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RATIONAL EXPECTATIONS MODELS IN MACROECONOMICS

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ABSTRACT

This paper is a review of rational expectations models used in macroeconomic research. The purpose is to examine in some detail the differences between the models, the advantages and disadvantages of alternative models, the empirical support for the models and their policy implications. The main theme is that there is a wide diversity among rational expectations models in macroeconomics, despite their common expectational assumptions and methods of analysis. Information-based and contract-based theories are reviewed as alternative models of aggregate supply. A brief review of rational expectations models of the demand side is also provided, along with a discussion of some problems with the rational expectations assumption.

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Rational Expectations Models in Macroeconomics

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1 THE MOTIVATION FOR A RATIONAL EXPECTATIONS APPROACH

One of the most conspicuous features of macroeconomic fluctuations is the close association between the fluctuations in output and prices over the business cycle. In statistical terms, there is a marked positive correlation between aggregate production and the rate of change in the aggregate price level. The relationship between output and inflation is not a new phenomenon, although it has shifted over time as expectations of inflation have changed. It has appeared with few exceptions in business cycles as far back as data on business cycles exist. It was observed and studied by Irving Fisher, A. C. Pigou, J. M. Keynes and many other economic theorists in the early part of this century, and it received even wider notice after being embodied in a simple econometric equation by A. W. Phillips in 1958. The price–output correlation is usually given a top billing in the 'aggregate supply' chapters of modern macroeconomic textbooks – the term 'aggregate supply' itself connoting a positive association between prices and output. And, of course, particular realizations of the correlation have always been major news events; the recent downside realization – the worldwide recession and the decline in the inflation rate – is certainly no exception.

Many macroeconomic policy recommendations have been based on this price–output correlation. In the 1920s business cycle theorists drew conclusions about stabilization policy from it. Examining data for the United States, Irving Fisher argued that fluctuations in economic activity could be reduced by a macroeconomic policy that simply stabilized the aggregate price level. Noting similar correlations in the United Kingdom, Pigou (1927) argued for a policy of 'preventing prices from rising in booms and falling in depressions' and thereby 'lessening industrial fluctuations.' And in his tract *Monetary Reform*, Keynes (1923) also argued for a policy of price stabilization citing Fisher's evidence in the United States. The causal assumption implicit in such policy recommendations clearly is that price fluctuations are the direct cause of production and employment fluctuations.

Although based on the same Phillips-curve-type correlations, policy recommendations in more recent times have been quite different. In the 1960s many macroeconomists argued that a policy of price stabilization, or a low inflation target, would disrupt production and increase unemployment. Price stabilization proposals have been revived in recent years, but the conclusion that too much price stabilization would reduce output stability is still held by many macroeconomists. Given such wide differences in policy recommendations, all arising from the same statistical correlation, the need for a clear and quantifiable theory to explain and understand this correlation seems obvious.

The development in the early 1970s of rational expectations models in macroeconomics – the subject of this paper – was largely in response to such a need. Of course, economic theories of the Phillips curve had already been the subject of an intensive research effort when rational expectations models were introduced, but there were still some problems with this research. Consider, for example, the research of Edmund Phelps (1967) and Milton Friedman (1968), which showed that there is an important distinction between the long-run and the short-run output–inflation relationship. This distinction is due to expectations. According to the Phelps–Friedman theory, the stimulating effects associated with a steady rise in prices could not last, because firms and workers would eventually expect these movements and adjust their behavior accordingly. The theory is elegant, logically consistent, and indeed empirically accurate in its predictions for the *long-run* inflation–output correlation. The problems with the theory are in its description of the *short-run* correlations between inflation and output, where it relies on adaptive expectations to explain why firms and workers would be slow to adjust their expectations to business cycle conditions.

The adaptive expectations assumption might be a reasonable description of how expectations adjust after a major unprecedented development, but it seems particularly inappropriate as an explanation of a phenomenon that has been observed regularly as part of economic fluctuations for hundreds of years. To the extent that business cycles are recurrent phenomena, the assumption that people form expectations adaptively, learning from scratch about the dynamics of each business cycle as if it were a unique event, does not seem appropriate. Almost all applications of economic theory are based on the assumption that individual beliefs are influenced by experience. There is no reason why macroeconomic applications should be different.

John Muth's (1961) rational expectations assumption seems more satisfactory for recurrent phenomena like business cycles, and primarily for this reason it was used by Robert Lucas in his studies of aggregate supply. With rational expectations, agents have already learned from past experience and utilize all information available to them. Moreover, as Muth showed, the approach can be used in practice to derive explicit testable implications. Because of this advantage in business cycle applications, rational expectations models have been extended beyond their original Phillips curve (or aggregate supply) application to many other areas of macroeconomics, including the key components of aggregate demand and open-economy macroeconomics. Rational expectations models are now the rule rather than the exception in macroeconomic research. They have been used as theories to explain other business cycle regularities, such as the persistence of output and inflation, as well as their co-movements. Econometric estimation, optimal control and nonlinear solution techniques have also been modified so as to be compatible with the rational expectations models. I will review these developments in this paper. However, as I have characterized it, the original, as well as the most controversial, part of rational expectations research has been in macroeconomic models of aggregate supply, and I will concentrate most of my review in this area. The rational expectations approach is not without its own inadequacies, and I will review these in the course of the paper.

Before proceeding, it may be appropriate briefly to review how the research surveyed here relates to other research developments that have implications for macroeconomics. The 'disequilibrium' approach to macroeconomics surveyed by Malinvaud (1978), for example, is concerned with the implications of a fixed (or exogenous) vector of wages and prices rather than with how these wages and prices are determined, or how they fluctuate over the cycle with production and employment. The main motivation is with a rigorous development of the Keynesian consumption function, with spillover effects in a multi-sector model, and with the *level* of unemployment given this wage–price vector. Although there does not appear to be any substantive reason why rational expectations methods could not be fruitfully integrated with these disequilibrium models, this is a technically difficult problem. The work by Green and Honkapohja (1983), Neary and Stiglitz (1979) and Green and Laffont (1981) seems to be moving in this direction. In particular, Green and Laffont's approach to anticipatory price setting is closely related to some of the work I will review in this paper. The technical problems arise because of the difficulties of obtaining closed-form solutions when there are nonlinearities associated with the spillover effects and with the 'min' condition in *stochastic* rational expectations models.

A second development in macroeconomics, which has evolved from work in a number of areas of microeconomics (asymmetric information, search), is concerned with investigating whether the *average* level of unemployment is efficient or not. Papers by Arnott and Stiglitz (1981), Calvo (1979b), Diamond (1982) and Salop (1979) are examples of this type of research and illustrate the wide variety of approaches that have been taken in such investigations. These models give rise to equilibrium (perhaps inefficient) unemployment, but are not directly concerned with the *dynamic co-movements* of inflation and unemployment as are the rational expectations models surveyed here. Peter Diamond (1982) explains the difference in terms of a general research strategy: 'Inflation and unemployment are both such difficult problems to understand, that it is a good strategy to attempt to model each of them separately before worrying about a model that would address both of them at once.' As should already be clear, the rational expectations modelers discussed in this lecture have been worrying about too much, according to this view.

2 ALTERNATIVE RATIONAL EXPECTATIONS MODELS OF AGGREGATE SUPPLY

Robert Lucas introduced rational expectations to the study of aggregate supply in a series of now famous papers (see Lucas, 1972a, 1972b, 1973). As I will describe in more detail later, the introduction of the rational expectations approach requires a very well specified and detailed model. As a result, the Lucas models are much more explicit than earlier models in describing the reasons for the short-run inflation–output relationship. In addition to the rational expectations assumption, they are explicit about assuming perfectly flexible prices and market-clearing at every date. The mechanism generating the inflation–output correlations is information-based; a limitation is placed on the information available to agents in different markets. This explicitness has enormous advantages from the viewpoint of statistical testing, as I will describe later. Moreover, the policy implications of the theory are also very specific. According to the theory, a well-understood monetary policy does not affect real variables. These implications of the model of Lucas were studied and extended by Sargent and Wallace (1975) and Barro (1976), and now by many others. The term 'new classical macroeconomics' is used for these models.

But the Lucas market-clearing type was not the only rational expectations model being explored as a theory to explain the price–output fluctuations and derive policy implications. An alternative rational expectations approach to the problem was taken by Stanley Fischer (1977) and Phelps and Taylor (1977). Although the Fischer and Phelps–Taylor models were at least partially motivated by the policy implications of the Lucas models, other aspects of economic behavior and policy were also explored. Rather than describing price movements using the market-clearing assumptions, these models contain explicit mechanisms to describe how prices (or wages) are determined. The rigidities in these models are due to sticky prices. There is a finite period of time in which a *nominal* wage or price is set and transactions are assumed to take place at that price. Formal wage or price contracts are not necessarily involved; wage-setting customs are sufficient. These models give rise to a quite different mechanism for price and output fluctuations than those introduced by Lucas, and their properties and policy implications are much different. One difference that has attracted much attention is that anticipated and perceived changes in the money supply can affect output and employment.

