j=0}^{\infty} G^j HDA_{t-j+1} + \Sigma_{j=0}^{\infty} G^j JDA_{t-j}$$

and

$$\begin{pmatrix} Dk^*_t \\ \\ D1^*_t \end{pmatrix} = G^{*t} \begin{pmatrix} Dk^*_0 \\ D1^*_0 \\ D1^*_0 \end{pmatrix} + \Sigma_{j=0}^{\infty} G^{*j}H^*DA^*_{t-j+1} + \Sigma_{j=0}^{\infty} G^{*j}J^*DA^*_{t-j}.$$

Assume that certainty equivalence holds approximately and that the vector $(DA_t, DA^*_t)'$ follows a Markov process,

$$\begin{pmatrix} DA_{t+1} \\ \\ DA^*_{t+1} \end{pmatrix} = \begin{bmatrix} p_0 & p_1 \\ \\ p^*_1 & p^*_0 \end{bmatrix} \begin{pmatrix} DA_t \\ \\ DA^*_t \end{pmatrix} + \begin{pmatrix} u_{At+1} \\ \\ u_{A^*t+1} \end{pmatrix}$$

where $u = (u_A, u_A^*)$ is a random variable with mean zero and covariance matrix V_A. Then the system can be written in the form of a first-order difference equation

$$\begin{pmatrix} Dk_{t+1} \\ DA_{t+1} \\ DA^*_{t+1} \\ Dk^*_{t+1} \end{pmatrix} = \begin{bmatrix} h_k & h_A & h_A^* & 0 \\ 0 & p_0 & p_1 & 0 \\ 0 & p^*_1 & p^*_0 & 0 \\ 0 & h^*_A & h^{**}_A & h^{**}_k \end{bmatrix} \begin{pmatrix} Dk_t \\ DA_t \\ DA^*_t \\ Dk^*_t \end{pmatrix} + \begin{pmatrix} 0 \\ u_{At+1} \\ u^*_{A\,t+1} \\ 0 \end{pmatrix}.$$

Let w and w* denote (real) wage rates, let r and r^* denote real interest rates in terms of good one and good two, respectively, and let q denote the relative price of good two in terms of good one. These and the other endogenous variables (Dc,,, Dc,, , Dc^*_{1}, Dc^*_{2t}, DN, , DN^*_t, Dy_t, Dy^*_t, Di_t, Di^*_t, Dw_t, Dw^*_t, $r_t - r$, $r^*_t - r^*$, Dq_t} can then be written as linear functions of the state vector

$$s_t = (Dk_t, DA_t, DA^*_t, Dk^*_t)'.$$

The parameters of this model are the two depreciation rates of capital; the utility-of-labor functions v () and $v^*()$; the production parameters a and a*; the utility weight w; the discount rate β; the growth rates g_x and g_x^*; the parameters of the Markov process on productivity shocks, p_0, p_1, p^*_0, p^*_1; and the covariance matrix of productivity shocks V_A. These parameters can be chosen in the ways described above to match historical observations on growth rates, labor's share of gross domestic product (GDP), and so on, and estimated parameters from microeconomic studies (such as the elasticity of the function v (), and to make the model reproduce some of the variances and covariances of key macroeconomic aggregates.

As noted above, the model has implications for the terms of trade, which is the only "real exchange rate" in the model and is, in real-world data, very highly correlated with the exchange rate. Consequently, the model has implications for exchange rates as in the equilibrium models referred to previously. Tables 3 through 8, described below, show roughly zero correlations between GNP and the U.S. dollar exchange rates of Japan and the United Kingdom. When U.S. GNP is controlled for, however, the partial correlation between the exchange rate and GNP in Japan and the United Kingdom rises to the range of .2 to .3.

Tables 3 through 8 display correlations between some macroeconomic aggregates and GDP for Japan and Great Britain, and the corresponding standard errors of the variables.[6] Baxter and Stockman (1988) show that these and many other similar variances and covariances are independent of the exchange-rate system, so the correlations in the tables refer to the time periods 1961:IQ-1986:IIQ for the United Kingdom and 1964:IQ-1987:IQ for Japan.

