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What Does Unemployment Tell Us About Future Inflation?

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The unemployment rate commonly is used as an indicator of future inflation, with a low unemployment rate, for example, assumed to imply higher inflation. This negative correlation between current *unemployment and* future *inflation assumes that aggregate demand factors primarily are responsible for movements in these variables. However, as discussed in this paper, changes in aggregate supply conditions, such as technology and labor supply, also cause movements in unemployment and inflation. These factors lead to a* positive *relationship between future unemployment and current inflation. Consequently, a given rate of unemployment could be associated with almost any rate of inflation, depending on the source of the shock. In this paper, we attempt to disentangle demand and supply shocks, and analyze their influence on unemployment and inflation in the post-World War II U.S. economy.*

The level of the unemployment rate commonly is used as an indicator of future inflation. When unemployment is judged to be below (above) its long-run, or "natural" rate, inflation is projected to rise (fall) in the future. This negative correlation between unemployment and inflation is fundamental to the Keynesian, expectations-augmented Phillips curve, which expresses inflation as a function of the unemployment rate relative to its long-run level, expected inflation, and changes in certain relative prices such as those of oil and the dollar.

This interpretation of the relationship between unemployment and inflation focuses primarily on the effects of demand factors, such as monetary and fiscal policies. In recent years, however, macroeconomic research increasingly has incorporated such aggregate supply factors as changes in technology and the supply of labor in models of the behavior of the economy. "Real business cycle" models, in particular, attempt systematically to incorporate the effects of supply factors. As discussed below, this real business cycle approach[1] suggests a *positive* correlation between unemployment and inflation.

Conceptually, the correlations between inflation and unemployment implied by both the Phillips-curve and real business cycle models may coexist. The observed relationship in any given period thus depends on whether demand or supply factors were the more influential during that period. Accordingly, in this paper we estimate a model that treats unemployment and inflation as endogenous variables that respond to both aggregate demand and aggregate supply factors.

We find that both kinds of shocks are important in explaining movements in inflation and unemployment, and that both produce the well-known clockwise temporal loops observed when the actual inflation rate is plotted against the actual unemployment rate. Thus these loops, which commonly are presented in macroeconomic textbooks as arising from demand shocks in the context of the Phillips-curve relationship, also are consistent with supply shocks playing an important role. In addition, we find that while the effects of demand shocks on the unemployment rate reverse themselves in one to two years, the effects of supply shocks last much longer, and appear to have been responsible for large, persistent movements in the unemployment rate. Finally, the fact that *both* demand and supply shocks play significant roles diminishes the usefulness of the unemployment rate as an indicator of future inflation, since policy makers must be able to identify the source of a change in the unemployment rate before that variable can be used to make a forecast of future inflation.

The remainder of the paper is organized as follows. Section I spells out the kinds of correlations between inflation and unemployment that may be expected on *a priori* grounds in response to demand and supply shocks. Section II discusses the econometric method we use to estimate demand and supply shocks, and presents some evidence on the characteristics of these shocks. In Section III we present empirical estimates of how inflation and unemployment react to these shocks, and also the role played by the shocks in generating the observed correlation between inflation and unemployment over the past 25 years. Finally, Section IV discusses some policy implications.

I. Inflation-Unemployment Correlations in Theory

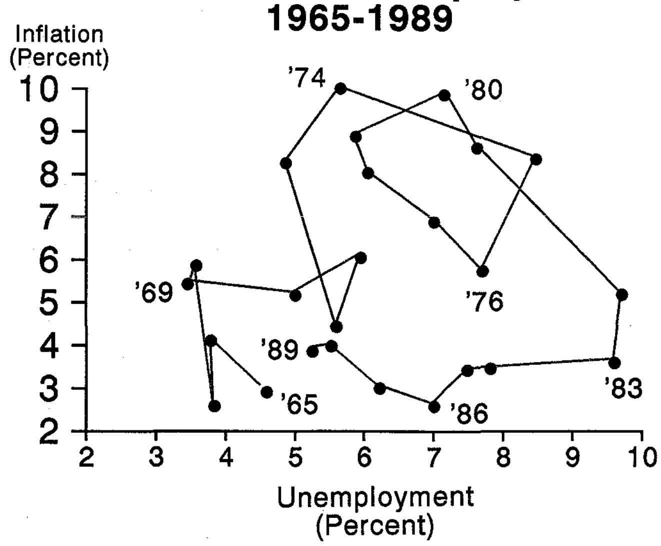
Keynesian theory stresses the role of aggregate demand factors in causing business cycles, and focuses on capacity bottlenecks caused by excess demand as the catalyst for inflation. In this view, prices rise to relieve shortages of labor and capital, and when monetary policy accommodates these price pressures, inflation results. The expectations-augmented Phillips curve embodies this hypothesis; in this case, for a given level of expected inflation, the difference between the prevailing rate of unemployment and the bench-mark rate (the so-called "natural" rate) provides a measure of aggregate-demand pressures on inflation.[2]

The inflation process can be illustrated with the following example. A positive demand shock induces firms to hire more workers. As the unemployment rate falls below the natural rate, labor markets become increasingly tight, and firms push wages up as they bid for labor. Faced with rising labor costs, firms raise product prices to maintain their mark-up over cost.[3] Thus, a decrease in the unemployment rate is followed by higher inflation. Ultimately, however, the unemployment rate returns to its original (long-run) level.[4] When the unemployment rate is graphed against the inflation rate over time, this sequence of events leads to clockwise loops similar to those shown in Chart 1.

Current research on the Phillips curve relationship also allows some kinds of relative prices to affect the inflation rate, such as changes in the relative price of oil and the real foreign-exchange value of the dollar. However, the Phillips curve captures only the direct price effects of a change in relative prices. By construction, it excludes possible effects on the unemployment rate of supply shocks associated with changes in relative prices. For example, a rise in the price of oil not only can be expected to raise the aggregate price index, but also may raise the unemployment rate.[5] Moreover, the Phillips curve omits by construction a broad range of other types of supply shocks, the most significant of which may be changes in technology and in the labor-leisure decisions of households. Attempts to incorporate aggregate supply factors into the Phillips curve model have been *ad hoc,* and do not represent a comprehensive and systematic treatment of this aspect of economic behavior.[6]

By contrast, real business cycle models attempt to explain business cycles entirely on the basis of real developments, such as shocks to labor supply and technology.[7] These models de-emphasize demand factors in much the same way that Keynesian models de-emphasize supply factors. The real business cycle approach received considerable impetus from the observation that the levels of many real variables, including real GNP, contain permanent, random-walk-like components.[8] Given that

Chart 1
Inflation and Unemployment
1965-1989



economic theory suggests that demand factors cannot permanently affect the levels of real variables, supply shocks, which can have permanent effects, must play a role in explaining fluctuations in real GNP.