Despite this apparently fundamental difference, there are similarities between the two approaches. Of course, because of the rational expectations assumption the mathematical techniques are very similar. But there is also a substantive similarity in that wage and price decisions are forward-looking. Decisions are forward-looking if expectations of future events matter for current decisions regardless of how expectations are formed. The prices in the *information-based* market-clearing rational expectations models are obviously forward-looking; but, as I will emphasize in this paper, price and wage decisions in the sticky price models are also forward-looking. The prices in these models are like capital: once in place they are predetermined (at least beyond one market-clearing period under normal conditions), but the way they are set in place depends on future developments such as expected demand conditions and price developments in other markets. Because price and wage-setting is anticipatory, the policy implications of the sticky price rational expectations models are much different from sticky price or wage models without rational expectations.

The terminology used here deserves some comment. I use the term 'information-based' because the models rely on informational restrictions on firm's and worker's perceptions about other markets in the economy. I use the term 'sticky price' rather than 'contract' because the rigidities are not necessarily due to the types of factors considered in the *contract theory* studies such as by Azariadis (1975) and Bailey (1974). The use of the term 'information-based' may be too narrow because the macroeconomics of the sticky-price models are based partly on information arguments.

Information-based models

The information-based models proceed from the simple assumption that the positive relation between aggregate prices and output is due to movements along a *producer's or worker's supply curve*. For this reason, the version of the Phillips curve that has emerged from this research has come to be called the 'Lucas supply curve.' Movements along supply curves can occur only if there is an increase in some *relative* price: for a firm, the output price must rise relative to input prices; for a worker, the wage must rise relative to the price level. Because the phenomenon we wish to explain concerns an increase in the general price level where all prices rise together, it is necessary to impose informational constraints on suppliers about certain prices in the economy. These constraints give rise to a perception of a relative price increase when in reality there is none. Firms are assumed to have difficulty obtaining information about what is going on outside the market in which they are selling. It is here that the models get 'rigged,' as later characterized by Lucas (1981).

An exposition of the model

The best way to see the importance of this theory is to study it in detail. I have found that attempts to summarize it less formally do not give one the same appreciation of its theoretical innovation. With the help of some diagrams and elementary statistics, the rudimentary model developed by Lucas (1973) can be explained rather simply.

We start with a supply curve for a representative firm:

$$y_i = c(p_i - p_i^e) + y_i^f, \qquad i = 1, \ldots, n \tag{1}$$

where y_i is the ith firm's production, p_i is the ith firm's price, and y_i^f is the ith firm's normal level of production. The variable p_i^e is the ith firm's *perception* of the average price level (i.e. the 'general' price level) elsewhere in the economy, and c is a parameter. The general price level should be an indicator of the firm's input costs. (Alternatively, if we think of a worker-supplier, p_i would be the wage and the general price level would be the price index of consumer goods.) Equation (1) states that the firm will produce more if the price of its products rises *relative* to the general price level. Note that, if both p_i and p_i^e rise by the same amount, the firm will not produce more, because the relative price does not change. Hence, equation (1) shows explicitly why a properly specified supply curve will not explain Phillips curve correlations in which the general level of prices (all prices) and production move together. According to (1), a general price rise that is fully perceived by all firms will not affect production, because p_i and p_i^e would move together.

As suggested earlier, the Phillips curve correlations come from confusion on the part of firms about what is happening to the general price level. Suppose that firm i cannot immediately observe the general price level, but that it can still observe its own price. Then, when all prices rise simultaneously, firm i will not know that these other prices are rising. It will see only its own price rise. Hence, it will produce more. If other firms have similar lack of information, this confusion could cause production in the entire economy to increase, because all firms will mistake a general price rise for a rise in their own relative price. Phillips curve correlations will result. Essentially, firms are fooled into producing more.

It should be noted that, if we interpret the 'general price level' as an indicator of the firm's input costs, then the model implies that the firm has less information about its input costs than it does about its own price. If we think of the model as describing a worker supplying labor, then we are assuming that the worker will know more about his own wage than about prices generally. These features of the model have been questioned by some as being unrealistic.

Even if the firm cannot observe the general price level, the observation on its own price might provide useful information about the general price level. At the extreme, if relative prices *never* changed, then the firm would realize that the price of all other goods was increasing whenever its own price went up. Even in a less extreme situation, when price changes *sometimes* represent a relative shift, firms would guess that an increase in their own price might reflect an increase in inflation generally.

The information-processing problem faced by the typical firm i is illustrated in a scatter diagram in figure 6.1. The diagram represents the historical experience of the firm during several fluctuations in its own price and general price level. It is a scatter plot of these historical observations on prices. It plots the general price level p on the vertical axis and the firm's own price on the horizontal axis, both measured relative to the unconditionally expected level of prices $\hat{p}$. By 'unconditional' we mean without knowledge of the firm's own price p_i. This could be a forecast at the start of the year based on some econometric forecasting service. According to the picture, when the firm's price is above normal, the general price level is frequently, but not always, above normal. The deviations of the scatter from the 45° line represent *relative* price changes. Based on this historical experience, and despite the deviations from the 45° line, the firm would be wise to estimate that *some* general increase in prices had occurred whenever it saw its own price higher than normal. The firm could make this estimate by putting a least squares line through the points as shown in the diagram. Clearly, the slope of the least squares line depends on the spread of the scatter of points. As shown in figure 6.2, if the cluster of points are all close to

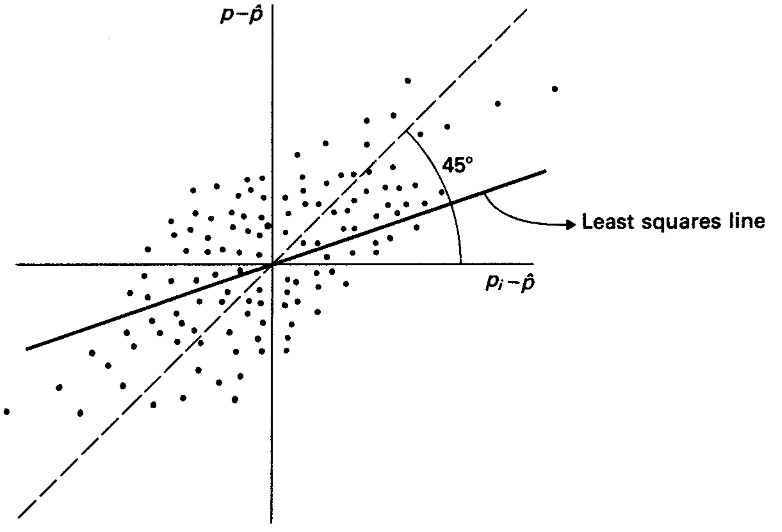

FIGURE 6.1

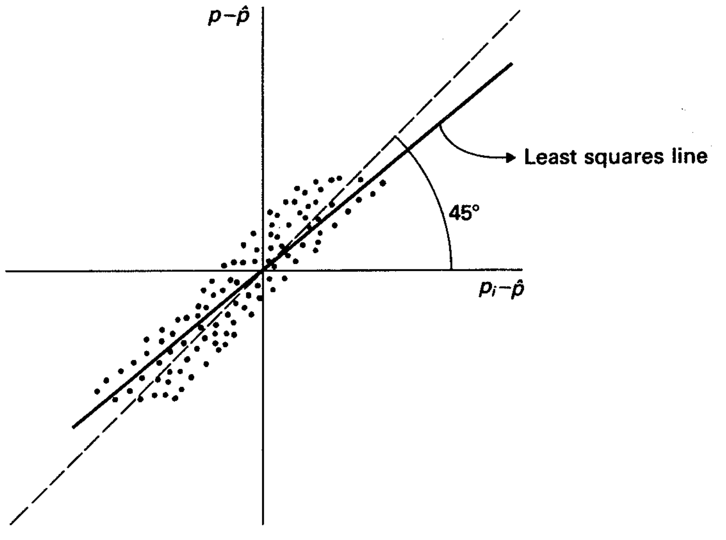

FIGURE 6.2

the 45° line, so that there are only small relative price shifts compared with aggregate price movements, then the slope of the line gets close to 1. As the points spread, representing larger relative price shifts, the slope goes to zero.

Write the least squares regression equation corresponding to the line in figures 6.1 and 6.2 as

$$p - \hat{p} = b(p_i - \hat{p}). \qquad (2)$$

Then the scatter diagrams suggest that the coefficient b is between 0 and 1 and is a decreasing function of variability of relative prices (measured by the horizontal spread of the observations from the 45° line), and an increasing function of the variability of the general price level (represented by the vertical spread of the observations along the 45° line).