On the other hand, that research also indicated that covariances such as these are sometimes very sensitive to the method of detrending the data. The tables therefore present correlations with output after each of two types of detrending: the removal of a deterministic linear time trend and first-differencing.' In addition,

■ 6 The series presented have been chosen to make the tables analogous to table 1.

7 Use of the Hodrick-Prescott filter always resulted, with the data used for these tables, in a correlation bounded by those presented here.

TABLE 3

Japanese Business Cycle Statistics, 1964:IQ-1985:IVQ First-Difference Filter

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	1.8%	.03	1.00	.03
Consumption	1.5	.11	.56	.01
Investment	3.2	.08	.70	.17
Government spending	7.8	-.11	.18	-.08
Real exports	4.9	-.01	.10	.02
Real imports	5.6	.05	.08	.16
Net exports	4.6	-.07	.02	-.18
Average hours worked	.8	-.01	.30	-.06
Total hours worked	1.0	.11	.29	.03
Employment	.5	.24	.09	.17
labor force	.5	.22	.08	.11
GNP/total hours	1.8	-.04	.85	.00
GNP/worker	1.8	-.04	.97	-.02
Exchange rate	4.2	.03	-.02	-.03

NOTE: Con. = correlation. Correlations above .2 are significant at .05; correlations above .27 are significant at .01.
SOURCES: Japanese Central Bank and International Monetary Fund.

TABLE 4

Japanese Business Cycle Statistics, 1964:IQ-1985:IVQ Linear Trend Filter

Variable	Standard Deviation	Corr. with GNP (- 1	Corr. with GNP	Corr. with GNP (+1)
GNP	10.5%	.98	1.00	.98
Consumption	8.9	.93	.94	.93
Investment	15.6	.95	.97	.96
Government spending	11.5	.75	.78	.78
Real exports	13.9	.64	.66	.65
Real imports	21.6	.49	.53	.56
Netexports	12.3	-.12	-.19	-.26
Average hours worked	2.8	-.50	-.50	-.53
Total hours worked	3.3	-.35	-.38	-.42
Employment	1.1	.24	.19	.11
labor force	1.0	.19	.13	.05
GNP/total hours	12.0	.94	.96	.95
GNP/worker	10.4	.98	.99	.98
Exchange rate	10.8	.10	.10	.05

NOTE: Corr. = correlation. Correlations above .2 are significant at .05; correlations above .27 are significant at .01.
SOURCES: Japanese Central Bank and International Monetary Fund.

the tables show results for the components of the foreign variables that are orthogonal to U.S. GNP, calculated by taking residuals from an OLS regression of the variables on U.S. GNP before applying the other filters.

The tables clearly indicate quantitative differences across countries in the characteristics of business cycles. The results using the Hodrick-Prescott filter are closest to those reported in the tables for the deterministic linear trend filter, so I focus on those results. The standard deviation of consumption in the United Kingdom and Japan is about equal to the standard deviation of GNP; in the United States, the standard deviation of consumption is only about three-fourths that of GNP.

In Japan, the standard deviation of investment relative to that of GNP is about half the size of that ratio in the United States or in the United Kingdom. The relative variability of the average number of hours worked per week in Japan is also much smaller than in the other two countries. The standard deviation of the average productivity of labor is about twice as large, relative to that for GNP, in Japan and the United Kingdom as in the United States. Finally, the variability of imports exceeds that of exports in all countries. Net exports, as discussed above, are countercyclical in all three countries.

The correlations with output also differ. The most striking difference is in the correlation between GNP and the average number of hours worked per week. In the U.S. data, this correlation is large and positive; for the United Kingdom and Japan, it is negative. In Japan, average hours variation dominates employment variation so that total hours worked, calculated by the product of employment and average hours, is actually countercyclical. The correlation between the average productivity of labor and GNP is much higher in Japan and the United Kingdom than in the United States.