The simple model of aggregate demand and supply commonly used in macroeconomic textbooks can be used to illustrate how a supply shock would affect the correlation between inflation and output. A positive technology shock, for instance, leads to an increase in aggregate supply (that is, a rightward shift in the aggregate supply curve), implying an increase in equilibrium output and a fall in the price level. In a dynamic context, a rise in aggregate supply would translate into lower inflation and higher real GNP growth.

Rigorously-derived real business cycle models that allow a role for money also predict such a negative correlation between inflation and output.[9] Moreover, a positive (negative) technology shock will have sustained negative (positive) effects on the unemployment rate in these models as long as searching for labor is costly.[10] For example, a higher marginal product of labor (positive technology shock) raises the marginal net benefit to searching for labor, and thus lowers the unemployment rate.

Putting these elements together implies a *positive* relationship between inflation and the unemployment rate. Whether the predicted co-movements are consistent with the clockwise temporal loops shown in Chart 1 depends upon the dynamic properties of the responses of inflation and unemployment to supply shocks. For instance, clockwise loops likely would result if the inflation rate responded first to supply shocks, and the unemployment rate responded afterwards. Theory does not predict the exact dynamic pattern that will occur, so the question must be resolved empirically.

Real business cycle and Phillips curve models both imply extreme views of the source of observed co-movements in the inflation and unemployment rate data. Theory does not rule out the possibility that *both* demand and supply factors operate simultaneously, and combine to produce the data we observe. The magnitude of each factor's independent influence, then, is an empirical issue. A balanced approach, in which neither demand nor supply factors are excluded, appears to be the most fruitful strategy for research. In the next section, we use an approach that is theoretically agnostic about the relative importance of demand and supply factors, and instead uses the data to estimate the magnitudes of each of those influences.

II. Estimates of Demand and Supply Shocks

In assessing the major forces determining the inflation-unemployment relationship, economic time series that directly measure aggregate demand and supply shocks would be most helpful. However, this is not possible in most cases.

Demand shocks can arise from a number of sources including changes in monetary policy, fiscal policy, inflation expectations, and consumer tastes, among others. Deregulation of the financial system has made the money supply (historically a good source of information on demand shocks emanating from Federal Reserve policy) a poor measure of these shocks.[11] Interest rates might provide an alternative measure since they are influenced by Federal Reserve actions. But because they also are influenced by other factors such as fiscal policy, inflation expectations, and aggregate supply, they are likely to be poor measures of monetary policy shocks as well.

With respect to variables representing fiscal policy, there are major problems in the national income accounts that make it difficult to obtain conceptually appropriate measures of government activity, including the inability to distinguish between capital and current expenditures and the exclusion of the "revenues" generated by the inflation "tax".[12] Other factors that can induce demand shocks—such as changes in the public's expectations of inflation or consumer confidence—also are difficult to measure directly.

Similar problems exist in attempting to measure supply shocks. These shocks originate from a variety of sources, including the development of new products (for example, computers), new ways to combine labor and capital more efficiently, changes in individuals' willingness to work, changes in tax laws, as well as sudden changes in the relative prices of important inputs to production such as oil. While certain taxes and relative prices can be measured directly, the other potential sources of supply shocks do not have direct empirical counterparts.[13]

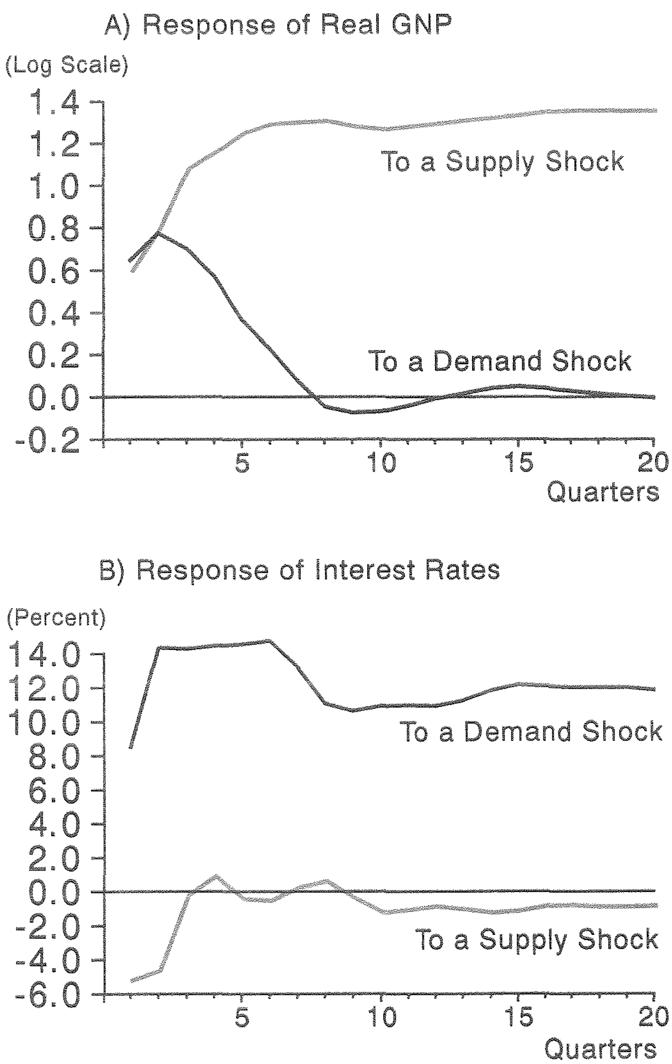
Econometric Method

An alternative approach to direct measurement is to estimate econometrically the demand and supply shocks that have influenced the aggregate macroeconomic time series data. The method used in this paper is that of Blanchard and Quah (1989) and involves estimating a vector autoregression under the assumptions that supply shocks can have long-run effects on real variables, while demand shocks can have only temporary effects.

Using these assumptions, it is possible to obtain estimates of demand and supply shocks from a VAR containing two variables: the rate of growth of per capita real GNP, y, and the quarterly change in the three-month Treasury bill rate, i.[14] Two types of (unobserved) structural disturbances are assumed to affect these variables. We identify these disturbances, respectively, with aggregate demand and aggregate supply. This procedure is described in the Box.