In fact, the firm is facing an elementary signal extraction problem, and the previous informal description of its behavior can be formalized by assuming that the firm extracts the signals optimally. This can be derived most easily using a bivariate normal model.

The algebraic representation of the individual firm's price p_i relative to the general price level p corresponding to the diagram is given by

$$p_i = p + \epsilon_i, \qquad (3)$$

where ϵ_i is an additive relative price shift. This is the horizontal distance between the 45° line and each point in the diagram. In order to derive the slope of the regression line in figures 6.1 and 6.2, it is useful to treat the prices as random variables with a normal distribution. Then the best guess of the aggregate price level p from the viewpoint of firm i can be interpreted formally as the conditional expectation of p given the individual firm's observation on p_i. That is, $p_i^e \equiv E(p \mid p_i)$. If p and p_i are jointly normally distributed, then this expectation can be easily derived from well-known properties of the normal distribution.

Define the mean and variance of p and ϵ_i as $Ep = \hat{p}$, $\operatorname{var} p = \sigma_p^2$, $E\epsilon_i = \hat{\epsilon}$, and $\operatorname{var} \epsilon_i = \sigma_\epsilon^2$. Since ϵ_i represents relative price fluctuations, it is appropriate to assume that these average out to zero for each firm and are uncorrelated with the general price level. That is, $\hat{\epsilon}_i = 0$ and $\operatorname{cov}(p, \epsilon_i) = 0$.

In order to calculate $E(p_i \mid p)$ we need to calculate the mean and variance of p_i and the covariance between p_i and p. From equation (3), the *mean* of p_i is given by

$$Ep_i = \hat{p}, \qquad (4)$$

and the *variance* of p_i is given by

$$\begin{aligned} \operatorname{var} p_i &= \operatorname{var} p + \operatorname{var} \epsilon_i \\ &= \sigma_p^2 + \sigma_\epsilon^2. \end{aligned} \tag{5}$$

The covariance between p_i and p is then computed as

$$\begin{aligned} \operatorname{cov}(p_i, p) &= E(p_i - \hat{p})(p - \hat{p}) \\ &= E(p + \epsilon_i - \hat{p})(p - \hat{p}) \\ &= E(p - \hat{p})^2 + E(p - \hat{p})\epsilon_i \\ &= \operatorname{var} p + \operatorname{cov}(p, \epsilon_i) \\ &= \sigma_p^2. \end{aligned} \tag{6}$$

The variables p and p_i are viewed as jointly normally distributed with these means, variances and covariances. From the properties of the normal distribution, the conditional expectation of p given p_i can be computed from the formula:

$$E(p \mid p_i) = Ep + \frac{\operatorname{cov}(p_i, p)}{\operatorname{var} p_i}(p_i - Ep_i). \tag{7}$$

Substituting in the means and variances, this gives

$$p_i^e = \hat{p} + \frac{\sigma_p^2}{\sigma_p^2 + \sigma_\epsilon^2}(p_i - \hat{p}). \tag{8}$$

Comparing equation (8) with equation (2) above, we see that the slope coefficient of the regression line is given by

$$b = \frac{\sigma_p^2}{\sigma_p^2 + \sigma_\epsilon^2}. \tag{9}$$

The term σ_ϵ^2 represents the variability of relative prices. Clearly, as this variability gets larger the slope is reduced. At the extreme case where σ_ϵ^2 is infinite, an increase in the individual firm's own price provides no information about the general price level. These results of the theory are potentially important, for they provide an empirical test.

Substituting equation (8) into (1) results in

$$y_i = c(1-b)(p_i - \hat{p}) + y_i^f. \tag{10}$$

The behavior of output and prices for the economy as a whole can now be obtained by aggregating over all the producers. Note that we avoid a number of aggregation problems by assuming that all firms have identical supply functions. Simple summation then gives the aggregate supply function. The general story is not dependent on their being identical firms, however. Letting the same symbols without subscripts represent the aggregate and summing up results in

$$y = \gamma(p - \hat{p}) + y^f, \tag{11}$$

where $\gamma = c(1-b)n$. This is the Lucas supply function. Another way to write (11) is to put the price level p on the left-hand side and subtract the lagged aggregate price level from both sides. This results in

$$p - p_{-1} = \hat{p} - p_{-1} + \lambda(y - y^f), \tag{12}$$

where $\lambda = \gamma^{-1}$. Equation (12) now has the form of an 'expectations-augmented' Phillips curve.

The relationship between the slope parameter b and the variability of prices can now be interpreted in terms of the slope of the Phillips curve λ. Since λ is an increasing function of b, any increase in the variance of overall prices will increase the slope of the short-run Phillips curve. At the time in which this model was derived, an increased slope represented a 'less favorable' trade-off since it meant that an increase in inflation would result in a smaller stimulus to production and employment. Now, such a slope increase would be 'more favorable,' since it would permit a reduction in inflation with a smaller loss of production and employment. In any case, this prediction of the theory provided one of the earliest tests.

Note how this equation captures both the long-run vertical Phillips curve (an anticipated inflation with $p = \hat{p}$ will result in production at normal levels with $y = y^f$) and the short-run positive correlation noted at the start of the paper (a temporary unanticipated movement in inflation causing $p > \hat{p}$ will result in above normal production). The economic explanation underlying these correlations is that firms or workers are producing more than was expected when the aggregate price level is greater because they think that there is a good chance that their own price has risen.

Policy implications

The policy implications of this information-based model are quite striking. To derive the implications, first introduce a simple aggregate demand equation

$$y = a_0 + a_1(m - p), \tag{13}$$

where m is the log of the money supply. Now, suppose $\hat{m}$ is the 'rational' expectation of the level of m; then the rational forecasts of p and y must satisfy (from (13)) the relationships

$$\hat{y} = a_0 + a_1(\hat{m} - \hat{p}), \tag{14}$$

and (by taking expectations in (11))

$$\hat{p} = \hat{p} + \lambda(\hat{y} - y^f). \tag{15}$$

Equation (15) implies that $\hat{y}$ is equal to y^f, and therefore from (14) we have

$$y^f = a_0 + a_1(\hat{m} - \hat{p}). \tag{16}$$

Now, solve (13) and (16) for p and $\hat{p}$ and substitute (11) to get

$$y - y^f = \frac{a_1\gamma}{a_1 + \gamma}(m - \hat{m}). \tag{17}$$

The policy implications follow from equation (17): if monetary policy is perfectly anticipated, then $m = \hat{m}$ and output does not deviate from normal levels. Hence, *anticipated* changes in money do not affect real GNP: they affect only the price level. Put differently, only *unanticipated* money $(m - \hat{m})$ affects GNP. This is the central policy ineffectiveness result established in a slightly more elaborate model by Sargent and Wallace (1975), and it forms the basis for tests of the hypothesis by Barro (1977, 1978). Announced (and believed) changes in money can affect prices (and therefore inflation) with no real output effects. Note also that, according to this theory, disinflation would not require any lost output, a possibility investigated by Sargent (1982) in a study of the Eastern European hyperinflations.

These results highlight the importance of distinguishing between anticipated and unanticipated policy in rational expectations analyses. In rational expectations models based on contracts or sticky prices, this distinction is also important, but it is not so extreme.

Empirical evidence

As shown above, the information-based model was designed specifically to explain the long-observed empirical relationship between prices and output over the cycle. In this sense it was successful; it fitted the facts it was designed to explain. But because the model was laid out so explicitly, many other testable implications could be derived, and these have formed the basis of a vast array of statistical tests of the model. In my view this is an important advantage of the information-based model. Were it less explicit – or based on the informal explanations used by many early business cycle theorists – these testable implications could not have been derived, and as a consequence we would know much less about the validity of the model.

The implication that the Phillips curve slope should be positively related to the variability of the overall price level served as the first test of the model conducted by Lucas (1973). Deriving Phillips curve slopes for 20 countries and comparing these with the variability of the overall price level, Lucas found some evidence for the hypothesis, but this was based on two outliers in his sample, Argentina and Paraguay, which had steep Phillips curves (a small γ in the previous notation) and high aggregate price variance. For the other 18 countries, and for the OECD countries, there was little evidence for the hypothesis. If the theory was correct, it seemed to show up only in countries with extremely high inflation variability, outside the realm of experience of many industrial economies.