These differences must be explained either by differences in parameters or by differences in the disturbances facing the three economies. Each

TABLE 5

Japanese Business Cycle Statistics, 1964:IQ-1985:IVQ
Filter: Linear Trend and Residuals from Projection onto U.S. GNP

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	9.2%	.96	1.00	.96
Consumption	8.5	.83	.90	.88
Investment	13.6	.92	.92	.86
Government spending	11.8	.70	.76	.77
Real exports	15.7	.69	.70	.65
Real imports	22.8	.61	.61	.56
Net exports	12.3	–.22	–.23	–.20
Average hours worked	2.7	–.56	–.59	–.61
Total hours worked	3.3	–.44	–.46	–.48
Employment	1.1	.07	.08	.05
Labor force	1.2	.01	.05	.02
GNP/total hours	9.0	.95	.99	.94
GNP/worker	9.2	.95	.99	.96
Exchange rate	11.5	.36	.32	.26

NOTE: Corr. = correlation. Correlations above .2 are significant at .05; correlations above .27 are significant at .01.
SOURCES: Japanese Central Bank, International Monetary Fund, and Citibase.

TABLE 6

British Business Cycle Statistics, 1961:IQ-1986:IIQ
First-Difference Filter

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	1.7%	-.18	1.00	-.18
Consumption	1.9	–.03	.47	–.15
Investment	4.4	–.22	.31	.04
Government spending	2.2	.16	–.04	–.08
Real exports	9.7	.19	.26	–.21
Real imports	4.8	.07	.34	–.01
Net exports	9.1	.16	.10	–.22
Average hours worked	1.2	–.11	.33	.06
Total hours worked	1.5	–.14	.34	.17
Employment	6.5	–.11	.16	.22
Iabor force	4.6	.06	.03	.02
GNP/total hours	1.8	–.10	–.10	–.04
GNP/worker	1.7	.00	.00	.00
Exchange rate	3.9	.13	.03	–.07
Net capital stock	0.3	.02	.07	.10
Equipment	0.3	–.02	.06	.10
Buildings	0.3	.04	.08	.10

NOTE: Corr. = correlation.
SOURCES: Bank of England, European Economic Community, and International Monetary Fund.

explanation has implications for the behavior of exports, imports, and the trade balance. The question of whether RBC models like those currently being analyzed will survive such extensions must await future research.8

8 Other useful extensions of RBC analysis include further research integrating it with growth theory, as emphasized by King, Plosser, and Rebelo (1988b); the inclusion of private information into the analysis so that fluctuations are not unconstrained-Pareto-optimal; the inclusion of distorting government policies such as taxes and regulations (also emphasized by King, et al.); further examination of the behavior of prices, including interest rates, relative prices in multisector models, and so on; work on heterogeneity and aggregation problems; and extensions of the theory to include roles for financial intermediaries (and possibly government regulation of them), particularly since there is evidence connecting intermediation to business cycles.

VII. Policy Implications

Should any of the developments so far in RBC analysis affect current policy? Obviously, the answer involves the optimal formation of policy under uncertainty. If the standard macro models, say with sticky prices, are correct, then monetary policy can be designed to help, while if the RBC models are correct, then monetary policy will have no effects. It is clearly not correct to argue, however, that because we do not know which model is correct, we should use monetary policy as if the standard model were correct: even if it is wrong, there is little or no cost in trying it.

That argument is wrong precisely because there may be a large cost in using monetary policy if both the standard and the RBC models have

TABLE 7

British Business Cycle Statistics, 1961:IQ-1986:IIQ Linear Trend Filter

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	3.5%	.88	1.00	.88
Consumption	3.6	.71	.73	.64
Investment	9.0	.81	.88	.86
Government spending	4.8	.56	.55	.55
Real exports	10.2	.38	.43	.36
Real imports	12.2	.59	.66	.67
Net exports	9.6	-.36	-.39	-.47
Average hours worked	2.2	-.29	-.27	-.33
Total hours worked	2.7	.13	.22	.22
Employment	1.9	.58	.65	.71
Labor force	1.4	-.03	-.03	-.03
GNP/total hours	3.9	.68	.73	.63
GNP/worker	2.6	.73	.83	.63
Exchange rate	11.8	-.06	-.12	-.17
Net capital stock	3.5	.78	.79	.79
Equipment	3.4	.76	.77	.77
Buildings	3.8	.79	.80	.80

NOTE: Corr. = correlation.
SOURCES: Bank of England, European Economic Community, and International Monetary Fund.