As noted earlier, the purpose of obtaining estimates of demand and supply shocks is to see if they help explain the dynamic relationship between inflation and unemployment. We chose to estimate the shocks independently of the inflation and unemployment data. Our concern was that if we estimated the shocks within the context of a model of inflation and unemployment, we would run an unacceptably high risk of capturing spurious correlations between the shocks, on the one hand, and inflation and unemployment, on the other hand. Of course, we recognize that output and interest rates are related to inflation and unemployment. However, by not using the latter two variables directly in the estimation of the shocks, we have reduced the chance of obtaining spurious results.

Chart 2
Dynamic Responses



Properties of the Estimated Shocks

To provide an indication of the nature of the shocks we estimated, Chart 2 presents plots of the dynamic effects of the typical demand and supply shocks on real GNP and the nominal interest rate over the 1955–89 period. Real GNP increases almost monotonically in response to a positive supply shock, growing rapidly in the first year following the shock, and then slowing down to its new long-run level about four years after the initial shock. Although the steady-state growth rate of real GNP is not affected by the supply shock, the *level* of real GNP remains permanently higher in steady-state.

The response of real GNP to demand shocks peaks in about two quarters and then dies out after approximately two years. In the case of a demand shock, by construction, both the level and the growth rate of real GNP are left unchanged in steady state.

In contrast, as shown in the second panel of Chart 2, a positive demand shock permanently raises the nominal interest rate. Supply shocks appear to have little or no effect on the nominal interest rate.

Table 1
Variance Decompositions
(Percent)

Forecast Horizon	Real GNP		Interest Rate	
Quarters Ahead	Supply Shocks	Demand Shocks	Supply Shocks	Demand Shocks
1	46	54	27	73
2	49	51	15	85
4	65	35	7	93
8	83	17	3	97
12	89	11	2	98
60	98	2	1	99

Estimating Demand and Supply Shocks From A Vector Autoregression

We employ moving-average representations of the quarterly changes in real per capita GNP (y) and the three-month Treasury bill rate (i) to illustrate how estimates of the underlying disturbances (v and e) are obtained. For illustrative purposes, we introduce dynamics into a simplified version of our model by including only one lag of v in each equation, although the estimated model contains more lags.

Assume, then, that the behavior of y and i is described by:

$$y_t = a_1 e_t + b_1 v_t + c_1 v_{t-1} \quad \text{(B1)}$$

$$i_t = a_2 e_t + b_2 v_t + c_2 v_{t-1} \quad \text{(B2)}$$

In order to study the dynamics of this system, estimates of the coefficients in equations (B1) and (B2) are needed. By placing certain identifying restrictions on the unobserved disturbances e and v, we are able to obtain estimates of the impact of each of them from observations on y and i. In traditional fashion, we assume that e and v are uncorrelated with each other and have unit variance. In addition, e and v are assumed to be serially uncorrelated. Given the representations in equations (B1) and (B2), these assumptions imply the following identifying restrictions:

$$\sigma_y^2 = a_1^2 + b_1^2 + c_1^2$$

$$\sigma_i^2 = a_2^2 + b_2^2 + c_2^2$$

$$\sigma_{y_t, i_t} = a_1 a_2 + b_1 b_2 + c_1 c_2$$

$$\sigma_{y_t, i_{t-1}} = c_1 b_2$$

$$\sigma_{y_{t-1}, i_t} = b_1 c_2$$

where σ_y^2 is the (observed) variance of y, σ_i^2 is the variance of i, $\sigma_{y,i}$ is the contemporaneous covariance of i and y, and the other variances are defined similarly.

So far, there are five conditions and six coefficients to estimate. One more restriction is needed to identify the model. Our final restriction comes from the assumption that v has no long-run effect on output; that is,

$$b_1 + c_1 = 0. \quad \text{(B3)}$$

This restriction, together with the conventional restrictions on variances and covariances, is just sufficient to identify the unobserved shocks from observations on y and i. The restriction defined by this final assumption is consistent with our interpretation of the underlying structural disturbances: v can be interpreted as an aggregate-demand shock, since it can have no long-run effect on y. In other words, the permanent level of real GNP is determined by real factors and can be only temporarily disturbed by aggregate demand factors. The effects of aggregate supply shocks will be captured by e, since these shocks are permitted to have permanent effects on the real variable, y.

In practice, these restrictions can be imposed in one of two ways. The first way—followed by Blanchard and Quah (1989)—is to estimate the usual vector autoregression (which involves regressing both y and i on lagged values of both variables) to obtain the variance-covariance matrix of the residuals. This matrix then is transformed to satisfy the restrictions given above. The second method (employed here) is due to Shapiro and Watson (1988), and is easier to implement. The two estimated equations are specified as

$$y_t = \sum_{j=1}^{n} \beta_{1,j} y_{t-j} + \sum_{j=0}^{n-1} \beta_{2,j} \Delta i_{t-j} + \epsilon_{1,t} \quad \text{(B4)}$$

$$i_t = \sum_{j=1}^{n} \gamma_{1,j} y_{t-j} + \sum_{j=1}^{n} \gamma_{2,j} i_{t-j} + \gamma_3 \epsilon_{1,t} + \epsilon_{2,t} \quad \text{(B5)}$$

As explained in detail in Shapiro and Watson, the inclusion of the interest rate variable in second-difference form[1] in the output equation is key to isolating a series that has only temporary effects on output. This restriction corresponds to (B3) above.[2]

1. Inclusion of second differences is equivalent to including the first differences of the interest rate with the restriction that the coefficients sum to zero.

