

# RATIONAL EXPECTATIONS BUSINESS CYCLE MODELS: A SURVEY

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Development of rational expectations models of the business cycle has been the central issue on the macroeconomic research agenda since the influential analyses of Robert Lucas (1972a, 1972b). In this essay, we review these developments, focusing on the extent to which the rational expectations perspective has generated a new understanding of economic fluctuations.

Economists have long suspected that expectations play a central role in the business cycle, particularly in determining the relationship between money and economic activity. For example, Haberler's (1937) classic interwar survey of business cycle theory stresses the role of expectations, in a variety of theories that explain the business cycle as a Frischian (1933) interaction of external shocks and internal propagation mechanisms. Expectations also constitute an independent source of shocks in "psychological" theories of the business cycle. However, as Haberler's survey makes clear, there has long been substantial disagreement among economists about the relative importance of various economic factors—sources of shocks and propagation mechanisms—in determining the observed character of business fluctuations. With the development of formal econometric analyses of business cycles—beginning with Tinbergen's work (1939) and proceeding through Sargent (1981)—it has become clear that unrestricted models of expectations preclude a systematic inquiry into business fluctuations.

The postulate that expectations are rational in the sense of Muth (1961), i.e., that economic agents accumulate information and utilize information efficiently, imposes considerable discipline on business cycle analysis. At present, no single rational expectations model has captured all of the central elements

of the business cycle. One could take the view that an ultimate explanation of economic fluctuations will require a return to "psychological influences." We prefer to believe that existing individual models highlight specific features that are important and that the gradual accumulation of knowledge about shocks and propagation mechanisms will ultimately yield rational expectations models consistent with observed business cycles.

The organization of our discussion is as follows. First, we briefly consider a set of "stylized facts" that any successful model must minimally produce. Then, we turn to four categories of rational expectations models of the business cycle, considering in turn how each has been developed to account for some specific set of stylized facts. We then review the empirical evidence regarding the overall performance of each class of models.

We begin by exploring the role of expectations in the basic real business cycle models of Kydland and Prescott (1982) and Long and Plosser (1983), in which dynamics of business cycles reflect the interaction of temporary real shocks and intertemporal (capitalistic) production. We then consider the monetary business cycle models of Lucas (1972a, 1973) and Barro (1976, 1980) which utilize incomplete information as a rationale for temporary real effects of monetary disturbances. Although agents have rational expectations in these models, lack of timely information on monetary shocks implies that agents erroneously perceive price level movements as representing changes in relative prices. After considering equilibrium models of the business cycle—in which prices are flexible—we turn to Keynesian models of business fluctuation constructed under the rational expectations postulate. Our discussion begins with the analyses of Fischer (1977) and Gray (1976), who model temporary wage stickiness arising from nominal wage contracts. Subsequently, we consider the emerging class of theories that focus on commodity price stickiness, beginning with a parable told by McCallum (1982) and then considering some alternative formal developments by Rotemberg (1982), Mankiw (1985) and Blanchard and Kiyotaki (1987).

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Throughout our discussion, we follow the traditional macroeconomic practice of considering business cycles—defined as the stochastic components of macroeconomic time series—as stationary stochastic processes. This practice is followed in our description of stylized facts, but is also implicit in the theoretical economies that we consider, since the time series generated by these economies are stationary. If, in fact, economic time series exhibit nonstationarity, as argued by Nelson and Plosser (1982), then these classes of models are called into question. In a concluding section we briefly discuss the ongoing development of rational expectations business cycles that are capable of producing model economies that have nonstationary components.

### Stylized Facts

Much of our survey deals with the ability of various business cycle models to generate time series whose properties are consistent with commonly discussed summary statistics, i.e., the stylized facts of business cycles (see e.g., Lucas, 1977). Presentations of these stylized facts typically proceed as follows. First, certain smooth curves are removed from the data, frequently after a logarithmic transformation; these eliminate deterministic growth and seasonal components. Summary statistics are then calculated on the transformed data.

At a minimum the list of real quantity variables to be considered consists of the major national accounts aggregates—consumption, investment and output—along with measures of labor input (manhours, employment). In addition, real wages, real money balances and certain financial activity variables are frequently considered, as in the growth rate of some nominal variables such as the money stock, nominal interest rates and prices. All of the quantity series—including real balances—exhibit significant positive serial correlation at the annual or quarterly interval. They all also display positive covariation, both with output and with each other. They differ somewhat in relative volatilities, notably investment is more volatile than output, which in turn is more volatile than consumption. Evidence concerning the cyclical behavior of the real wage is inconclusive; in part, this reflects a variety of constructs used. In general, however, there does not appear to be a pronounced cyclical relation. Measures of financial activity—such as deposit turnover and bank clearings—are strongly procyclical (Mitchell (1951)). As Lucas (1977) observes, there is little reason to qualify the observations by reference to specific time periods.