TABLE 8

British Business Cycle Statistics, 1961:IQ-1986:IIQ Filter: Linear Trend and Residuals from Projection onto U.S. GNP

Variable	Standard Deviation	Corr. with GNP (-1)	Corr. with GNP	Corr. with GNP (+1)
GNP	2.5%	.76	1.00	.76
Consumption	2.5	.40	.43	.23
Investment	7.3	.52	.60	.67
Government spending	5.2	.46	.46	.38
Real exports	10.5	.37	.42	.27
Real imports	11.6	.60	.65	.60
Net exports	9.6	-.33	-.33	-.42
Average hours worked	2.2	-.18	-.15	-.20
Total hours worked	3.0	-.15	-.06	-.04
Employment	2.0	-.04	.01	.08
Labor force	1.4	-.22	-.19	-.15
GNP/total hours	4.1	.59	.67	.51
GNP/worker	3.2	.62	.77	.54
Exchange rate	12.6	.27	.27	.25
Net capital stock	3.6	.43	.46	.41
Equipment	3.2	.45	.48	.42
Buildings	3.8	.41	.45	.40

NOTE: Corr. = correlation.
SOURCES: Bank of England, European Economic Community, International Monetary Fund, and Citibase.

some explanatory power for business cycles. The cost is the *distortion* introduced into the economy if monetary policy does have real effects but is used in response to a ***real*** shock for which the economy is responding in an optimal way.

If policymakers want to use monetary policy for short-run stabilization rather than solely for longer-term inflation goals, they should base monetary policy on some indicators of the ***source*** of disturbances. If a previous change in the money supply has led to a change in output, and if there is time to reverse the money supply change to avoid the output change, then that reversal will reduce the inefficiency.

Similarly, if the economy is responding in an ***inefficient*** manner to some disturbance, and if monetary policy can help reduce the inefficiency, then it may be reasonable for policy to do so. But if the change in output is an optimal response to a real disturbance, then monetary policy will only introduce inefficiencies.

If policymakers could be sure of the source of disturbances, then they could use that information to formulate policy. Of course, they cannot be sure of the source. Therefore, an optimal statistical decision framework should be used for policy. This involves using existing information to try to determine, in the best way possible, the source of the disturbance, and using some estimates of the effects of money on output and of the losses from an inefficient level of output to set monetary control variables in the face of uncertainty.

The contribution of RBC theory has been to show that many aggregate fluctuations can possibly be viewed as optimal responses to external disturbances. If monetary policy is to be conducted with a goal of short-run stabilization, policymakers should use the information in RBC models to try to avoid interfering with these optimal responses.

One way to use the information would be to use a set of estimates similar to those in Christiano and Ljungqvist (1988), along with estimates of the difference between actual GNP and that predicted by RBC models, to infer the probability that the economy is responding optimally to a disturbance—as RBC models would predict—or whether it is responding, presumably inefficiently, to a monetary disturbance. The greater the likelihood that the fluctuation in GNP can be explained by the RBC model, the weaker the case for activist monetary policy, and vice versa. Of course, this presumes that the existing class of RBC models, in which the economy responds to disturbances in an optimal way, provides a good description of the response.

An alternative possibility is that disturbances are real rather than monetary in nature, but that the responses of the economy are suboptimal due to market failures of some kind.[9] This appears to place a caveat on the policy discussion here. But the caveat is not particularly strong, given the current state of knowledge, for several reasons. First, there is the question of whether government — particularly monetary policymakers — can do anything to improve welfare in suboptimal real business cycles, or to lessen the magnitude of business cycles (if that would improve welfare). Can monetary policy be of any use here, or must the government policies, if any are useful at all in this regard, be real? Second, attempts at such policies might do more harm than good in our current state of knowledge, even if they might be useful in the future. Third, there is the question of how much weight should be placed on the view that the economy responds in suboptimal ways to real disturbances. Inclusion of these features in RBC models has not been necessary to yield the degree of fit obtained so far.

Is there any reason to think that in the future RBC models will advance particularly by introducing these features, or is the tendency to include them more the result of a particular political propensity? No quantitative RBC model has yet been developed along these lines.[10]

Multicountry models such as the one outlined in section VI would be required to determine the appropriate policy response to a foreign shock. A *foreign* disturbance that induces inefficient aggregate fluctuations in that country might also induce inefficiencies in the U.S. economy and therefore warrant a domestic policy response. Alternatively, such a foreign disturbance might change opportunities only in the U.S. economy and result in efficient reactions to the inefficient foreign fluctuations, which would not warrant a domestic policy response. Further research on international transmission is required to determine the best policy response to foreign disturbances.