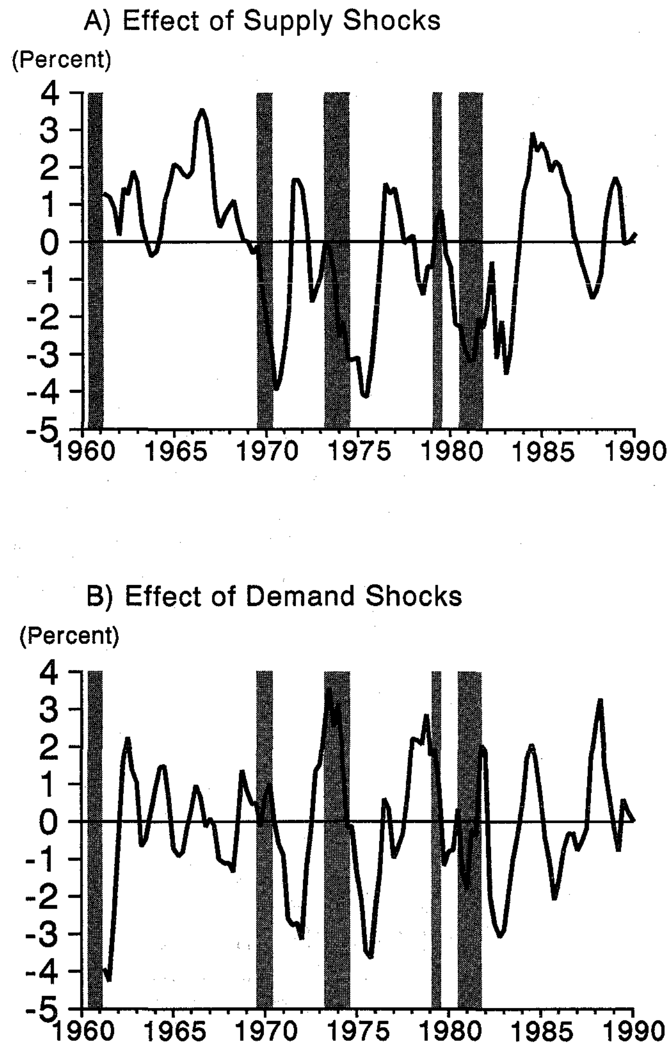
2. Two technical points are worth mentioning. First, inclusion of the contemporaneous interest rate term in the output equation implies that we must employ instrumental variables techniques in estimating the equation. We used lagged values of the variables in the model as instruments. Second, once the interest rate terms are included in this way, a Choleski decomposition can be used to recover ϵ_1 and ϵ_2. (See Shapiro and Watson for details.)

Table 1 presents the associated variance decompositions, which show the relative importance of demand and supply shocks in explaining the unpredictable movements in real GNP and the nominal interest rate. Demand shocks account for slightly more than one half of the unpredictable variation in output one quarter ahead, and about one third of that variation four quarters ahead. The remainder of the variation is accounted for by supply shocks. Thus, both demand and supply shocks play important roles in causing short-run fluctuations in real output. However, by construction, the long-run movements in the level of real GNP are the result only of supply shocks.

With respect to movements in interest rates, in contrast, demand shocks are much more important, accounting for about three fourths of the unpredictable interest rate variation one quarter ahead, and nearly all the variation at horizons of one year and beyond.

Chart 3 shows the estimated quarter-by-quarter effects of demand and supply shocks on real GNP over the period from 1960:Q1 to 1989:Q3.[15] These effects seem broadly consistent with the conventional interpretation of the major events in the period covered. As shown in the top panel, supply shocks were responsible for much of the above average economic growth during the 1960s, coinciding with the well-known productivity surge in that period. They also played a role in the 1973–75 and 1980–82 recessions, and may therefore be associated with the large oil shocks in those periods. Consistent with the recent history of monetary policy, the estimates shown in the bottom panel suggest that contractionary aggregate demand shocks played substantial roles in both the 1973–75 and the 1980–82 recessions, and that an expansionary demand shock was important in the late 1970s, when inflation accelerated.

Chart 3
Historical Decomposition of Real GNP Growth



III. Explaining Unemployment and Inflation

Having obtained measures of the supply and demand shocks during the 1960–89 period, our objective is to assess the relative importance of each of these shocks in explaining movements in inflation and unemployment. For this purpose, we estimated separate equations for unemployment and inflation as functions of current and lagged values of the estimated demand and supply shocks.

The equations are:

$$\pi_t = \sum_{i=0}^{16} \alpha_i s_{t-i} + \sum_{i=0}^{8} \beta_i d_{t-i} + \theta \bar{m}_t \qquad (1)$$

$$u_t = \sum_{i=0}^{4} \gamma_i s_{t-i} + \sum_{i=0}^{8} \delta_i d_{t-i} + \lambda u_{t-1} \qquad (2)$$

where π_t and u_t denote the rates of inflation and unemployment, respectively, and d_t and s_t are the (zero mean) demand and supply shocks. The inflation equation contains 16 lags of the supply shock variable and eight lags of the demand shock variable. These lag lengths were selected by doing F-tests on the relevant variables, four lags at a time. $\bar{m}_t$ denotes the average rate of M2 growth over the prior five years. It is included to allow the trend of inflation to move over the sample.[16] The demand and supply shock terms, then, explain deviations of inflation from the trend rate. Inclusion of $\bar{m}$ reduces the available sample size (compared with the sample used for the VAR above) because data for M2 begin only in 1959. Taking into consideration the lags in the model, 1965 is the earliest date at which we could begin the sample for the inflation equation.

The unemployment equation contains four lags of the supply shock, eight of the demand shock, and a lagged dependent variable. Without the latter variable, the significant lags on supply shocks in the unemployment equation were extremely long—at least 50 quarters. Thus, the lagged dependent variable was used to save degrees of freedom.[17]

In addition, we estimated

$$m_t = \sum_{i=0}^{8} \psi_i s_{t-i} + \sum_{i=0}^{4} \phi_i d_{t-i} + \sum_{i=1}^{3} \rho_i m_{t-i} \qquad (3)$$

where m_t denotes the rate of growth of M2. The M2 equation is required for dynamic simulations of the inflation equation, since the latter contains the 5-year average growth rate of M2 as a regressor. Equation 3 also contains constant dummy variables to eliminate the following observations from our sample: 1980:Q2 and 1980:Q3, because of the imposition and removal, respectively, of the Carter credit control program; and 1982:Q4 and 1983:Q1, because of the introduction of MMDAs. Finally, we also allowed the intercept term of the equation to change following the introduction of MMDAs.

Table 2
Summary Statistics From Regressions

	Dependent Variable		
Statistics	Unemployment Rate	Inflation	M2 Growth
Marginal Significance Levels of:			
F_1	.01	.01	.01
F_2	.01	.01	.01
t_1	—	.01	—
Adj. R^2	.99	.67	.79
SEE	.18	.40	.40
AR(1)	—	.41	—
(t-statistic)	—	(3.8)	—

F_1 is F statistic for null hypothesis that supply shocks have no impact on relevant variable.
F_2 is F statistic for null hypothesis that demand shocks have no impact on relevant variable.
t_1 is t-statistic for null hypothesis that M2 growth has no impact on inflation.

Table 2 presents summary statistics on these equations. Both the estimated demand and supply shocks are highly significant in all three equations. The errors from the ordinary-least-squares estimates of the inflation equation show evidence of first-order serial correlation, and we applied a correction for this. The first-order autocorrelation coefficient (AR(1)) estimate of 0.41 in the inflation equation compares to the AR(1) estimate of 0.75 in the raw inflation data, so our explanatory variables account for some, but not all, of the serial correlation in inflation.