A second test of the hypotheses was conducted by Sargent (1976), who utilized the fact that only *unanticipated* movements in the price level should affect production. Using various proxies for the expected price level and regressing the unemployment rate on the resulting measure of unanticipated prices (along with lagged values of unemployment), Sargent found evidence of a Lucas-type supply function for the United States during the 1951(I)–1973(III) sample period. The coefficient of $p - \hat{p}$ in the unemployment equation was negative and significant. Fair (1979), using a different estimation procedure, found that the slope coefficients in the supply curve were smaller than Sargent's and insignificant. Moreover, when he lengthened the sample to consider the period through 1977, he found that the coefficient reversed sign and became significant. Hence, the evidence suggests that unanticipated prices do not give the Phillips curve correlation necessary for the Lucas theory. Altonji (1982), using data on wages, obtained similar negative results focusing on the labor supply decision.

One reason for the reverse effect uncovered by Fair might be prevalence of supply shocks as distinct from demand shocks during the 1970s. Supply shocks – if they created movements along a negatively sloped aggregate demand curve in the (p, y) plane – could be responsible for the finding.

In a series of papers, Barro (1977, 1978) attempted to test the theory indirectly by studying the effects of unanticipated money on output (rather than the effects of unanticipated prices). Equation (17) shows how the Lucas theory can be interpreted in this way. The results of this approach were much more dramatic and showed a strong and significantly positive influence of money on real output. Moreover, Barro's results showed that anticipated money had a smaller effect which was frequently statistically insignificant.

Barro obtained measures of anticipated money by using regression methods to estimate a forecasting equation for money. The anticipated money values were taken to be the forecasts of a regression of the change in the growth rate of money (*DM*) on its own lagged values and on two other potential influences of money growth – de-trended federal government expenditures and the unemployment rate. The difference (*DMR*) between the forecasted *DM* and actual *DM* was then taken as a measure of unanticipated money and was in turn regressed on real GNP(y) with a time trend removed. In more recent work, the two-step procedure has been replaced by a joint estimation method but the general idea is the same. Subsequently Small (1979) and Germany and Srivastava (1979) have shown that these results are sensitive to how the forecasts of money are proxied. Since the Barro results appeared to be in such strong agreement with the theory, and because they have been quite influential in the field, it is worth focusing on them.

Figure 6.3 plots the annual data on *DM*, *DMR* and y used by Barro (1978). Although this is a busy chart the plot is quite revealing. Note that the short-run business cycle swings of both actual money (*DM*) and unanticipated money (*DMR*) correspond closely with the movements of real GNP. Both anticipated and unanticipated money seem important. In the period up to 1960 anticipated money seems

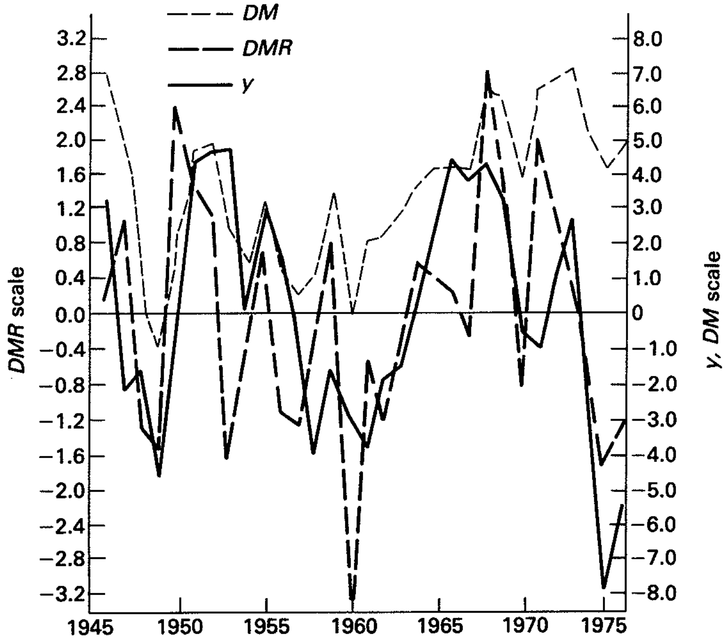

FIGURE 6.3

Source: Barro (1978).

more important. However, the real problem with the actual *DM* series is the secular increase which begins in the early 1960s as inflation began to accelerate. Clearly, anticipated money does not have a chance in a regression that includes both anticipated and unanticipated money, unless one takes out the changed trend. One way to do this would be to measure *DM* in real terms and thereby take out the inflationary trend. Another way would be to use a very long lag distribution. In fact, in recent work Mishkin (1982) has shown that the Barro results change significantly in that unanticipated money becomes relatively less important when the lag distribution in the output equation is increased.

The Barro test procedure was criticized by Fischer (1980a), who argued that, by replacing unanticipated *price* variables, as in the original Lucas model, by unanticipated *money* variables, the method could no longer distinguish between the Lucas model and other rational expectations theories such as the sticky price theories described later in this paper. In any rational expectations model in which there are rigidities that are not permanent, anticipated changes will have smaller real effects than unanticipated changes: adjustments can be made in advance when policy changes are anticipated. In rational expectations models with price rigidities, the anticipated policy variables will have effect, but the effect of unanticipated policy can often be larger. Hence, it is not clear what rational expectations model Barro's results were testing. In fact, the finding that unanticipated *money* has a much larger effect than unanticipated *prices* can be more easily reconciled with sticky price–wage models than with information-based models.

Some more recent empirical work sheds further doubt on the information-based models. Boschen and Grossman (1980) and Barro and Hercowitz (1980) show, using preliminary data on the money supply, that a very small part of the output effects can be caused by 'unperceived' as distinct from 'unanticipated' money. As is clear from the exposition of the Lucas model, if the current money supply or aggregate price level is known (even if it was unanticipated at the start of the period) it would not affect output. But in fact the misperceived part of money seems to be very small.

In addition, work by Hercowitz (1980), Fischer (1981), and Taylor (1981) seems to show that very little of the price *dispersion* in the cross-section can be explained by monetary shocks. At least in recent years the impulse to price movements have come from the supply side (energy, agricultural, and productivity shocks). These findings correspond with the intuitive explanation for the negative movement between prices and output, mentioned above in my discussion of the empirical tests of Fair.

Another approach to testing the information-based models has been to look directly at the intertemporal supply elasticities to determine whether these are at least plausibly high enough to explain the cyclical movements. If the information constraints turned out to be important, contrary to the above empirical results, then examining such elasticities would be a second check on the theory. Unfortunately, the results are very mixed here: Hall (1980) finds a high intertemporal macro labor supply elasticity and gives evidence from micro studies to indicate that the supply elasticities are plausibly high. Altonji (1982) as well as Mankiw, Rotemberg, and Summers (1982) have recently presented tests contrary to this finding. Kydland

and Prescott (1982) have argued that the conventional time separability assumption may be leading to the small supply response, but this has yet to be tested empirically.

Extensions

A number of extensions of the simple information-based model have appeared since Lucas's early work. Barro (1976) developed a considerably more detailed model in which aggregate demand was also derived from individual demand curves (a Lucas demand curve). Barro (1980) also developed a model with an economy-wide capital market in order to examine how information provided in such a market would influence the dynamics and the correlations of the model. Cukierman (1979) generalized the model to allow firms to spend research money in order better to determine economy-wide events. This modification makes the information structure endogenous in a particular way, and Cukierman finds that the general theoretical results are robust to such a change. McCallum and Whitaker (1979) showed that, if a policy variable could react to current events, as in the case of automatic fiscal stabilizers, then it could effectively stabilize real output.

Another type of generalization of the market-clearing information-based model has been investigated by Weiss (1980). In the Weiss model some agents (firms) are informed and some agents (workers) are uninformed. Monetary policy can be used to improve the transmission of information to the uninformed agents. By reacting to economic developments in a particular way, the monetary authorities reveal information about the state of the economy to workers, resulting in an allocation equivalent to that of the fully informed state.

The information-based models were not originally designed to capture the *serial* correlation of output and prices, but only the correlation between these variables. Some of the extensions of these models have been aimed at explaining this serial correlation, without abandoning the basic limited information market-clearing approach. For example, Lucas (1975) added fixed capital to the model to capture these dynamic effects. Blinder and Fischer (1981) included inventories in the model providing another source of serial correlation. Most recently, Kydland and Prescott (1982) have developed a complete model that uses construction lags, which have effects similar to capital stock adjustment costs, to explain serial correlation in a market-clearing model. Sargent (1978b) had earlier stressed adjustment costs as a source of persistence, focusing on firms' adjusting their labor force.

Sticky price models

The crucial difference between the models of aggregate supply described in this section and the information-based models is that prices are 'sticky.' Prices do not instantaneously adjust to clear all markets. In addition to the extensive use of rational expectations, these models also differ from earlier work on sticky wages and prices in that there is more development of the dynamics of price adjustment. Rather than just assuming that prices adjust slowly – as for example by using a simple price adjustment equation – there is an attempt to describe how prices and wages are determined. These models are 'period' models generating discrete-time stochastic difference equations, and my review will be limited to such discrete-time formulations. A continuous-time approach is found in Calvo (1982).