I do not want to minimize the difficulties in using RBC analysis, in its current state, to determine whether a policy response might be appropriate. But the existence of these difficulties neither precludes the use of the models in their current state nor warrants ignoring the evidence that, given current models, business-cycle phenomena can be quantitatively explained at least as well as an optimal response than as a suboptimal response to exogenous disturbances.

Prescott (1986a) states that the key policy implications of his research are that costly efforts at stabilization policy are likely to be counterproductive, because they may reduce the rate of technological change, and that economic fluctuations are optimal responses to uncertainty in the rate of technological change. He also contends that optimal policies should be designed to affect the long-run rate of technological change, but that the precise designs of institutions and policies requires further research on the determinants of technical progress. Given the current evidence on inflation and long-term economic growth, this conclusion supports a monetary policy geared toward low inflation and with less concern about fluctuations in real GNP.[11] Fortunately, this conclusion is consistent with the one based on stabilization considerations.

■ 9 These failures might involve externalities or inefficiencies resulting from government policies such as distorting taxation, unemployment insurance, effects of Social Security on savings, or government regulations

10 The most promising modifications in this regard may be the introduction of imperfect competition as in Hall (1988). However, in this case, it is not clear that *monetary* policy would have a role in an optimal policy response to external disturbances.

■ 11 See Gavin and Stockman (1988).

References

Abraham, Katharine G., and Lawrence F. Katz. "Cyclical Unemployment: Sectoral Shifts or Aggregate Disturbances?" *Journal of Political Economy.* 94, no. 3 (June 1986): 507-22.

Altug, Sumru. "Gestation Lags and the Business Cycle." Carnegie-Mellon University Working Paper, 1983.

Backus, David K., and Patrick J. Kehoe. "International Evidence on the Historical Properties of Business Cycles." University of Minnesota Working Paper, 1988.

Barro, Robert J. *Macroeconomics,* Second Edition. New York: John Wiley and Sons, 1987.

______. "A Capital Market in an Equilibrium Business Cycle Model." *Econometrica.* 48 (1980): 1393-1417.

______. "Rational Expectations and the Role of Monetary Policy." *Journal of Monetary Economics.* 2 (1976): 1-32.

Barsky, Robert B., and Jeffrey A. Miron. "The Seasonal Cycle and the Business Cycle." *Journal of Political Economy* (1988, forthcoming).

Baxter, Marianne, and Alan C. Stockman. "Business Cycles and the Exchange Rate Regime: Some International Evidence." Rochester Center for Economic Research Working Paper, 1988.

Benzivinga, Valerie. "An Econometric Study of Hours and Output Variation with Preference Shocks." University of Western Ontario Working Paper, 1987.

Berndt, Ernst. "Energy Price Increases and the Productivity Slowdown in U.S. Manufacturing." In *The Decline in Productivity Growth,* Conference Series No. 22. Federal Reserve Bank of Boston, 1981.

Bils, Mark J. "Real Wages over the Business Cycle: Evidence from Panel Data." *Journal of Political Economy.* 93, no. 4 (August 1985): 666-89.

Brock, William A. "Asset Prices in a Production Economy." In John J. McCall, ed., *The Economics of Information and Uncertainty.* Chicago: The University of Chicago Press, 1982.

Campbell, John Y., and N. Gregory Mankiw. "Permanent and Transitory Components in Macroeconomic Fluctuations." *American Economic Review Papers and Proceedings.* 77, no. 2 (May 1987a): 111-17.

______. "Are Output Fluctuations Transitory?" *Quarterly Journal of Economics.* 2 (November 1987b): 857-80.

Cho, Jang-Ok, and Richard Rogerson. "Family Iabor Supply and Aggregate Fluctuations." *Journal of Monetay Economics.* 21, no. 2/3 (March/May 1988): 233-46.

Christiano, Lawrence J. "Why Does Inventory Investment Fluctuate So Much?" *Journal of Monetary Economics.* 21, no. 2/3 (March/May 1988): 247-80.