However, the relationship between nominal variables and the cycle exhibits less stability over

time. In Mitchell's (1951) consideration of interwar data for the United States, the price level and short-term nominal interest rate were strongly procyclical. More recent investigations by Hodrick and Prescott (1980) into post-war U.S. cycles, document a changing relation, price levels are countercyclical during the latter half of their sample and short-term rates are not systematically related to economic activity. However, most investigations do document a positive relation between income velocity and real activity that mirrors the financial transactions data.

When many sectors are included in this analysis, as in Mitchell (1951), there is a tendency for comovement across sectors and considerable stability in lead-lag relations relative to aggregate output. There do appear to be different degrees of sectoral comovement and amplitude. For example, agriculture does not covary closely with the rest of the economy. The producer and consumer durable goods manufacturing sectors exhibit greater volatility than the services sector.

### Expectations and Real Business Cycles

In recent years, macroeconomists have begun the long-postponed task of developing basic equilibrium models of economic fluctuations. That this is an essential first step was cogently argued by Hicks (1933) over fifty years ago, who stressed that one could not measure the extent of disequilibrium without first determining the content of equilibrium theory and that, in a dynamic stochastic system, there is rich content to equilibrium theory.

The analyses of Kydland and Prescott (1982) and Long and Plosser (1983) explain the dynamics of business cycles as reflecting the interaction of real shocks—to total factor productivity—and intertemporal (capitalistic) production possibilities. The Long and Plosser (1983) analysis develops some general economic principles—mentioned by Haberler (1937)—by studying the decisions of a representative consumer (Robinson Crusoe) who directly operates the production technology of the economy. In this context the business cycles that arise are Pareto efficient. Thus, the mechanisms that generate cyclical activity are quite general and should carry over to richer macroeconomic models that possess incomplete information and nominal rigidities, including those that we consider below.

For example, the analysis of Long and Plosser shows that even if disturbances to production possibilities are temporally independent, real quantities—output, consumption and capital—display positive serial correlation. Shocks are propagated over time due to the preference of economic agents for

smoothing consumption, and the fact that the intertemporal technology makes smoothing feasible. However, the persistence of shocks is limited by the existence of fixed factors (such as a fixed endowment of time). For this reason, the ultimate effects of shocks are negligible. That is, in the periods after a productivity shock, there is negative net investment—relative to a trend value—as the economy adjusts back towards a steady-state. This residual role of investment implies that it displays great cyclical volatility (see King, Plosser, and Rebelo (1988a)). Thus, with temporally independent shocks, the basic equilibrium model predicts some of the central stylized facts—positive serial correlation in consumption and production, as well as the relative volatilities—but fails to capture the positive serial correlation of investment.

When there are many commodities, Crusoe's preference for diversity in his consumption bundle means that the effects of a temporary productivity shock in one sector are also transmitted across other sectors. Thus, as Long and Plosser (1983) stress, the basic equilibrium model also predicts that there will be co-movement, with economic activity in diverse sectors tending to rise and fall together. Therefore, the basic equilibrium model also predicts another of the centralized stylized facts emphasized by Mitchell (1951).

Temporary shocks to factor productivity typically exert offsetting income and substitution effects on the effort decision, so that Crusoe's optimal cyclical variation in employment is ambiguous. In the parametric models of Long and Plosser, these two effects offset exactly, so that there is zero cyclical variation in labor input. Kydland and Prescott (1982) explore the implications of greater intertemporal substitution in preferences, using a non-time-separable but recursive preference specification. In this case, Crusoe finds it optimal to substitute effort toward periods in which its marginal reward is high, which leads effort to respond positively to temporary productivity shocks.

Even with temporary shocks to productivity, the intertemporal consequences of capital accumulation and effort decisions imply that Crusoe must form expectations about future production opportunities. In general, optimal decision rules will be different when Crusoe makes alternative assumptions about the nature of shocks and for alternative specifications of preferences and technology. Furthermore, the rational expectations assumption plays a pivotal role in the process of transforming optimal social decisions into a competitive theory of fluctuations, for there will be a coincidence between Crusoe's (or a

social planner's) decisions and the decentralized actions of private agents only if expectations are rational.

Expectations have additional implications for Crusoe's decision rules when there is serial correlation in the exogenous factors, i.e., total factor productivity. For example, Crusoe's incentives for saving/investment to achieve consumption smoothing, are reduced if changes in (expected) future productivity accompany changes in current productivity because of larger wealth effects of such changes. Further, anticipated future variations in productivity also affect the marginal reward to current investment and the rewards to future effort, exerting additional substitution effects on current decisions.

### Evidence on Real Business Cycles

Although real business cycle models produce some qualitative features of the business cycle it remains to determine whether they explain fluctuations *quantitatively*. The initial research effort addressing these questions has been undertaken by Kydland and Prescott in an influential series of papers (summarized in Prescott (1986)).