To provide a better idea of the fit of these specifications, Chart 4 shows the actual values of inflation and the unemployment rate as well as dynamic simulations from our estimated equations. The equations do a good job of capturing the major swings in unemployment and inflation.

Chart 4
Dynamic Simulations

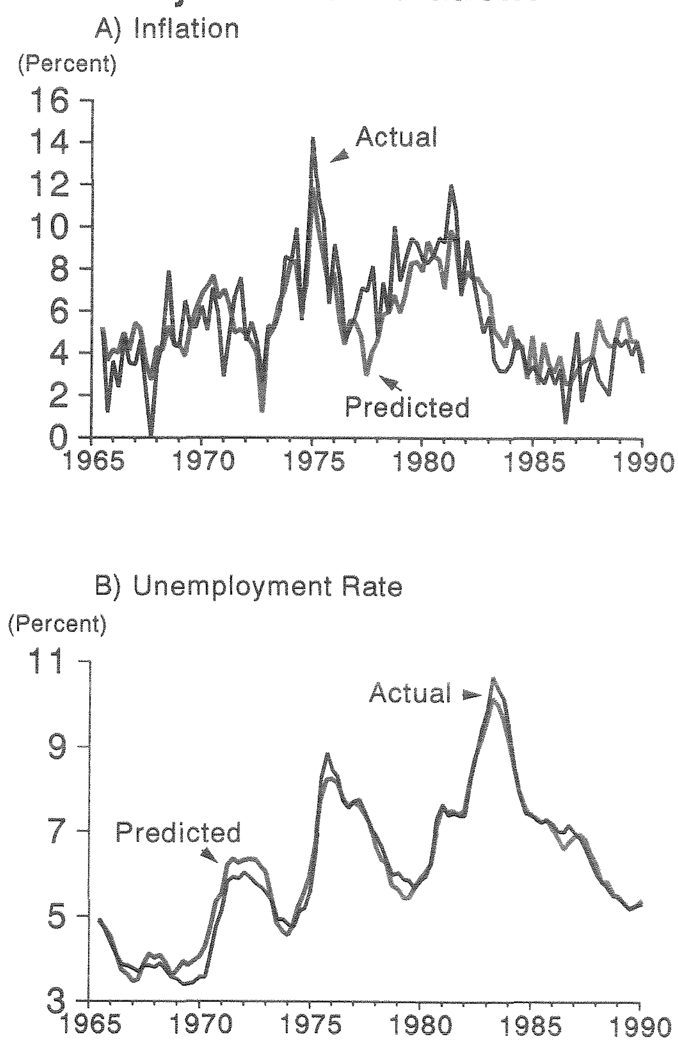


Chart 5
Dynamic Responses

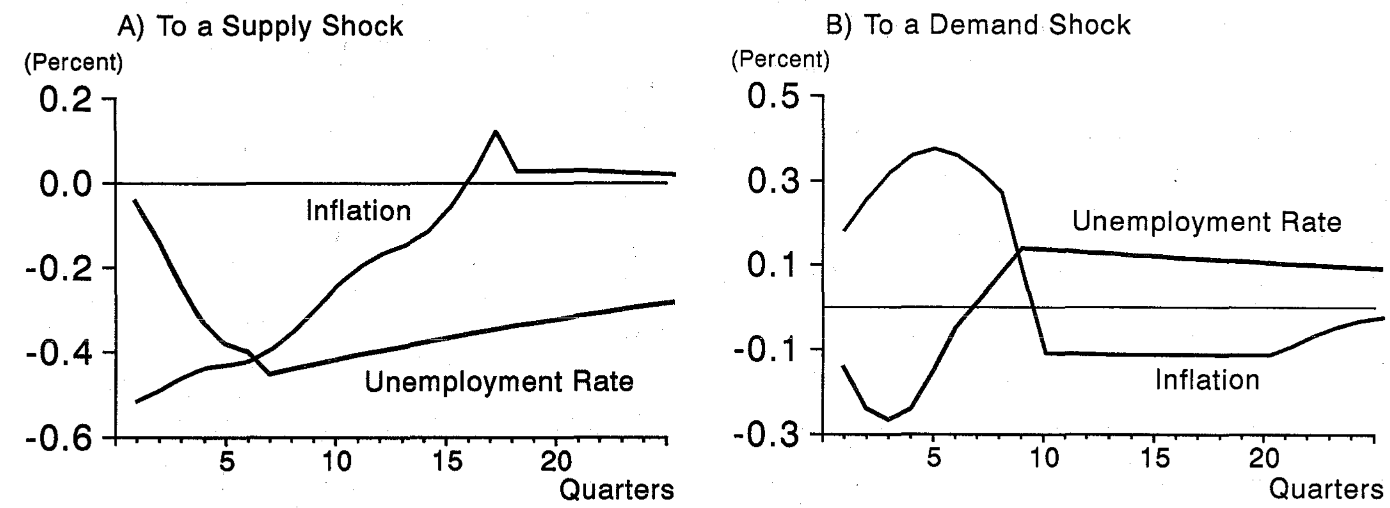


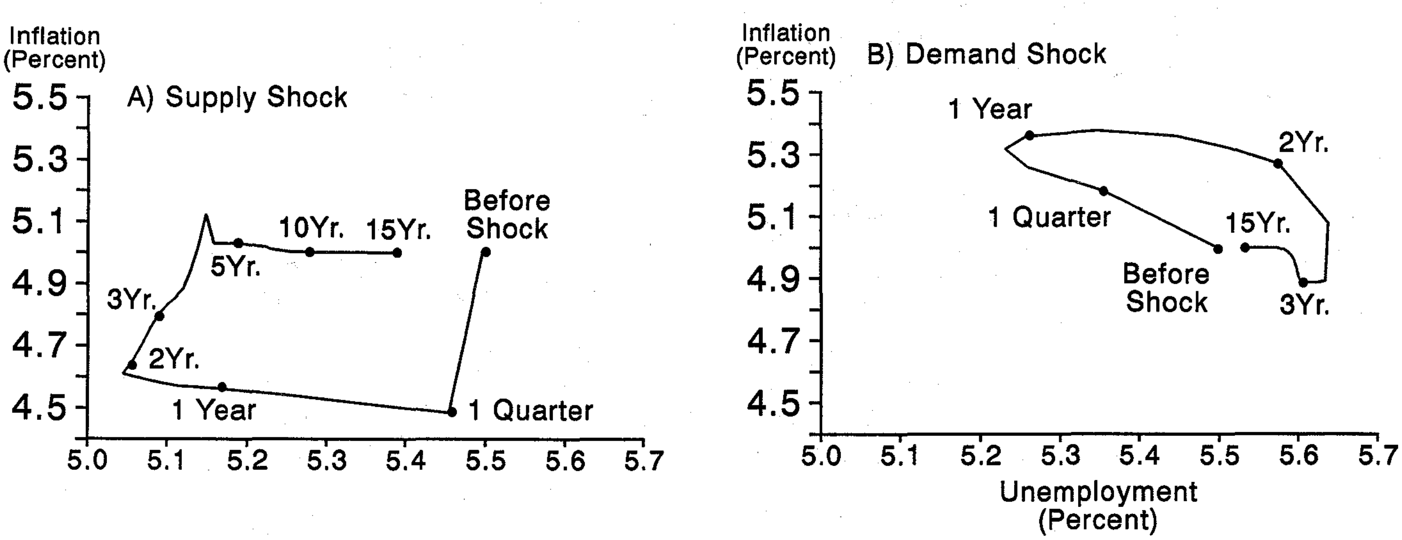
Chart 5 presents the estimated responses of inflation and unemployment to (one-standard-deviation) positive demand and supply shocks.[18] These dynamic responses have the signs predicted by theory. A positive demand shock reduces unemployment and raises inflation, while a positive supply shock reduces both unemployment and inflation.

Clockwise Loops

Chart 6 plots these dynamic responses in inflation-unemployment space. For illustrative purposes, we assume that the unemployment rate initially is 5.5 percent and the rate of inflation is 5.0 percent. The left panel shows the effects of a positive supply shock. The immediate response is a reduction in the inflation rate, after which unemployment gradually declines. The inflation rate moves back to its original level in two to four years after the shock, but the unemployment rate takes much longer to get back to its original level. Thus, even supply shocks lead to clockwise loops.

As shown in the right-hand panel, a demand shock initially has a larger impact on the unemployment rate. Unemployment reaches its minimum in less than a year, but by the end of the second year has risen back to its original level. The inflation rate rises as the unemployment

Chart 6
Dynamic Effects of Shocks on Unemployment and Inflation