______**, and Martin Eichenbaum.** "Is Theory Really Ahead of Measurement? Current Real Business Cycle Theories and Aggregate Iabor Market Fluctuations." National Bureau of Economic Research Working Paper No. 2700 (September 1988).

______**, and Lars Ljungqvist.** "Money Does Granger-Cause Output in the Bivariate Output-Money Relation." *Journal of Monetay Economics.* (1988, forthcoming).

Clark, Peter. "The Cyclical Component of U.S. Economic Activity." *Quarterly Journal of Economics.* 102, no. 4 (November 1987): 797-814.

Cochrane, John H. "How Big is the Random Walk in GNP?" University of Chicago Working Paper, 1986.

Davis, Steven J. "Fluctuations in the Pace of Iabor Reallocations." Volume 27 in the Carnegie-Rochester Conference Series on Public Policy, Autumn 1987, 335-402.

Donaldson, John B., and Rajnish Mehra. "Stochastic Growth with Correlated Production Shocks." *Journal of Economic Theoy.* 29, no. 2 (April 1983): 282-312.

Eichenbaum, Martin, Lars P. Hansen, and Kenneth J. Singleton. "A Time Series Analysis of Representative Agent Models of Consumption and Leisure Choice Under Uncertainty." National Bureau of Economic Research Working Paper No. 1981 (July 1986).

Evans, George W. "Output and Unemployment Dynamics in the United States: 1950-1985." Stanford University Working Paper, 1986.

Fay, **Jon A., and James L. Medoff**. "labor and Output Over the Business Cycle: Some Direct Evidence." *American Economic Review.* 75, no. 4 (September 1985): 638-55.

Friend, Irwin, and Marshall E. **Blume**. "The Demand for Risky Assets." *American Economic Review.* 65, no. 5 (December 1975): 900-22.

Gavin, William T., and Alan C. Stockman. "The Case for Zero Inflation." Federal Reserve Bank of Cleveland. *Economic Commentary,* September 15, 1988.

Greenwood, Jeremy, Zvi Hercowitz, and Gregory W. Huffman. "Investment, Capacity Utilization, and the Real Business Cycle." *American Economic Review.* 78, no. 3 (June 1988): 402-17.

Hall, Robert E. "A Non-competitive, Equilibrium Model of Fluctuations." National Bureau of Economic Research Working Paper No. 2576 (May 1988).

Hamilton, James D. "A Neoclassical Model of Unemployment and the Business Cycle." University of Virginia Working Paper, 1987a.

_______. "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle." University of Virginia Working Paper, 1987b.

_______. "Historical Causes of Postwar Oil Shocks and Recessions." *Energy Journal.* 6 (1985): 97-116.

_______. "Oil and the Macroeconomy Since World War II." *Journal of Political Economy.* 91, no. 2 (April 1983): 228-48.

Hansen, Gary D. "Indivisible Iabor and the Business Cycle." *Journal of Monetay Economics.* 16, no. 3 (November 1985): 309-27.

Hansen, Lars P., and Kenneth J. Singleton. "Stochastic Consumption, Risk Aversion, and the Temporal Behavior of Asset Returns." *Journal of Political Economy.* 91, no. 2 (April 1983): 249-65.

Heckman, James J., and Thomas E. MaCurdy. "A Life Cycle Model of Female Labour Supply." *Review of Economic Studies.* 47, no. 1 (1980): 47-74. *[Corrigendum.* 47 (October 1982): 659-60.]

Horning, Bruce C. "labor Hoarding and the Business Cycle." Vanderbilt University Working Paper, 1988.

Jones, Ronald W., and Douglas D. Purvis. "International Differences in Response to Common External Shocks: The Role of Purchasing Power Parity." In E. Claassen and P. Salin, eds., *Recent Issues in the Theoy of Flexible Exchange Rates.* Amsterdam: North-Holland Press, 1983, 33-55.

King, Robert G., Charles I. Plosser, and Sergio T. Rebelo. "Production, Growth, and Business Cycles, I: The Basic Neoclassical Model." *Journal of Monetay Economics.* 21, no. 2/3 (March/May 1988a): 195-232.