Following the methodological recommendations of Lucas (1980), Kydland and Prescott restrict the number of free parameters in their model economy by a number of steady-state conditions and also by the extensive use of behavioral parameter estimates taken from applied studies in other fields. For example, they use the observed constancy of labor's share to pin down the parameters in a Cobb-Douglas production function, and results from analyses of financial markets to restrict a preference curvature parameter governing the extent of intertemporal substitution/risk aversion. Following Solow (1957), they measure variations in total factor productivity as a residual from the aggregate production function and choose a simply Markovian stochastic process to capture the serial correlation in this series.

The results of the Kydland-Prescott studies have been surprising to most economists. The initial model economy produced summary statistics—second moments of consumption, investment, output, productivity, and effort—that accorded with the stylized facts described previously. (The specific presentation of the stylized facts to which the Kydland-Prescott model was compared is contained in Hodrick and Prescott (1980)). However, it is also clear that the basic neoclassical business cycle model as developed by Kydland and Prescott does not meet the stringent standards of rational expectations econometrics. Altug (1988) subjects the Kydland-Prescott model to rational expectations econometric procedures and finds that the model's restrictions are

rejected by the data. Given the level of abstraction currently found in this model this rejection is perhaps not surprising; it is nevertheless encouraging that these types of models can loosely mimic some important aspects of cyclical activity.

The basic neoclassical model of Kydland and Prescott has been criticized on a number of other grounds that warrant further discussion. First, the model has no implications for any cyclical variation in employment or unemployment. That is, the model uses the representative agent paradigm and permits a smooth tradeoff between hours and output so all adjustments in labor effort take place in terms of hours and not numbers of workers. Forcing a (more realistic) choice between working full time or not at all would generally introduce problematic nonconvexities in production possibilities. However, the important work of Rogerson (1988) provides a method for analyzing production nonconvexities in a representative agent model. Rogerson uses the fact that by introducing social arrangements that formally resemble lotteries—in that they specify probabilities of working full time or not at all—the representative agent problem can be made convex. This contrived randomness in the representative agent and corresponding social planner's problem improves welfare by smoothing the opportunities for effort by averaging across the population. It corresponds in a competitive, multi-agent framework to an economy in which some agents are employed and some are not, and in which their relative numbers can fluctuate over time. Further, the indivisibility of work effort results in a dramatic change in the corresponding social planner's problem that can be used to compute competitive outcomes. This optimum problem can be interpreted as that of a single agent with a greater degree of intertemporal substitution in labor supply than that of the identical agents that populate the economy. This is empirically important within the Kydland-Prescott model, since the greater degree of intertemporal substitution in aggregate labor supply is capable of producing quantitatively greater variations in employment (see Hansen (1985)).

The main potential theoretical alternative for smoothing production nonconvexities is to allow for heterogeneity of preferences. However, given the primitive state of methods for solution and estimation of dynamic macroeconomic models this alternative is not practical at the moment. It is, therefore, likely that Rogerson's insight will be widely employed. Overall, the focus of most business cycle models on hours and not on the number of employed workers represents a transient feature and is not an essential character of the real business cycle approach.

The central criticism of the Prescott model is that its internal mechanisms do not by themselves produce much serial correlation in economic time series. This is because, even though the model provides a mechanism for the propagation of shocks, the share of physical capital in output is small (about one-third). Therefore, serial correlation introduced by capital accumulation in order to accomplish consumption smoothing cannot be very important quantitatively in this framework (see King, Plosser, and Rebelo (1988a)). Rather, the cyclical character of the variation in total factor productivity—the Solow residual which is a Markov process that is close to a random walk—is used to generate persistence.

The stochastic nature of the shocks is therefore a key ingredient for generating the cyclical behavior in the Kydland-Prescott model and there has also been some scepticism directed toward the nature of these shocks. For example, one questions whether this construct really captures an exogenous variable (technological change). If cyclical variations in the intensity of utilization of capital and labor inputs are significant, then important biases could arise, since endogenous decisions with respect to utilization will incorrectly be attributed to changes in technology. Further, in industries that are noncompetitive, there may be cyclical variations in the relationship between marginal cost and price (mark-ups) that would be counted as shocks to factor productivity by the Solow-Prescott procedure (see Bills, 1985). Also, Barro (1986) and others have expressed scepticism that there are real shocks of sufficient magnitude to generate observed cycles.

Finally, with the exception of King and Plosser (1984), these models cannot generate any of the observed correlations between money and economic activity, since financial sectors have been omitted from most real business cycle models.

King and Plosser (1984) extend the real business cycle model by incorporating accounting services as a factor in production of final goods. Consequently, when there are increases in total factor productivity in the final goods sector, there is an induced increase in the quantity of such services (an intermediate good), which rationalizes Mitchell's (1951) finding that measures of transactions activity in the banking sector are strongly procyclical. In considering extensions to incorporate demand deposits and outside currency, King and Plosser follow standard macroeconomic practice by assuming that service flows are proportional to asset stocks. Therefore, real quantities of currency and demand deposits covary positively with economic activity. Moreover, if price levels are not too countercyclical, then nominal demand

deposits will move with the cycle, while movements in nominal currency may be unrelated to the evolution of the cycle, a hypothesis for which King and Plosser provide some supporting empirical evidence. However, as McCallum (1986) points out, if the central bank is targeting currency plus deposits, then these correlations can also arise in a monetary business cycle.