rate declines, and remains high for nearly a year after the unemployment rate has returned to its original level. Thus, demand shocks produce the temporary trade-off predicted by the Phillips curve. Note that the effects of supply shocks evolve more slowly and take longer to be completed than those generated by demand shocks.

The loops in Chart 6 demonstrate why it is not possible to develop simple rules of thumb to judge future inflation based upon current observations of the level of unemployment. Any given rate of unemployment could be followed by almost any rate of inflation depending on the source of the shock. Further, since the loops ultimately go back to their starting points, a particular rate of unemployment will be associated with different rates of inflation at different points in time.

For similar reasons, *changes* in the unemployment rate are unlikely to provide accurate information about future changes in inflation. Consider, for instance, the left-hand panel of Chart 6. A falling rate of unemployment may be followed either by rising inflation (as inflation moves back to its original level between the second and fourth years after the shock), or by no change in inflation (as unemployment gradually adjusts back to its original level after the fourth year). Thus, Chart 6 provides an illustration of the general principle that using one endogenous variable to draw inferences about another endogenous variable can be a tricky enterprise.

Simulating Inflation-Unemployment Loops

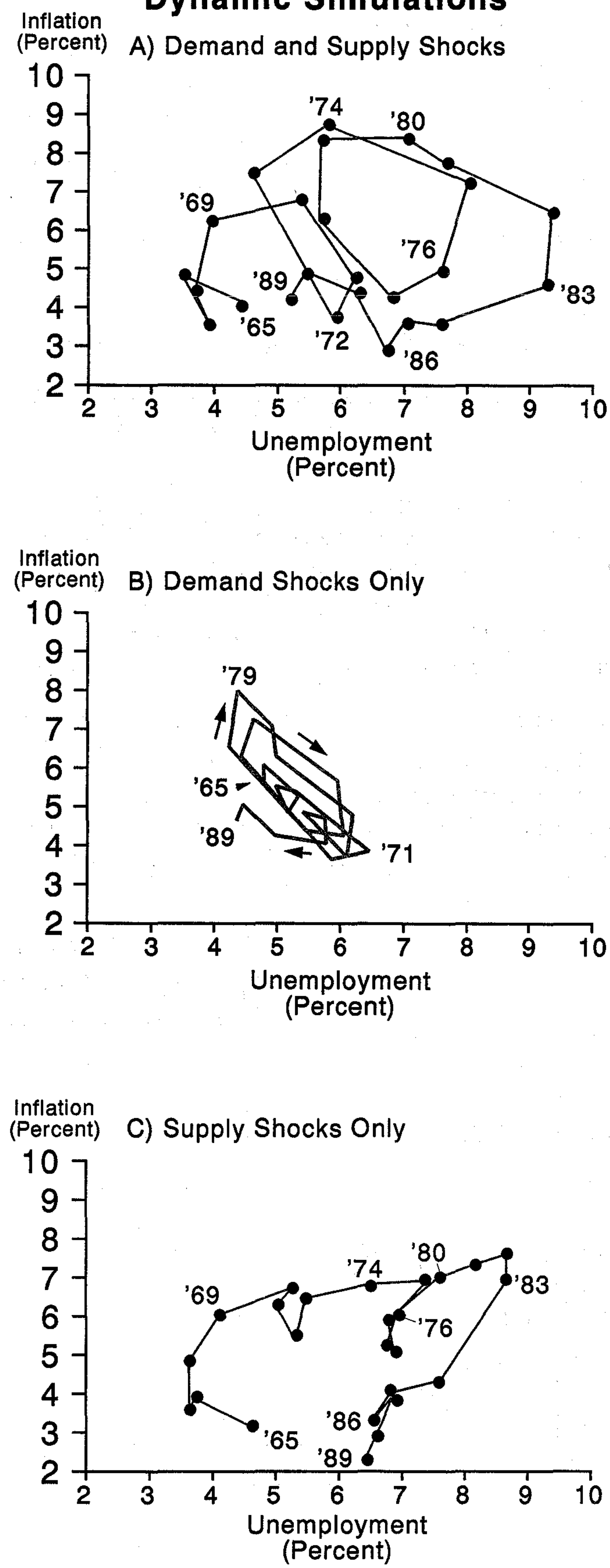
Chart 7 presents dynamic simulations of unemployment and inflation over the 1965–89 period, using the historical values of the estimated demand and supply shocks. The first panel shows the effects of both kinds of shocks over this period. The shape of our simulated loops is quite close to the actual data shown in Chart 1.