_______. "Production, Growth, and Business Cycles, II: New Directions." *Journal of Monetay Economics.* 21, no. 2/3 (March/May 1988b): 309-42.

Kravis, Irving B., and Robert E. Lipsey. "Toward an Explanation of National Price Levels." Princeton Studies in International Finance, No. 52 (November 1983).

Kydland, Finn E. "labor-Force Heterogeneity and the Business Cycle." In Karl Brunner and Allan H. Meltzer, eds., *Essays on Macroeconomic Implications of Financial and Labor Markets and Political Processes.* Volume 21 in the Carnegie-Rochester Conference Series on Public Policy, Autumn 1984, 173-208.

, **and Edward C. Prescott.** "The Workweek of Capital and its Cyclical Implications." *Journal of Monetary Economics.* 21, no. 2/3 (March/May 1988): 343-60.

_______, **and Edward C. Prescott.** "Time to Build and Aggregate Fluctuations." *Econometric~*50, no. 6 (November 1982): 1345-70.

Lilien, David M. "Sectoral Shifts and Cyclical Unemployment." *Journal of Political Economy.* 90, no. 4 (August 1982): 777-93.

Long, John B. Jr., and Charles I. Plosser. "Real Business Cycles." *Journal of Political Economy.* 91, no. 1 (February 1983): 39-69.

Loungani, Prakash. "Oil Price Shocks and the Dispersion Hypothesis." *Review of Economics and Statistics.* 68, no. **3** (August 1986): 536-39.

Lucas, Robert E. Jr. "On the Mechanisms of Economic Development." *Journal of Monetary Economics.* 22 (1988): 3-42.

______. "Interest Rates and Currency Prices in a Two-Country World." *Journal of Monetay Economics.* 10, no. 3 (November 1982): 335-60.

. "An Equilibrium Model of the Business Cycle." *Journal of Political Economy.* 83, no. 6 (December 1975): 1113-44.

MaCurdy, Thomas. "An Empirical Model of labor Supply in a Life-Cycle Setting." *Journal of Political Economy.* 89, no. 6 (December 1981): 1059-85.

Mankiw, N. Gregory. "Real Business Cycles: A Neo-Keynesian Perspective." *Journal of Economic Perspectives.* (1988, forthcoming).

Manuelli, Rodolfo E. "Modern Business Cycle Analysis: A Guide to the Prescott-Summers Debate." Federal Reserve Bank of Minneapolis. *Quarterly Review.* 10, no. 4 (Fall 1986): 3-8.

McCallum, Bennett T. "Real Business Cycle Models." In Robert J. Barro, ed., *Handbook of Modern Business Cycle Theoy.* (1989, forthcoming.)

______. "On 'Real' and 'Sticky-Price' Theories of the Business Cycle." *Journal of Money, Credit, and Banking.* 18 (1986): 397-414.

______. "On Consequences and Criticisms of Monetary Targeting." *Journal of Money, Credit, and Banking.* 17, no. 4 (November 1985): 570-97.

Mehra, Rajnish, and Edward C. Prescott. "The Equity Premium: A Puzzle." *Journal of Monetary Economics.* 15, no. 2 (March 1985): 145-61.

Miron, Jeffrey. "A Cross-Country Comparison of Seasonal Cycles and Business Cycles." University of Michigan Working Paper, 1988.

Mishkin, Frederic S. "The Real Interest Rate: An Empirical Investigation." In Karl Brunner and Allan H. Meltzer, eds., *The Costs and Consequences of Inflation.* Volume 15 in the Carnegie-Rochester Conference Series on Public Policy, Autumn 1981, 151-200.

Murphy, Kevin M., and Robert H. Topel. "The Evolution of Unemployment in the United States: 1968-1985." In Stanley Fischer, ed., *National Bureau of Economic Research Macroeconomics Annual 2.* Cambridge, Mass.: The MIT Press, 1987.

Nelson, Charles R, and Charles I. Plosser. "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications." *Journal of Monetay Economics.* 10, no. 2 (September 1982): 139-62.

Parkin, Michael. "How Firm is the 'Deep Structure' of Real Business Cycle Theory?" *Carnegie-Rochester Conference Series on Public Policy.* (1988, forthcoming).