The main contribution of this literature is the detailed development of propagation mechanisms which may not be sensitive to the nature of the initiating shocks. Therefore, the real business cycle literature may serve as a useful complement to other equilibrium business cycle models, such as those involving monetary impulses. It is to this class of models that we now turn.

### Money, Expectations and Business Cycles

The pioneering work incorporating rational expectations into monetary models of the business cycle was undertaken by Lucas (1972a, 1972b, 1973). Macroeconomists' concern with linking the real and monetary sides of the economy probably stems from the influential work of Friedman and Schwartz (1963), which appears to document an important causal role for nominal impulses including shifts in the money supply and the velocity of circulation.

The basic feature of imperfect information variants of equilibrium business cycle theory can be depicted in a simple log-linear business cycle model that essentially follows Lucas (1973). In this model, a non-storable commodity is produced at distinct locations indexed by  $z$ . Production in each location depends linearly on last period's output and on the perceived relative price,  $p_t(z) - E_t p_t$ , where  $E_t p_t$  is the expected value of the log of the aggregate price level. Output demand at any location is positively related to factors influencing aggregate demand and a relative demand shock.

To close the model, one must specify a stochastic process governing the supply of money and the information set available to agents at each location. Agents are typically assumed to know the economy's structure, their current local price,  $p_t(z)$ , and past values of all variables and disturbances. They do not observe the contemporaneous values of aggregate data or of the disturbances.

This simple framework yields a number of key results that extend to other members of this class of equilibrium business cycle models. The primary result is that it is only *unperceived* monetary disturbances which produce real effects. Perceived changes in money affect both local and aggregate prices uniformly so that these are neutral toward relative

prices and real activity. It is instructive to trace through the effects of a positive monetary shock. The demand for goods at location  $z$  rises, causing an increase in the price at location  $z$ . With incomplete information, suppliers in location  $z$  do not know whether any particular increase in  $p_t(z)$  such as that arising from the monetary shock is due to aggregate or relative disturbances. Given the stochastic structure of the model, agents will generally attribute some of a money induced movement in  $p_t(z)$  to an improvement in relative prices and therefore they will supply more. (The proportion of the price movement attributed to relative shifts in demand depends on the underlying variances of two shocks.) Therefore, an *unanticipated* increase in the money supply will cause output to rise precisely because it is mistakenly perceived as representing a change in relative prices. If, on the other hand, agents accurately perceived the shift in the money supply, they would neutralize the effects of this disturbance. Sargent and Wallace (1975) use this to develop the implication that anticipated movements in money supply have no real effects.

An initial criticism of Lucas's analysis involved the fact that this simple model could not generate the serial correlation evident in economic time series (Hall, 1975). But, as Lucas (1975) argues, linking the model of monetary shocks to capital accumulation and the other propagation mechanisms of real business cycle theory potentially overcomes this difficulty. For example, Sargent (1979) provides a nicely worked out linear business cycle model that utilizes adjustment costs to propagate temporarily misperceived nominal shocks.

The neutrality of perceived monetary disturbances represents a substantial problem for this class of equilibrium business cycle models. In reality, monetary data (although somewhat noisy) is produced in a very timely manner. If the relevant decision period is approximately one quarter, agents' information sets should plausibly be modeled as including the available contemporaneous monetary data. In this situation, King (1981) shows that fluctuations in output should be uncorrelated with the reported monetary statistics, essentially because expectation errors about relative prices should be uncorrelated with available information. Further, revisions in the monetary statistics should be correlated with real activity because the initial reporting errors induce misperceptions.

Thus, if monetary disturbances are accurately perceived then they cannot be business cycle impulses in the manner suggested by Lucas (1972a, 1973). It is important to stress that this monetary

neutrality does not rule out incomplete information as a rationale for the non-neutrality of other nominal disturbances (such as money demand shocks) that may more plausibly be not directly observable over the relevant decision period.

Moreover, King's (1981) result relies on the assumption that monetary disturbances are exogenous. If the central bank leans against changes in interest rates or if changes in inside money are correlated with real activity, then contemporaneous monetary statistics may be correlated with output even if they are accurately perceived. King and Trehan (1984) show that monetary shocks can be non-neutral due to a signaling effect, if these statistics convey information about unobservable real economic conditions that influence agent's production and investment decisions.