Two different approaches to wage and price determination can be distinguished. One approach, used by Fischer (1977), Gray (1976) and Phelps and Taylor (1977), starts with a set-up in which wages or prices are set at least one period in advance of when they will apply. One can think of this as a contract, in that the price is determined in advance, but there is no presumption that actual contracts are written. The distinguishing feature of this approach is that prices or wages are assumed to be set as if they were *expected to clear markets* during the period in which they will apply. Economic agents are assumed to make conditional forecasts of supply and demand conditions. Actual supply and demand conditions will differ from these forecasts because of unexpected events, such as productivity or monetary shocks. Since the conditional forecasts of demand and supply depend on the price, it is possible to determine the price so that forecasted demand equals forecasted supply; this price is the *expected market-clearing price*. The assumption is that the prices actually set by firms and workers are equal to this expected market-clearing price. When the next period occurs actual demand will not equal actual price because the price level is fixed.

The assumption used in the rational expectations macro-literature has been that the demand side rules the market. This assumes, of course, that there are always sufficient stocks and enough excess productive capacity that the required amount of production is feasible. Because these models are stochastic, there is an advantage to the 'demand is determining' condition in that it preserves linearity, unlike the 'min' condition. Hence it is not necessary to take expectations of nonlinear functions of random variables when finding agents' expectations, and it is primarily for this reason that such an assumption is used. (As I mentioned previously, this technical factor may be one of the reasons why the rational expectations assumption has not yet been explored extensively in the disequilibrium macroeconomic literature.)

This general approach to wage and price determination can obviously be applied in many different ways. In Phelps and Taylor (1977) it is assumed that the aggregate price level is set so that expected total aggregate demand is equal to expected total aggregate supply. Aggregate demand depends negatively on the price level through the usual real balance channel: a higher price level reduces real money supplied and raises real interest rates; expected aggregate supply is assumed always to equal the unconditional average or normal level of supply. Although interest rate determination as well as the dynamics of inventory behavior are modeled explicitly, the basic mechanism can be explained (although at the risk of some oversimplification) using the simple aggregate demand equation (13). If normal or capacity output is equal to the constant y^f (using the same notation as in the previous section), then from (13) the price level that is expected to clear markets in any period is given by

$$p_{-1} = \frac{1}{a_1}(a_0 + a_1\hat{\hat{m}} - y^f). \tag{18}$$

The subscript on the price level in (18) indicates that it was set at the start of the previous period. Equation (18) indicates in a very elementary way how price setting is *anticipatory* in this type of model; *tâtonnement* price adjustment mechanisms do not have this feature. The double circumflex over the money supply is meant to indicate that this was the expectation of the money supply based on information at the *beginning* of the *previous* period (recall that the single circumflex used in the previous section on market-clearing models indicated an expectation based on information at the beginning of the *current* period). This difference is essential to the predictions of the model.

Substituting (18) into (13) results in

$$y = a_1(m - \hat{m}) + y^f. \tag{19}$$

As (19) indicates, output deviates from full-capacity output by the amount that the money supply differs from what was announced at the start of the previous period. Hence, an increase in the money supply that is *announced* and perceived at the start of the current period (after prices for the period have been set) will affect output. It is in this sense that anticipated changes in the money supply can affect output – as long as they are not anticipated for a period longer than the time that prices are sticky. Monetary policy has effect in this model because, by assumption, the monetary authorities have a shorter lead time in their money supply decisions than do firms in their pricing decisions. In the flexible-price market-clearing models this lead time is ruled out by assumption, as a comparison of equation (17) with (19) should make clear. McCallum (1980) has shown how it is possible to rig sticky-price models so that changes in expectations can affect actual prices in a way in which policy-makers cannot exploit this lead time.

The rational expectations models developed by Fischer (1977) and Gray (1976) assume that wages are sticky, permitting prices to be perfectly flexible. Changes in the real wage are the source of output fluctuations. Wage determination in these models is analogous to the price determination in the Phelps–Taylor model. Fischer also assumes that wage-setting is staggered over time, but this does not affect the conclusions of his analysis in any way. Again, anticipated monetary policy can affect real variables only if the monetary authorities can act with less lead time than wage-setters. Casual observation suggests that this time advantage of monetary policy does exist for wage determination, even if it is more questionable for price determination.

An important feature of all these models, which also emerges from the algebra, is that monetary policy is neutral in the long run, even if not in the short run. In fact, output returns to normal after only one period in the model in equation (19), corresponding to the single-period price-setting assumption. Serial correlation of output (more specifically, the autocorrelation function) cannot be longer than the length of the longest contract in these models, unless other sources of persistence are added.

The expected market-clearing approach to wage and price determination is clearly an 'as if' technique, and has many similarities with the market-clearing approach in which wages and prices actually do clear markets. An advantage of this approach is that it preserves *long-run* neutrality properties. This advantage has recently been emphasized by McCallum (1982).

An entirely different approach to modeling how prices are determined in sticky-price rational expectations models is to focus directly on the price decision of individual agents. Consider, for example, a nearly competitive market consisting of n firms in which a firm's unit sales decline slowly if the firm charges a price above the prevailing market price, and increase slowly if the firm charges a price below the market price. In other words, suppose that there are enough substitution possibilities between the products of different firms that the demand for each firm's product depends on the price of that firm measured *relative* to the average price at other firms, but not so many substitution possibilities that the firm's sales are infinitely responsive to any deviation from the market price. Suppose also that firms set their prices at different points in time; that is, that price-setting is staggered or non-synchronized. Let x_t be the price set by firms who set price at time t and suppose that the n firms each set their price every $1/n$ periods. The average price of all firms in the market is then

$$p_t = \frac{1}{n} \sum_{s=1}^{n} x_{t-s+1}. \tag{20}$$

Figure 6.4 illustrates the way in which prices will evolve in a steady inflation when $n=3$.

What might be a reasonable pricing strategy for firms in such an environment? In the absence of a need for a change in sales, the representative firm would attempt to meet the prevailing price *during* the period when its own price was applicable; that is, during the 'contract' period. Algebraically, this might be captured by assuming that prices are formed using the following equation:

$$x_t = \frac{1}{n} \sum_{s=0}^{n-1} \hat{p}_{t+s}. \tag{21}$$

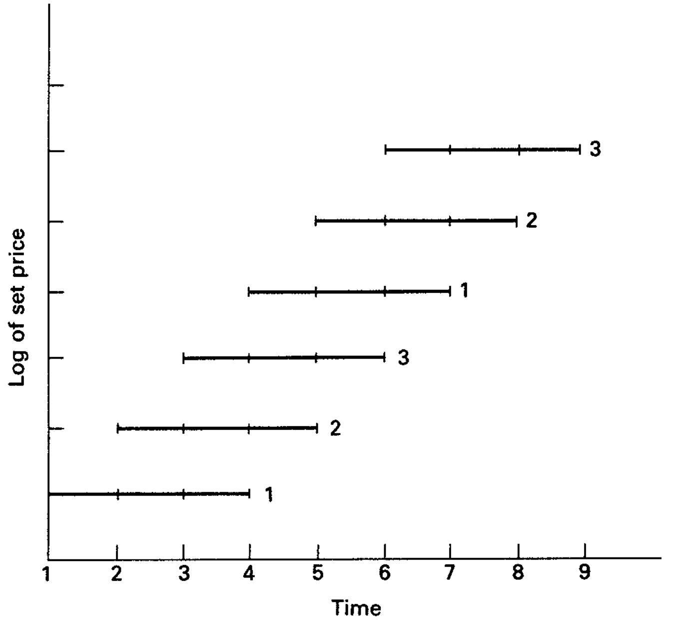

FIGURE 6.4 **Price setting by three groups of firms in a steady inflation**

In other words, the 'contract' price x_t of the firm is set to equal the expected average price of other firms during the n future periods in which x_t is expected to apply. If the firm found that it was out of equilibrium, then its price decisions would differ from (21). For example, if an increase in sales were desired, the firm would charge a price below the value in (21), and if it wanted to reduce sales it would charge a higher price. A simple way to capture this 'disequilibrium' would be to modify (21) by incorporating a term reflecting the firm's sales relative to normal (desired) levels. That is, equation (21) would become

$$x_t = \frac{1}{n} \sum_{s=0}^{n-1} \hat{p}_{t+s} + \frac{c}{n} \sum_{s=0}^{n-1} (\hat{y}_{it+s} - y_i^f). \tag{22}$$

The pricing equation in (22) is similar to that used in Taylor (1979, 1980a) and Phelps (1978), in the case of either wage determination or price determination. Blanchard (1982), Calvo (1983) and Dornbusch (1982) have also used this general approach. Relative to the *expected* market-clearing pricing approach, this type of price determination has some empirical advantages. The dynamics of the price and output correlation that can emerge from an equation like (22) are much richer than the simple expected market-clearing approach. In fact, it was in response to empirical requirements that this alternative to the expected market-clearing approach was developed. In the early empirical work on sticky-price rational expectations models that was eventually reported in Taylor (1979), it was found that the expected market-clearing approach did not produce enough serial correlation in either output or prices to be empirically realistic. From a technical viewpoint, equations like (22) can produce more realistic price and output behavior because of their lagged dependent variables. Although such lags are not immediately visible in (22), substitution of equation (20) into (22) results in an equation with $(n-1)$ lags in x_t, along with $(n-1)$ leads. The lags arise because of the lasting effect of past price decisions on today's prices. In fact, equation (22) implies both forward-looking and backward-looking behavior.