Pencavel, John. "Labor Supply of Men: A Survey." In Orley Ashenfelter and Richard Layard, eds., *Handbook of Labor Economics.* Amsterdam: North-Holland Press, 1986.

Phillips, Kerk L. "Exploring the Correlation Between Net Exports and Output." University of Rochester Working Paper, 1988.

Prescott, Edward C. "Theory Ahead of Business-Cycle Measurement." In Karl Brunner and Allan H. Meltzer, eds., *Real Business Cycles, Real Exchange Rates, and Actual Policies.* Volume 25 in the Carnegie-Rochester Conference Series on Public Policy, 1986a, 11-44.

______. "Response to a Skeptic." Federal Reserve Bank of Minneapolis. *Quarterly Review.* 10, no. 4 (Fall 1986b): 28-32.

Rogerson, Richard. "Indivisible Labor, Lotteries, and Equilibrium." *Journal of Monetay Economics.* 21, no. 1 (January 1988): 3-16.

______. Topics in the Theory of labor Economics. University of Minnesota, Ph.D. Dissertation, 1984.

, **and Peter Rupert.** "The Effects of Measurement Error on Estimating Equilibrium Models of the Aggregate labor Market." Stanford University Working Paper, 1988.

Rogoff, Kenneth. "'Theory Ahead of Business-Cycle Measurement,' A Comment on Prescott." In Karl Brunner and Allan H. Meltzer, eds., *Real Business Cycles, Real Exchange Rates, and Actual Policies.* Volume 25 in the Carnegie-Rochester Conference Series on Public Policy, 1986, 45-48.

Romer, Paul M. "Increasing Returns and Long-Run Growth." *Journal of Political Economy.* 94, no. 5 (October 1986): 1002-37.

Rush, Mark "Real Business Cycles." Federal Reserve Bank of Kansas City. *Economic Review.* 72, no. 2 (February 1987): 20-32.

Salyer, Kevin D. "Exchange Rate Volatility: The Role of Real Shocks and the Velocity of Money." *Economic Inquiry.* (1988, forthcoming).

Sims, Christopher A. "Policy Analysis with Econometric Models." *Brookings Papers on Economic Activity.* (1982): 107-52.

_______. "Macroeconomics and Reality." *Econometric~*48, no. 1 (January 1980): 1-48.

Solow, Robert M. "Technical Change and the Aggregate Production Function." *Review of Economics and Statktics.* 39 (1957): 312-20.

Stock, James H., and Mark W. Watson. "Testing for Common Trends." Harvard University Working Paper, 1986.

Stockman, Alan C. "Sectoral and National Aggregate Disturbances to Industrial Output in Seven European Countries." *Journal of Monetay Economics.* 21, no. 2/3 (March/May 1988a): 387-410.

. "Real Exchange Rate Variability Under Pegged and Floating Nominal Exchange Rate Systems: An Equilibrium Theory." In Karl Brunner and Allan Meltzer, eds., *Carnegie-Rochester Conference Series on Public Policy.* (1988b, forthcoming).

_______. "The Equilibrium Approach to Exchange Rates." Federal Reserve Bank of Richmond. *Economic Review.* 73, no. 2 (March-April 1987): 12-30.

_______. "A Theory of Exchange Rate Determination." *Journal of Political Economy.* 88, no. 4 (August 1980): 673-98.

_______**, and Lars E.O. Svensson.** "Capital Flows, Investment, and Exchange Rates." *Journal of Monetay Economics.* 19, no. 2 (March 1987): 171-202.

_______**, and Harris Dellas.** "International Portfolio Nondiversification and Exchange Rate Variability." *Journal of International Economics.* (1988, forthcoming).

Summers, Lawrence H. "Some Skeptical Observations on Real Business Cycle Theory." Federal Reserve Bank of Minneapolis. *Quarterly Review.* 10, no. 4 (Fall 1986): 23-27.

Walsh, Carl E. "New Views of the Business Cycle: Has the Past Emphasis on Money Been Misplaced?" Federal Reserve Bank of Philadelphia. *Business Review.* (January 1986): 3-13.

Watson, Mark W. "Univariate Detrending Methods with Stochastic Trends." *Journal of Monetay Economics.* 18 (July 1986): 49-75.