It has also been suggested that King's result may be too strong, since although monetary data is available it may also be quite costly to process. Therefore, agents may in some sense ignore the data in making their labor/leisure decisions, which would imply that the initial specification of the information set was appropriate. (Edwards (1981) constructs a model in which there is a competitively determined fraction of agent that acquire costly information about the true monetary state, but it is unclear from his analysis whether business cycles can be a large social problem if the individual costs of information are small.) The preceding argument reveals the arbitrary manner in which information structures are specified in this class of models and this is a problem that has not been dealt with satisfactorily in the macroeconomics literature to date.

There are numerous extensions and modifications of the simple model just considered. The most notable are those of Barro (1976, 1980), which are motivated by intertemporal substitution possibilities rather than by contemporaneous expected relative prices (as in Lucas (1973) and Friedman (1968)). But these analyses preserve the central empirical implications of the simple model: (i) the irrelevance of predictable variations in monetary policy, and (ii) the causal link between unperceived monetary disturbances and real activity.

### **Empirical Analyses of Money and Business Cycles**

The empirical work on monetary impulses in equilibrium business cycle models is much too extensive to cover completely in this essay. Rather, we review three major lines of empirical investigation that bear on the relevance of this line of research. By and large, the evidence suggests that models of this class

do not adequately represent links between money and business cycles.

*Tests based on monetary decompositions.* The first layer of tests examined the relationship between unanticipated movements in nominal variables and economic activity, with the key references being Sargent (1973, 1976) and Barro (1977, 1978). Following Barro's lead, subsequent investigations have focused on reduced form relations between money and economic activity, rather than estimation of systems incorporating a "Lucas supply function" as in Sargent's early studies. The idea behind the Barro-type tests is to decompose the observed monetary time series into unanticipated and anticipated components by specifying a prediction rule. This two-stage procedure involves estimation of a money supply process, with the residuals treated as unanticipated money and the fitted values treated as anticipated money. The empirical studies then investigate whether constructed unanticipated money influences various measures of economic activity and if the constructed anticipated components of money are neutral. Initial tests by Barro utilized a two-step procedure, with later investigations employing the econometrically more efficient method of estimating a simultaneous equation system and testing cross equation restrictions (Leiderman (1980), and Abel and Mishkin (1983)).

These tests concern the joint hypothesis that expectations are rational, that the money supply process is correctly specified, that the process governing the behavior of the economy is correct, and that anticipated money is neutral. Thus, correct specification of all of these elements is necessary for successful execution of these tests. For example, if the Federal Reserve's reaction function is misspecified through the exclusion of relevant variables then measures of unanticipated money will include the effects of these variables. If these excluded variables are correlated with explanatory variables in equations that depict the behavior of the relevant economic magnitudes under consideration, which is likely to be the case, then coefficients will be biased and test statistics will be inappropriate.

The results of this type of tests are mixed. The analysis of Barro (1977) concerning the relationship between money and unemployment supports the implications of equilibrium business cycle theory. Working at the annual interval, Barro provides evidence that (i) anticipated monetary changes do not affect real activity in a statistically significant manner, and (ii) that unanticipated money growth affects output over three years, with the peak effect

concentrated in the second year. A follow-up study of the price level at the annual interval, Barro (1978), provides evidence that price level movements accord less well with the predictions of theory. Although anticipated monetary changes have a one-for-one impact on the price level, the response of the price level to monetary shocks is more protracted than the response of real activity. Barro and Rush (1980) provide additional evidence using data on unemployment, output, and prices from the quarterly post-war time series, the interval that has subsequently been studied by most researchers. Generally this study confirms Barro's earlier results that unanticipated money influences real GNP (positively) and unemployment (negatively) but, as with the annual data, the results involving the price level are less persuasive. Although unanticipated money does affect the price level less than one for one, the lag structure for unanticipated money is inconsistent with lags found in output and unemployment equations.

Working at the quarterly interval, Mishkin (1982) and Merrick (1983) provide evidence against the neutrality hypothesis, where the hypothesized money supply process and lag lengths are altered from the Barro-Rush specification. Merrick essentially tries to replicate the Barro-Rush quarterly results on real GNP, after altering the money supply process by including lagged Treasury bill rates and stock market returns. He finds that unanticipated money no longer affects real GNP, but that anticipated money does. Mishkin also alters the money supply process by including past Treasury bill rates but finds that this does not affect the Barro-Rush results over a somewhat different sample period, where an eight-quarter-maximum lag is imposed. However, upon extending the lag lengths on unanticipated and anticipated money to twenty quarters, he is able to reject the joint hypothesis of rationality and neutrality. The Merrick and Mishkin results cast doubt on the robustness of the neutrality results obtained at the annual interval. However, in interpreting the above results, one must keep in mind that a composite hypothesis is being tested. For example, if anticipated money was neutral, but if the central bank engaged in interest-rate smoothing—as in Goodfriend (1987)—then variations in money growth would accompany changes in the real interest rate. If the factors that lead to these changes in the real interest rate are omitted in the output equation, anticipated money will spuriously appear to be non-neutral.