By adding to equation (22) a model for the determination of actual demand (so that the rational expectations assumption can be used) the following conclusions are easy to derive. First, there is no long-run effect of a steady inflation on the deviations of output from normal levels. (In other words, the long-run Phillips curve is vertical.) This can easily be shown by noting that, if $x_t - x_{t-1} = \mu$ for all t, then $y_{it} = y_i^f$ for all t. Second, anticipated changes in the money supply will affect real output even if the announced lead time is longer than the length of the longest contract. Third, the effect of an anticipated change in monetary policy is quite different from the effect of an unanticipated change.

Empirical tests of the sticky-price models have not yet been as extensive as tests of the information-based models. A comparison of predicted and actual output correlation for the United States reported in Taylor (1980a) indicates that the non-synchronized price (or wage) model captures some of the serial correlation properties. But more detailed tests of the model reported in Taylor (1980b) and Ashenfelter and Card (1982) indicate that there are some problems in matching the exact shape of the lag distributions and the pattern of intertemporal correlation between output and prices. Generalizations of the non-synchronized price determination model to allow for the real-world fact that all contracts do not last the same length of time appear to improve the fit of the models. I am not aware of any published tests of the expected market-clearing pricing models of aggregate supply.

The micro-foundations behind the sticky-price models generally rely on some type of cost of adjustment idea. Barro (1972) and Sheshinski and Weiss (1977) have taken this approach. Because of adjustment costs it is optimal for firms to adjust their prices at discrete intervals; hence, there are periods of time when prices are sticky.

Despite these advances, there is a need for more microeconomic work to be done before we can make policy evaluations using sticky-price models at the same level of rigor as modern welfare economics (optimal taxation, for example). Nevertheless, the policy problems that these models are designed to address are present and important. As further progress on the microeconomic foundations is being made, certain features of these models – for example, the explicit attempt to model and test the price-setting mechanism, the use of the forward-looking expectations assumption, and the focus on policy rules – could provide an important improvement over 'pre-rational expectations' models that have been and are currently used in policy analysis.

3 RATIONAL EXPECTATIONS MODELS OF THE COMPONENTS OF AGGREGATE DEMAND

In discussing the implications of alternative theories of aggregate supply in the previous section, it was necessary to make at least some rudimentary assumptions about aggregate demand. Another area of rational expectations research in macroeconomics has been the development of more detailed models of aggregate demand. In fact, although most rational expectations research in the early 1970s focused on questions relating to aggregate supply, in the late 1970s and early 1980s this emphasis of research has been shifting to the demand side, and especially to consumption and investment. It is impossible to review all the research here, but a brief summary of its highlights might be useful.

Consumption

Rational expectations has generated a renewed interest in the permanent income hypothesis of consumption behavior. Recent literature on the consumption function has emphasized that the permanent income hypothesis places restrictions on the relationship between consumption and current and past income flows. Moreover, these restrictions depend on the time-series properties of income. Sargent (1978a), Hall (1978), Blinder (1981) and Flavin (1981) have estimated models of consumption using the permanent income hypothesis and rational expectations. With few exceptions, the general approach in this research has been to use the traditional permanent income hypothesis, and simply add to it the hypothesis of rational expectations. Early on this approach seemed to work well; in particular, Hall (1978) found broad agreement between the theory and the facts. More recently, however, there have been discrepancies. Using panel data, Hall and Mishkin (1982), for example, found that the permanent income model with rational expectations can be rejected. Findings such as this are likely to lead to modifications of the permanent income hypothesis, perhaps using liquidity constraints; but this is yet a topic for future research.

Investment

It is impossible to do justice here to all the work on investment modeling with rational expectations. Lucas and Prescott (1971) focused on investment behavior in one of the first fully developed rational expectations models under uncertainty, and in a long unpublished paper Lucas (1966) explored a model of firms' investment demand using rational expectations. Most of the research on investment since this early work has been motivated by the problems of the neoclassical model, as pioneered by Jorgenson, which does not deal explicitly with expectations. Implicit in the Jorgenson model is an assumption that the variables influencing investment are permanent and fully anticipated. Recently more complicated expectations effects have been approached empirically by formally modeling the cost of adjusting the capital stock as part of the firm's optimization problem. Sargent (1979) devotes several sections of his text to reporting and further developing this literature. Tobin's (1969) theory of q has been extremely helpful in expectations modeling, because it automatically incorporates future expectations in the value of the firm. The q theory has been studied in a rational expectations context, for example, by Summers (1981) and Hayashi (1982). An alternative to the adjustment cost approach is to incorporate construction (or gestation) times directly into the firm's optimization problem. This has been done by Kydland and Prescott (1982) and by Taylor (1982) in an applied investment policy problem.

Inventory investment models with rational expectations have also been intensively investigated recently. The Blinder and Fischer (1981) study – mentioned earlier as an example of an extension of the information-based models – develops a complete model of inventories using rational expectations assumptions. Blanchard (1983) has designed and estimated a detailed model of automobile inventories with rational expectations.

4 TECHNIQUES FOR ESTIMATION AND POLICY EVALUATION

Macroeconometric techniques have also been developed and modified to handle rational expectations models in macroeconomics. To some extent the pace of development here has lagged behind the substantive theoretical needs, and for this reason many rational expectations models have been given a very simple structure. The most extensive research effort in this area is that exemplified by Hansen and Sargent (1980, 1981), and Chow (1981), whose econometric strategy is to estimate the parameters of utility functions of agents solving maximization problems under rational expectations. A number of applications of this approach are currently under way. An example is the Blanchard (1982b) application previously mentioned. In addition, techniques for solving and estimating general rational expectations models have been developed and experimented with in work by Lipton *et al.* (1982), Fair and Taylor (1983), and Blanchard and Kahn (1980).

As I indicated earlier, policy questions arising from the appropriate interpretation of the Phillips curve correlations have been a major concern of rational expectations research. The general problem of interpreting such time-series correlations for policy questions was generalized and developed into a broad critique of conventional econometric work by Lucas (1976). The Lucas critique has had a profound influence on policy evaluation research in macroeconomics. To date, most of the influence has been to shed doubts on traditional econometric policy studies, but in recent years attempts have been made to deal constructively with the Lucas critique in policy work by using rational expectations explicitly in econometric models. Two of my research studies (Taylor, 1979, 1982) are examples of this, and the research effort by Hansen, Sargent and many others has the general aim of improving existing policy evaluation methods in this way.

An important macroeconomic policy issue that emerged from policy evaluation research in macroeconomics is the time inconsistency issue (see Kydland and Prescott, 1977; Calvo, 1979a; Fischer, 1980b; Barro and Gordon, 1983). Because anticipated as well as actual policy affects the behavior of agents, there is a temptation to use announced policy as an additional policy instrument. Time inconsistency occurs because, once a policy is announced and time has passed, it will generally be optimal to change the policy. The problem is not unique to macroeconomics, and its resolution is likely to come in fully developed theories of reputation and credibility (see Kreps and Wilson, 1980, for example).

5 PROBLEMS WITH RATIONAL EXPECTATIONS IN MACROECONOMICS

I started this paper by regarding rational expectations models in macroeconomics as a needed improvement over previously available methods for studying macroeconomic fluctuations. But rational expectations itself is likely to be modified and improved upon as research in macroeconomics proceeds. There are already a number of problems with rational expectations models that suggest the need for such improvement, at least for the study of certain policy issues.

The question of how agents learn about the economic environment that influences their behavior is rarely addressed in rational expectations research. Bayesian or least-squares learning rules were suggested in macroeconomic research by Taylor (1975) and Friedman (1979). The econometric difficulties in incorporating such learning assumptions in practical work has probably been one reason why these approaches have not had more applications in macroeconomics. The research by Bray (1982) and Blume and Easley (1982) has developed ways to deal with learning in which the behavior of individual agents is modeled explicitly.