The second panel shows how unemployment and inflation would have evolved if there had been no supply shocks over this period. As expected, we obtain negatively sloped loops, with the number of loops attesting to the relatively short period over which the effects of a demand shock dissipate.

The third panel shows what would have happened if there had been no demand shocks over this period. The plot shows little tendency to loop around and come back to its original position, reflecting the long-lived effects of supply shocks.

Supply shocks have moved the unemployment rate and inflation over a much wider range than have demand shocks. Thus, they account for more long-run volatility in

Chart 7
Dynamic Simulations



these variables. Supply shocks are estimated to have caused inflation and unemployment to move within ranges that are 5.3 and 5.1 percentage points wide, respectively. The comparable figures for demand shocks are 4.3 and 2.2 percentage points.

In Section II, we discussed how our decomposition of movements in output into those caused by demand and supply shocks compared with conventional wisdom regarding the events over our sample period. Using Chart 7, we can now repeat this exercise in terms of combinations of inflation and unemployment. The largest movements that are estimated to have been caused by demand shocks occurred in 1977–79, and in 1980–83. In the earlier period, widely recognized as one of excessively expansionary monetary policy, the estimates suggest that demand shocks raised inflation by about 3½ percentage points and lowered the unemployment rate by about one percentage point. In the latter period, the Federal Reserve adopted reserves-oriented monetary policy procedures to reduce inflation. We estimate that this negative demand shock reduced inflation by about 4½ percentage points and raised the unemployment rate by nearly two percentage points in this period.

The largest supply shocks occurred in 1973–74, 1979–80, and 1983–86. The positive shock in the 1960s, presumably related to the large persistent productivity surge in those years, is mostly excluded by our 1965–89 sample period.[19] The 1973–75 and 1979–81 periods are associated with well known oil price shocks. According to our estimates, negative supply shocks raised inflation by about 1½ and two percentage points in these two periods, respectively, and raised unemployment by 2½ and 1¼ percentage points.

A large positive supply shock shows up in 1983–86. Any hypothesis concerning the source of this shock would be especially speculative. However, the period roughly corresponds with the cut in marginal tax rates in the early 1980s, which some have suggested was a supply-side source of rapid investment and increased work effort. In addition, rapid technological change in personal computing appears to have begun in the early 1980s, and this factor could be related to the estimated positive supply shock.

IV. Policy Issues

A major long-run goal of U.S. monetary policy is to eliminate inflation.[20] One way to attempt to meet this goal is to use (formal or informal) forecasts of future inflation to judge the appropriateness of the current stance of monetary policy. For example, given the current stance of policy, a forecast of inflation for any period in the future that exceeds the inflation goal would indicate that policy should be tightened. Our results suggest that the Phillips curve model of inflation could provide misleading signals under this forecast-oriented approach to policy.

The empirical importance of supply shocks as well as the long duration of their effects means that the unemployment rate can remain above or below its steady state value for long periods.[21] Consequently, to determine what a given rate of unemployment implies for future inflation, it is necessary first to determine the factors that are responsible for the prevailing unemployment rate. When analyzed in terms of the Phillips curve, supply-induced movements in the unemployment rate can lead to inappropriate policy actions. For example, a relatively low level of unemployment resulting from supply shocks offers little or no reason for concern about the potential for an acceleration of inflation. However, when viewed through the Phillips curve, such a change in the unemployment rate would suggest that policy should be tightened.

The preceding discussion is not meant to suggest that the Phillips curve model is inferior to other models of inflation that are currently available. On the contrary, the Phillips curve models appear to be at least as accurate at forecasting as the other available demand-side models. Stockton and Struckmeyer (1989), for example, support this conclusion with tests of forecasts from Phillips curve, monetarist, and monetary-misperceptions models. We have focused on the Phillips curve in this paper simply because it is incorporated into the large Keynesian-style "structural" models that are most widely used in macroeconomic forecasting.

Our major point is that there is good evidence that aggregate supply factors, in addition to aggregate demand factors, affect inflation dynamics in complex ways. Models that ignore part or all of these supply factors run the risk of making large errors in episodes when these supply shocks are important.

One response to this potential problem is to use an unrestricted vector autoregression for forecasting. VARs can capture both demand and supply factors, at least insofar as the average behavior of these shocks over the estimation period applies to the forecast period. Thus, this approach may provide more accurate forecasts on average; however, it appears susceptible to large errors in episodes involving large, atypical shocks.

Another response would be to develop a forecasting model along the lines of the approach used in this paper. Whether this approach would be fruitful is uncertain, since we are not aware that any such model has been built. In any event, given our finding that both demand and supply factors have been important in determining short- to intermediate-run macroeconomic developments over the past three decades, it would seem worthwhile to explore ways to disentangle the effects of these shocks in the context of forecasting future economic developments.

NOTES

1. Plosser (1989) questions the usefulness of distinguishing between demand and supply shocks, as well as the identification of real business cycle models with supply factors. Instead, he prefers to make a distinction between real and nominal factors.

2. For a discussion of the traditional Phillips curve, see Gordon (1982). Ball, Mankiw and Romer (1988) discuss the "new" Keynesian approach. Finally, for alternative theories concerning unemployment and inflation, see Lucas (1973) and Taylor (1980).

3. See Brayton and Mauskopf (1985) and Gordon (1982).

4. For analysis of the theoretical basis for the natural rate of unemployment, see Phelps (1970).

5. Within the context of a full Keynesian-style model, an oil shock can have an effect on the unemployment rate. At given nominal interest rates, for example, an adverse oil price shock could reduce real GNP by lowering business fixed investment and thus raise unemployment (via the IS and Okun's law relationships.) Note, however, that the increase in unemployment would feed into the Phillips curve like a demand shock: i.e., it would reduce inflation, tending to offset the direct upward pressure on prices from the oil shock.

6. For example, the inclusion of the relative price of oil occurred when the Phillips curve relationship became unstable in the mid 1970s following the oil embargo.

7. For discussions of real business cycle models and further references, see Plosser (1989) and Mankiw (1989).

8. Nelson and Plosser (1982).

9. See Huh (1990) and Cooley and Hansen (1989).

10. For unemployment to exist in equilibrium business cycle models, we need to allow for heterogeneity of firms or workers, necessitating job search. For a discussion, see Blanchard and Fischer (1989), pp. 346-350.