Leiderman (1983) investigates the cyclical pattern of real wage movements in response to money on both annual and quarterly data. According to neoclassical theory, the real wage should decline with

application of an increased amount of effort to a fixed stock of capital. Thus, if misperceived monetary shocks fool labor suppliers into working more, then monetary shocks should lower real wages and increase output, so that a countercyclical relationship emerges between monetary shocks and real wages. Also, predictable shifts in money will leave real wages unaffected. Leiderman finds some support—at both the annual and quarterly intervals—for countercyclical variation in the real wage, which is strongest when the real wage is deflated by the wholesale price index and when overtime payments are excluded. However, in a recent study of a number of manufacturing industries, Kretzmer (1985) finds evidence that industry specific product wages (industry wage divided by the industry wpi component) are uniformly positively related to unanticipated monetary shocks.

*Granger causality test.* Another type of neutrality test is based on the following observation: given the relevant state of the economy (capital, etc.), the history of monetary shocks should have no effects on real activity. Sargent (1976) and Sims (1980) utilized this perspective to construct neutrality tests along Granger causality lines. In a multivariate context nominal variables should not Granger-cause (predict) a vector of real variables if these contain the economy's state variables. (Conditions that assure that the state variable is reputable in this form are provided by Sargent (1979)—some may be unwilling to impose such lag length restrictions on error terms, which Sims (1980) argues are incredible.) Sargent (1976), Sims (1980) and Eichenbaum and Singleton (1987) illustrate that the results of such tests are heavily dependent on variable selection and data processing, particularly treatment of nonstationarities.

A variant of this procedure is employed by Haraf (1983), who examines a four-variable-vector autoregression using real output, employment, inventories, and backorders. A constructed unanticipated money series does not Granger-cause the vector process governing the four real variables in the model, a result that is consistent with the simple equilibrium business cycle model. However, Haraf also finds that with the exception of real GNP, contemporaneous unanticipated movements in money have little explanatory power once lagged model variables are taken into account.

*Tests based on contemporaneous monetary data.* The previous tests concentrated on the distinction between unanticipated and anticipated changes in money. However, equilibrium business cycle theory typically predicts that the relevant distinction is

between perceived and unperceived movements in money. Since monetary statistics are readily available, agents misperceive the true monetary state of the economy only to the extent that monetary statistics contain some reporting errors. Therefore, revisions in monetary statistics are indicators of misperceived money, and it is misperceived money that should be the relevant variable in explaining real economic fluctuations. Specific tests of the equilibrium business cycle theory using contemporaneous monetary data—historical statistical reports that were *potentially* available to private agents—are conducted by Barro and Hercowitz (1980) and Boschen and Grossman (1982).

Both of these papers contain evidence contradicting the implications of the simple equilibrium business cycle model outlined above. Barro and Hercowitz find that revisions in the monetary data do not help explain cyclical fluctuations of output or unemployment. Boschen and Grossman focus on King's (1981) observation that output should be uncorrelated with available monetary data. They begin by constructing a more elaborate procedure that yields valid tests of the real effects of exogenous perceived money on output when misperceived money can affect output through a specific propagation mechanism. They find that contemporaneous monetary data is significantly (partially) correlated with real activity, which is inconsistent with the theory. Boschen and Grossman also test whether monetary reporting errors have real consequences and as in Barro-Hercowitz, there is no evidence of real effects. Thus, the Boschen and Grossman findings are inconsistent with the joint hypothesis of (i) a specific equilibrium business cycle model, (ii) that agents utilize contemporaneous information as money, and (iii) that measures of money (original and final reports) are exogenous.

Although properly specified tests are difficult to conduct, the mixed results of these three types of tests does not provide strong support for the equilibrium monetary business cycle view. Consequently, investigation of Keynesian alternatives seems warranted. We begin with the notion that multiperiod contracting imparts some stickiness to the nominal wage.

### Nominal Wage Contracting Models

Much of the nominal wage contracting literature is based on two lines of work. One originates in Taylor (1979, 1980) and the other follows from Gray (1976) and Fischer (1977).

Taylor (1979, 1980) develops a model with multiperiod, overlapping nominal wage contracts and

mark-up pricing. Simulations of the model under the assumption that wage contracts last for three or four quarters are used to investigate the dynamics of output or unemployment. Without any of the neoclassical propagation mechanisms, Taylor's models generate substantial serial correlation from the interactions of wage setting rules and expectations—shocks can last for more than the contract length because these are passed along via other, subsequent contracts. But Taylor's models have been criticized as departing too far from wage setting rules that could plausibly be rationalized by neoclassical methods—thus involving wage setting based on predetermined wage rates of others, which should be irrelevant—and for not containing the natural rate property (for further discussion of Taylor's models, see McCallum (1982)).