Another problem with rational expectations is related to the uniqueness of rational expectations equilibria. Because of the self-fulfilling feature of rational expectations, there is generally a continuum of solutions to rational expectations models. Uniqueness has usually been obtained by assuming stability (i.e. no speculative bubbles) of the paths of expectations of variables, and in most cases this approach works (see Taylor, 1977, for a discussion of cases where it does not work). But the stability assumption itself has not always been motivated adequately, and recent research has attempted to test whether speculative bubbles do exist. Flood and Garber (1980) and Blanchard and Watson (1982) are examples of this type of empirical work.

A third problem with the rational expectations approach is that it implicitly assumes that agents expect that other agents have the same view of the economic environment as they do. In cases where events are recurrent, such as the business cycle phenomena discussed earlier, this assumption seems reasonable. But for the unusual events it should be questioned. Frydman and Phelps (1983) have discussed this problem in detail, and research is beginning to develop practical ways to deal with the problem (see Townsend, 1983, for example).

6 CONCLUDING REMARKS

This paper has concentrated on models of macroeconomic activity that use the rational expectations assumption. The aim has been to examine in some detail the differences between the models, the advantages and disadvantages of alternative models, the empirical support for the models, and their policy implications. The theme has been that there is wide diversity among rational expectations models in macroeconomics, despite their common expectational assumptions and techniques of analysis.

Continuing research on rational expectations models in macroeconomics – both in applications and in modifications of the basic assumption – indicates that it is still a developing field. Its overall contribution to economics will be better evaluated in later surveys with a perspective on these and future developments. At this time, however, it is clear that, despite the empirical shortcomings of the information-based models and the needed improvements in the microeconomic foundations for the sticky-price models, the rational expectations research to date has forced a useful rethinking of many relationships in macroeconomics (including the price–output relation emphasized here). Many of these relationships have been and are being used for policy analysis. Perhaps more importantly, it has also provided a methodology – along with requisite theoretical and empirical techniques – to continue developing an understanding for these relationships with the ultimate aim of sounder policy evaluation.

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REFERENCES

Altonji, J. G. (1982), 'The Intertemporal Substitution Model of Labor Market Fluctuations: An Empirical Analysis,' *Review of Economic Studies*, **49**, 783–824.

Arnott, R. and Stiglitz, J. E. (1981), 'Labor Turnover, Wage Structures, and Moral Hazard: The Inefficiency of Competitive Markets,' Economic Research Program Working Paper no. 289, Princeton University.

Ashenfelter, O. and Card, D. (1982), 'Time-series Representations of Economic Variables and Alternative Models of Labor Market,' *Review of Economic Studies*, **49**, 761–82.

Azariadis, C. (1975), 'Implicit Contracts and Underemployment Equilibria,' *Journal of Political Economy*, **83**, 1183–202.

Baily, M. N. (1974), 'Wages and Employment under Uncertain Demand,' *Review of Economic Studies*, **41**, 37–50.

Barro, R. J. (1972), 'A Theory of Monopolistic Price Adjustment,' *Review of Economic Studies*, **39**, 17–26.

Barro, R. J. (1976), 'Rational Expectations and the Role of Monetary Policy,' *Journal of Monetary Economics*, **2**, 1–32.

Barro, R. J. (1977), 'Unanticipated Money Growth and Unemployment in the United States,' *American Economic Review*, **67**, 101–15.

Barro, R. J. (1978), 'Unanticipated Money, Output and the Price Level in the United States,' *Journal of Political Economy*, **86**, 549–80.

Barro, R. J. (1980), 'A Capital Market in an Equilibrium Business Cycle Model,' *Econometrica*, **48**, 1393–417.

Barro, R. J. and Gordon, D. B. (1983), 'A Positive Theory of Inflation in a Natural Rate Model,' *Journal of Political Economy*, **91**, 589–610.

Barro, R. J. and Hercowitz, Z. (1980), 'Money Stock Revisions and Unanticipated Money Growth,' *Journal of Monetary Economics*, **6**, 257–67.

Blanchard, O. J. (1982), 'Price Desynchronization and Price Level Inertia,' NBER Working Paper no. 900.

Blanchard, O. J. (1983), 'The Production and Inventory Behavior of the American Automobile Industry,' *Journal of Political Economy*, **91**, 365–400.

Blanchard, O. J. and Kahn, C. (1980), 'The Solution of Linear Difference Models under Rational Expectations,' *Econometrica*, **48**, 1305–11.

Blanchard, O. J. and Watson, M. (1982), 'Bubbles, Rational Expectations and Financial Markets,' NBER Working Paper no. 945.

Blinder, A. (1981), 'Temporary Income Taxes and Consumer Spending,' *Journal of Political Economy*, **89**, 26–53.

Blinder, A. and Fischer, S. (1981), 'Inventories, Rational Expectations and the Business Cycle,' *Journal of Monetary Economics*, **8**, 277–304.

Blume, L. E. and Easley, D. (1982), 'Learning to be Rational,' *Journal of Economic Theory*, **26**, 340–51.

Boschen, J. F. and Grossman, H. I. (1980), 'Tests of Equilibrium Macroeconomics using Contemporaneous Monetary Data,' *Journal of Monetary Economics*, **10**, 309–33.

Bray, M. (1982), 'Learning, Estimation, and Stability of Rational Expectations,' *Journal of Economic Theory*, **26**, 318–39.

Calvo, G. (1979a), 'On the Time Consistency of Optimal Policy in a Monetary Economy,' *Econometrica*, **46**, 1411–28.

Calvo, G. (1979b), 'Quasi-Walrasian Theories of Unemployment,' *American Economic Review*, Papers and Proceedings, **69**, 102–7.

Calvo, G. (1983), 'Staggered Contracts and Exchange Rate Policy,' in J. A. Frenkel (ed.) *Exchange Rates and International Macroeconomics*, University of Chicago Press.

Chow, G. (1981), 'Estimation and Control of Rational Expectations Models,' *American Economic Review*, Papers and Proceedings, **71**, 211–16.

Cukierman, A. (1979), 'Rational Expectations and the Role of Monetary Policy: A Generalization,' *Journal of Monetary Economics*, **5**, 213–30.

Diamond, P. A. (1982), 'A Search Equilibrium Approach to the Micro Foundations of Macro Models,' Wicksell Lectures.

Dornbusch, R. (1982), 'PPP Rules and Exchange Rate Stability,' *Journal of Political Economy*, **90**, 158–65.

Fair, R. (1979), 'An Analysis of the Accuracy of Four Macroeconomic Models,' *Journal of Political Economy*, **87**, 701–18.

Fair, R. and Taylor, J. B. (1983), 'Solution and Maximum Likelihood Estimation of Nonlinear Dynamic Rational Expectation Models,' *Econometrica*, **51**, 1169–85.

Fischer, S. (1977), 'Long-term Contracts, Rational Expectations, and the Optimal Policy Rule,' *Journal of Political Economy*, **85**, 191–206.

Fischer, S. (1980a), 'On Activist Monetary Policy with Rational Expectations,' in S. Fischer (ed.), *Rational Expectations and Economic Policy*, University of Chicago Press for National Bureau of Economic Research.

Fischer, S. (1980b), 'Dynamic Inconsistency, Cooperation, and the Benevolent Dissembling Government,' *Journal of Economic Dynamics and Control*, 2, 93–107.

Fischer, S. (1981), 'Towards an Understanding of the Costs of Inflation: II,' in K. Brunner and A. H. Meltzer, *The Costs and Consequences of Inflation*, North-Holland, Amsterdam.

Fisher, I. (1925), *Purchasing Power of Money*, Macmillan, New York.

Flavin, M. (1981), 'The Adjustment of Consumption to Changing Expectations of Inflation,' *Journal of Political Economy*, **89**, 974–1009.

Flood, R. P. and Garber, P. M. (1980), 'Market Fundamentals versus Price-level Bubbles: The First Tests,' *Journal of Political Economy*, **88**, 745–70.

Friedman, B. (1979), 'Optimal Expectations and the Extreme Information Assumptions of "Rational Expectations" Macromodels,' *Journal of Monetary Economics*, **5**, 23–42.

Friedman, M. (1968), 'The Role of Monetary Policy,' *American Economic Review*, **58**, 1–17.

Frydman, R. and Phelps, E. S. (1983), 'Individual Expectations and Aggregate Outcomes: An Introduction to the Problem,' in R. Frydman and E. S. Phelps (eds), *Individual Forecasting and Aggregate Outcomes: 'Rational Expectations' Examined*, Cambridge University Press.

Germany, J. D. and Srivastava, S. (1979), 'Empirical Estimates of Unanticipated Policy Issues in Stability and Identification,' unpublished paper, Princeton University.

Gray, J. A. (1976), 'Wage Indexation: A Macroeconomic Approach,' *Journal of Monetary Economics*, 2, 221–36.

Green, J. and Honkapohja, S. (1983), 'Variance Minimizing Monetary Policies with Lagged Price Adjustment and Rational Expectations,' *European Economic Review*, **20**, 123–41.