11. For a discussion of financial deregulation and its adverse effects on the stability of the monetary aggregates, see Simpson (1984). These developments do not imply, however, that there necessarily has been a change in the long-run relationship between M2 and inflation.

12. For discussion of issues in measuring the budget deficit and further references, see Gramlich (1989), Barro (1989), Bernheim (1989), and Eisner (1989).

13. Boschen and Mills (1988) have attempted to relate real shocks to various economic time series.

14. In an earlier paper, Judd and Trehan (1989), we used a five variable VAR to analyze unemployment rate dynamics. Using real GNP, the unemployment rate, a short-term nominal interest rate, the ratio of U.S. real exports to imports, and working-age U.S. population, we allowed for four different kinds of shocks—domestic technology, labor supply, (two different) demand shocks, and a foreign shock. That paper focused on relationships between these shocks and the unemployment rate, and did not explicitly analyze the inflation rate within the model.

15. These effects are obtained by multiplying the coefficients in the impulse response functions by the appropriate historical shocks as measured by the model. We use a forecast horizon of 40 quarters for this purpose, which moves the starting date of our sample to 1960:Q1.

16. As noted earlier, financial deregulation has made the relationship between M2 and inflation more susceptible to short-run disturbances. However, such disturbances can be expected to be internalized within the five-year-average observations used in equation (1).

17. Inclusion of the lagged dependent variable does not lead to demand shocks having long-lived effects on the unemployment rate because the later lags on the demand shocks have negative coefficients.

18. The estimated impulse response functions for inflation are noticeably jagged. Consequently, for the purposes of Charts 5 and 6, but not elsewhere in the paper, both the inflation and unemployment equations were re-estimated after imposing smoothness priors. For a discussion of these priors see Shiller (1973).

19. As discussed above, the inclusion of M2 forces us to shorten our sample period.

20. See Greenspan (1990) and Parry (1990).

21. When interpreted within the context of a Phillips curve equation, these supply-induced movements in the unemployment rate could appear to be changes in the so-called natural rate of unemployment.

REFERENCES

Ball, Lawrence, N. Gregory Mankiw, and David Romer. "The New Keynesian Economics and the Output-Inflation Trade-off," *Brookings Papers on Economic Activity*, 1988.1.

Barro, Robert J. "The Ricardian Approach to Budget Deficits," *The Journal of Economic Perspectives*, Volume 3, Number 2, pp. 37-54.

Bernheim, Douglas B. "A Neoclassical Perspective on Budget Deficits," *The Journal of Economic Perspectives*, Volume 3, Number 2, pp. 55-72.

Blanchard, Olivier J. and Stanley Fischer. *Lectures on Macroeconomics*. Cambridge, Mass.: The MIT Press. 1989.

Blanchard, Olivier J. and Stanley Fischer. *Lectures on Macroeconomics*. Cambridge, Mass.: The MIT Press. 1989, pp. 520-23.

Boschen, John F. and Leonard O. Mills. "Tests of the Relation Between Money and Output in the Real Business Cycle Model," *Journal of Monetary Economics*, 22, 1988.

Brayton, Flint and Eileen Mauskopf. "The Federal Reserve Board MPS Quarterly Econometric Model of the U.S. Economy," *Economic Modeling*, July 1985.

Cooley, T.F., and G.D. Hansen. "The Inflation Tax in a Real Business Cycle Model," *American Economic Review*, Summer 1989, pp. 733-48.

Eisner, Robert. "Budget Deficits: Rhetoric and Reality," *The Journal of Economic Perspectives*, Volume 3, Number 2, pp. 73-93.

Gordon, Robert J. "Inflation, Flexible Exchange Rates, and the Natural Rate of Unemployment," in M. Bailey, ed., *Workers, Jobs and Inflation*. Washington, D.C.: The Brookings Institution, 1982, pp. 89-158.

Gramlich, Edward M. "Budget Deficits and National Saving: Are Politicians Exogenous?," *The Journal of Economic Perspectives*, Volume 3, Number 2, pp. 23-35.

Greenspan, Alan. Testimony Before the Subcommittee on Domestic Monetary Policy, House Committee on Banking, Finance and Urban Affairs, U.S. House of Representatives, February 20, 1990.

Huh, Chan G. "Output, Money and Price Correlations in a Real Business Cycle Model," *Working Paper 90-02*, Federal Reserve Bank of San Francisco, May 1990.

Judd, John P. and Bharat Trehan. "Unemployment Rate Dynamics: Aggregate-Demand and -Supply Interactions," *Economic Review*, Federal Reserve Bank of San Francisco, Fall 1989, pp. 20-38.

Kydland, F.E. and E.C. Prescott. "Time to Build and Aggregate Fluctuations," *Econometrica*, 50, 1982, pp. 1345-1370.

Lucas, Robert E. "Some International Evidence on Output-Inflation Tradeoffs," *American Economic Review*, 63, 1973.

Mankiw, N. Gregory. "Real Business Cycles: A New Keynesian Perspective," *The Journal of Economic Perspectives*, Volume 3, Number 3, Spring 1989, pp. 79-90.

Motley, Brian. "Has There Been a Change in the Natural Rate of Unemployment?," *Economic Review*, Federal Reserve Bank of San Francisco, Winter 1990, pp. 3-16.

Nelson, Charles R. and Charles I. Plosser. "Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications," *Journal of Monetary Economics*, 10, 1982.

Parry, Robert T. "Price Level Stability," *FRBSF Weekly Letter*, Federal Reserve Bank of San Francisco, March 2, 1990.

Phelps, Edmund S. *Microeconomic Foundations of Employment and Inflation*. New York: W.W. Norton, 1970.

Plosser, Charles I. "Understanding Real Business Cycles," *The Journal of Economic Perspectives*, Volume 3, 1989, Number 3, pp. 51-77.

Shapiro, Matthew D. and Mark W. Watson. "Sources of Business Cycle Fluctuations," *NBER Macroeconomics Annual 1988*, Cambridge, Mass.: M.I.T. Press.

Shiller, Robert J. "A Distributed Lag Estimator Derived from Smoothness Priors," *Econometrica*, 1973, pp. 775-788.

Simpson, Thomas D. "Changes in the Financial System: Implications for Monetary Policy," *Brookings Papers on Economic Activity*, 1, 1984.

Stockton, David J. and Charles S. Struckmeyer. "Tests of the Specification and Predictive Accuracy of Non-nested Models of Inflation," *The Review of Economics and Statistics*, 1989, pp. 275-283.

Taylor, John B. "Aggregate Dynamics and Staggered Contracts," *Journal of Political Economy*, February 1980, pp. 1-23.