The Gray (1976)-Fischer (1977) perspective on wage contracts can be developed as follows. Production takes place at various locations or industries indexed by  $z$ , and depends negatively on the real wage  $w_t(z) - p_t(z)$  in each location. (All variables are expressed in logarithms.) In the one period ahead contracting version of the model, the nominal wage  $w_t(z)$  is set according to the rule  $w_t(z) = E_{t-1} p_t + \gamma(z)(P_t - E_{t-1}P_t)$ ,  $\gamma(z)$  indicates the extent of indexing in industry  $z$ . If  $\gamma(z) = 1$ , then wages in  $z$  are completely indexed to the aggregate price level. Given the nominal wage, firms determine employment along their marginal product curve, the efficiency condition being that the marginal product of labor equals  $w_t(z) - p_t(z)$ . Therefore a rise in the real wage reduces employment and output at location  $z$ .

Aggregate demand at any location is directly related to aggregate real balances and a relative demand shock, as in the equilibrium business cycle model. Also, the money supply is assumed to follow a random walk. In this setting, with incomplete indexing ( $\gamma(z) < 1$ ), a positive money supply shock causes real wages to fall and output to rise. Also, with contracts set at one period in length, shifts in money that were anticipated at  $t-1$  have no real effects. Therefore, tests that only consider the distinction between anticipated and unanticipated money cannot distinguish between equilibrium business cycle models with no contemporaneous information and models with nominal contracts extending for only one period.

However, as Fischer (1977) indicates, when contracts last for more than one period, shifts in money that are anticipated at  $t-1$  will have real effects since some locations are locked into contracts conditioned on period  $t-2$  information. However, Fischer (1980) reports some difficulties in implementing this strategy.



A direct test of the contracting model is performed by Ahmed (1987). Ahmed undertakes a careful study of the relationship between the Phillips curve slope and the degree of wage indexation in a particular industry. (The data set includes 19 Canadian industries.) The contracting model predicts that the responsiveness of industry specific output to unanticipated changes in money should be inversely related to the degree of indexing. That is, greater indexation by a particular industry reduces the responsiveness of real wages to unanticipated money and reduces the change in industry output to a monetary disturbance. Ahmed finds no evidence that there is any relationship between indexation and the magnitude of responsiveness of industry specific output to an aggregate monetary shock. These results are at variance with the implications of the contracting model.

Therefore, the strategy of producing monetary business cycles through nominal wage rigidities does not receive strong empirical support. This has led Keynesians to refocus their attention on nominal rigidities that may occur in other areas of the economy, namely in the price of specific commodities.

### Sticky Prices and Business Cycles

After the Dunlop-Keynes-Tarshis controversy of the 1930s unveiled the lack of confirmation for countercyclical real wages, Keynesian macro-theorists turned from models incorporating stickiness of wages to models featuring stickiness of product prices. This activity spanned the range from rationalizations of the pricing equations in large scale econometric models to the abstract dynamic pricing model of Phelps and Winter (1970) and the nonmarket clearing theory of Barro and Grossman (1976). Curiously, this prior path seems to have been ignored by the profession at large. Until recently, there has been substantial effort allocated to sticky wage models despite their reliance on a countercyclical path for the real wage. However, the past several years have seen increased attention to sticky price models. Although this line of research is still at an early stage and has, as yet, generated little empirical literature, we provide a brief review because of its likely importance in coming years.

Simultaneously with Fischer's wage contract model, Phelps and Taylor (1977) propounded a basic rational expectations model with price stickiness, in a paper that has received far less professional attention than Fischer (1977). However, research into sticky price models was continued by McCallum in an important series of papers. Initially, McCallum focused his investigations on the conditions under

which sticky price models rationalized nonneutrality of monetary shocks while maintaining the neutrality of anticipated monetary policy (1978, 1979, 1980).

More recently, McCallum (1982, 1986) has provided a detailed outline of interactions between nominal shocks, price adjustment, and real activity, which presumably will be developed further in coming years. The key elements of this story are as follows. To economize on certain costs, firms find it optimal to maintain a set nominal price over some period, accommodating variations in relative and aggregate demand through alterations in production and inventories. Thus, monetary shocks have real effects. However, price adjustments incorporate firms' anticipations about monetary policy, so the real consequences of anticipated movements in money are much smaller than unanticipated movements and may be fully neutralized.

In McCallum's work the period over which stickiness prevails plays a crucial role. If price stickiness is to be assigned a major role in business cycles—even as an impulse mechanism—then the period over which firms elect to make prices sticky must be nontrivial. McCallum (1982, 1986) begins by reviewing theoretical explanations of why producers might temporarily stabilize relative prices against shocks, for example to attract a clientele of customers who prefer relative price stability. He then argues that the costs within period adjustment of nominal prices—or of indexation that would neutralize monetary shocks—cannot be the physical costs of adjusting prices, but rather are computational costs associated with the difficulties that agents face in understanding more complex contracts. He also argues that indexation provides only small reductions in risks to participants, although it is unclear how this is consistent with business cycles that are an important social problem.