Green, J. and Laffont, J. J. (1981), 'Disequilibrium Dynamics with Inventories and Anticipatory Price-setting,' *European Economic Review*, **16**, 199–223.

Hall, R. E. (1978), 'Stochastic Implications of the Life-Cycle–Permanent Income Hypothesis: Theory and Evidence,' *Journal of Political Economy*, **86**, 971–87.

Hall, R. E. (1980), 'Labor Supply and Aggregate Fluctuations,' *Carnegie-Rochester Conference Series on Public Policy*, **12**, 7–33.

Hall, R. E. and Mishkin, F. S. (1982), 'The Sensitivity of Consumption to Transitory Income: Estimates from Panel Data on Households,' *Econometrica*, **50**, 461–81.

Hansen, L. P. and Sargent, T. J. (1980), 'Formulating and Estimating Dynamic Linear Rational Expectations Models,' *Journal of Economic Dynamics and Control*, **2**, 7–46.

Hansen, L. P. and Sargent, T. J. (1981), 'Linear Rational Expectations Models for Dynamically Interrelated Variables,' in R. E. Lucas and T. J. Sargent (eds), *Rational Expectations and Econometric Practice*, University of Minnesota Press, Minneapolis.

Hayashi, F. (1982), 'Tobin's Marginal *q* and Average *q*: A Neoclassical Interpretation,' *Econometrica*, **50**, 213–24.

Hercowitz, Z. (1980), 'Money and Relative Price Dispersion in the United States,' NBER Working Paper no. 433.

Keynes, J. M. (1923), *Monetary Reform*, Macmillan, London.

Kreps, D. M. and Wilson, R. (1980), 'Reputation and Imperfect Information,' *Journal of Economic Theory*, 27, 253–79.

Kydland, F. and Prescott, E. C. (1977), 'Rules Rather than Discretation: The Inconsistency of Optimal Plans,' *Journal of Political Economy*, **85**, 473–92.

Kydland, F. and Prescott, E. C. (1982), 'Time to Build and Aggregate Fluctuations,' *Econometrica*, **50**, 1345–70.

Lipton, D. *et al.* (1982), 'Multiple Shooting in Rational Expectations Models,' *Econometrica*, **50**, 1329–33.

Lucas, R. E., Jr (1966), 'Optimal Investment with Rational Expectations,' in R. E. Lucas, Jr and T. J. Sargent (1981), *Rational Expectations and Econometric Practice*, University of Minnesota Press, Minneapolis.

Lucas, R. E., Jr (1972a), 'Expectations and the Neutrality of Money,' *Journal of Economic Theory*, **4**, 103–24.

Lucas, R. E., Jr (1972b), 'Econometric Testing of the Natural Rate Hypothesis,' in O. Eckstein (ed.), *The Econometrics of Price Determination*, Board of Governors of the Federal Reserve System, Washington, DC.

Lucas, R. E., Jr (1973), 'Some International Evidence on Output–Inflation Tradeoffs,' *American Economic Review*, **63**, 326–34.

Lucas, R. E., Jr (1975), 'An Equilibrium Model of the Business Cycle,' *Journal of Political Economy*, **83**, 1113–44.

Lucas, R. E., Jr (1976), 'Econometric Policy Evaluation: A Critique,' *Journal of Monetary Economics*, Supplement, 19–46.

Lucas, R. E., Jr (1981), 'Tobin and Monetarism: A Review Article,' *Journal of Economic Literature*, **19**, 558–67.

Lucas, R. E. and Prescott, E. C. (1971), 'Investment under Uncertainty,' *Econometrica*, **39**, 659–81.

Malinvaud, E. (1978), *The Theory of Unemployment Reconsidered*, Basil Blackwell, Oxford.

Mankiw, N. G., Rotemberg, J. J. and Summers, L. H. (1982), 'Intertemporal Substitution in Macroeconomics,' NBER Working Paper no. 898.

McCallum, B. T. (1980), 'Rational Expectations and Macroeconomic Stabilization Policy,' *Journal of Money Credit and Banking*, **12**, 716–46.

McCallum, B. T. (1982), 'Macroeconomics after a Decade of Rational Expectations: Some Critical Issues,' unpublished paper, Carnegie-Mellon University.

McCallum, B. T. and Whitaker, J. K. (1979), 'The Effectiveness of Fiscal Feedback Rules and Automatic Stabilizers under Rational Expectations,' *Journal of Monetary Economics*, **5**, 171–86.

Mishkin, Frederic S. (1982), 'Does Anticipated Monetary Policy Matter? An Econometric Investigation,' *Journal of Political Economy*, **1**, 22–51.

Muth, J. (1961), 'Rational Expectations and the Theory of Price Movements,' *Econometrica*, **29**, 315–35.

Neary, J. P. and Stiglitz, J. E. (1979), 'Towards a Reconstruction of Keynesian Economics: Expectations and Constrained Equilibria,' NBER Working Paper no. 376.

Pigou, A. C. (1927), *Industrial Fluctuations*, Macmillan, London.

Phelps, E. S. (1967), 'Phillips Curves, Expectations of Inflation and Optimal Unemployment Over Time,' *Economica*, **34**, 254–81.

Phelps E. S. (1978), 'Disinflation without Recession: Adaptive Guideposts and Monetary Policy,' *Weltwirtschaftliches Archiv*, **2**.

Phelps, E. S. and Taylor, J. B. (1977), 'Stabilizing Powers of Monetary Policy Under Rational Expectations,' *Journal of Political Economy*, **85**, 163–90.

Phillips, A. W. (1958), 'The Relation between Unemployment and the Rate of Change of Wage Rates in the United Kingdom, 1861–1957,' *Economica*, **25**, 283–99.

Salop, S. C. (1979), 'A Model of the Natural Rate of Unemployment,' *American Economic Review*, **69**, 117–25.

Sargent, T. J. (1976), 'A Classical Macroeconometric Model for the United States,' *Journal of Political Economy*, **84**, 207–38.

Sargent, T. J. (1978a), 'Rational Expectations, Econometric Exogeneity, and Consumption,' *Journal of Political Economy*, **86**, 673–700.

Sargent, T. J. (1978b), 'Estimation of Dynamic Labor Demand Schedules under Rational Expectations,' *Journal of Political Economy*, **86**, 1009–44.

Sargent, T. J. (1979), *Macroeconomic Theory*, Academic Press, New York.

Sargent, T. J. (1982), 'The Ends of Four Big Inflations,' in Robert E. Hall (ed.), *Inflation: Causes and Effects*, University of Chicago Press.

Sargent, T. J. and Wallace, N. (1975), 'Rational Expectations and Optimal Monetary Instrument and the Optimal Money Supply Rule,' *Journal of Political Economy*, **83**, 241–54.

Sheshinski, E. and Weiss, Y. (1977), 'Inflation and the Cost of Price Adjustment,' *Review of Economic Studies*, **44**, 287–304.

Small, D. H. (1979), 'Unanticipated Money Growth and Unemployment in the United States: Comment,' *American Economic Review*, **69**, 996–1003.

Summers, L. H. (1981), 'Taxation and Corporate Investment: A *q*-Theory Approach,' *Brookings Papers on Economic Activity*, no. 1, 67–127.

Taylor, J. B. (1975), 'Monetary Policy during a Transition to Rational Expectations,' *Journal of Political Economy*, **83**, 1009–21.

Taylor, J. B. (1977), 'Conditions for Unique Solutions in Stochastic Macroeconomic Models with Rational Expectations,' *Econometrica*, **45**, 1377–86.

Taylor, J. B. (1979), 'Estimation and Control of a Macroeconomic Model with Rational Expectations,' *Econometrica*, **47**, 1267–86.

Taylor, J. B. (1980a), 'Aggregate Dynamics and Staggered Contracts,' *Journal of Political Economy*, **88**, 1–23.

Taylor, J. B. (1980b), 'Output and Price Stability: An International Comparison,' *Journal of Economic Dynamics and Control*, **2**, 109–32.

Taylor, J. B. (1981), 'On the Relation between the Variability of Inflation and The Average Inflation Rate,' in *Carnegie-Rochester Conference Series on Public Policy*, **15**, 57–86.

Taylor, J. B. (1982), 'The Swedish Investment Funds System as a Stabilization Policy Rule,' *Brookings Papers on Economic Activity*, no. 1, 57–99.

Tobin, J. (1969), 'A General Equilibrium Approach to Monetary Theory,' *Journal of Money Credit and Banking*, **1**, 15–29.

Townsend, R. M. (1983), 'Forecasting the Forecasts of Others,' *Journal of Political Economy*, **91**, 546–88.

Weiss, L. (1980), 'The Role for Active Monetary Policy in a Rational Expectations Model,' *Journal of Political Economy*, **88**, 221–33.