Some other recent attempts to give theoretical content to the idea of price stickiness have proceeded along two different paths. One avenue emphasized by Mankiw (1985) and Blanchard and Kiyotaki (1987) involves models with monopolistically competitive firms that face fixed (menu) costs of adjusting prices. So far, this line of research has concentrated on establishing that menu costs that are small can lead to large departures from socially efficient allocations when nominal shocks occur. These models are not yet dynamic, so that distinctions between anticipated and unanticipated movements in nominal variables have not yet been explored. But it stands to reason that there would be results that differed from McCallum's, since in his setup there are effectively zero costs of adjusting prices between periods

and infinite costs of changing prices within the period. First, as in Mankiw (1985), large nominal shocks—even if unanticipated—would tend to be neutralized. Second, small anticipated changes in money would tend not to be neutralized, as the menu costs would be prohibitive. Irrespective of one's view on the plausibility of menu costs, these recent analyses provide a clue as to how individual agents might regard the gains to altering nominal contracts as small even though the social benefits would be large, due to the suboptimality of monopolistically competitive equilibria.

Another line of research has been pursued by Rotemberg (1982), who employs quadratic costs of price adjustment to induce gradual price adjustment. As in Phelps-Winter, these costs are viewed as arising from an erosion of the firm's clientele, with a specific interpretation involving an individual's dislike of price volatility. Using rational expectations methodology, Rotemberg provides evidence that prices adjust gradually, although the specific structural models which he employs are inconsistent with the cross-equation constraints implied by the rational expectations postulate.

As the dynamic implications of sticky-price macro-models are developed in more detail, it will become possible to discriminate between these models and the flexible price equilibrium theories considered earlier. In this process, since price level behavior is a result of the interaction between private agents and the monetary authority, an adequate definition of price stickiness will be required. In particular most researchers have focused on the smoothing of price level variations that arises from private sector actions. However, smoothing can also arise from systematic actions by the monetary authority (see Goodfriend, 1987). Powerful tests will presumably require systematic examination of data generated prior to the creation of the Federal Reserve.

The microeconomic evidence developed by Carlton (1986)—working with the Stigler-Kindahl (1970) data—shows that some prices are fairly rigid. However, the rigidities do not seem to conform to those that have been postulated by macro-modelers. For instance, many price changes are extremely small, indicating that menu costs are not a pervasive factor. Carlton also does not find much evidence that buyers have strong preferences for products whose prices are relatively stable, implying that one rationalization of Rotemberg's costs of adjustment is apparently inoperative. As the particular mechanism that generates rigidities could be quite important for the dynamic implications of this class of models, identification of the empirically relevant sources of

rigidities is necessary. At this stage, this class of models should be regarded as a potentially promising means of resurrecting longstanding Keynesian notions. As of yet their value has not been proven.

## Conclusion

In our overview of rational expectations models of business fluctuations, we have consciously emphasized the extent to which this class of models has generated cyclical interactions that are consistent with empirical evidence. Evidently, progress has not been rapid and there is currently no compelling evidence for any particular description of cycles, despite the fact that the models quite frequently have substantially distinct policy implications. We do not regard this assessment as a reason for departing from the discipline imposed by rational expectations, but feel that this is rather an indication of the amount of work that remains to be done.

In fact, some recent research has led us to become less sure that the conventional representation of business cycles—the stochastic components of economic time series—is appropriate. Nelson and Plosser (1982) have produced some provocative empirical work which cannot reject the hypothesis that the stochastic components of economic time series are nonstationary, possessing random walk components. Although their tests have low power against the alternative that the stochastic components are stationary but highly persistent (McCallum, 1986), these results represent a serious challenge to existing views. Further, there are now basic equilibrium models of fluctuations that imply nonstationarity if the intertemporal technologies are restricted so that the mean rate of economic growth is endogeneously determined (King and Rebelo (1986)), basically because fixed factors are not too important. Further, these endogenous growth models have substantial implications for modelbuilding under the rational expectations postulate, for they imply that there are transformations of nonstationary economic variables that are stationary—that is, the macroeconomic data possess a cointegrated representation (King, Plosser, Stock and Watson (1986)).

Our forecast is that the construction of rational expectations model of the business cycle will be the centerpiece of the macroeconomic research agenda over the next fifteen years, as much as it has been over the fifteen that have passed since Lucas's influential contributions (1972a, 1972b). Recently, Lucas (1987) has argued that economic fluctuations pale in welfare significance relative to the factors that determine the growth path of a particular country's

economy; his research has recently turned to analyses of these factors (1988). Most macroeconomists presumably share McCallum's (1986) scepticism that economic fluctuations are second order problems relative to economic growth and, hence, would doubt that Lucas's current research direction will have the impact of his 1972 work. But we are not so sure,

for if the analysis of King and Rebelo (1986) is sustained in richer models, then it is inappropriate to separate the study of economic fluctuations from that of economic growth. That is, the fact that economies grow tells us that temporary shocks to the economy's production possibilities will have permanent effects on the level of output.

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