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PRICE INERTIA AND POLICY INEFFECTIVENESS IN THE UNITED STATES, 1890-1980

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ABSTRACT

This paper introduces a new approach to the empirical testing of the Lucas-Sargent-Wallace (LSW) "policy ineffectiveness proposition." Instead of testing that hypothesis in isolation from any plausible alternative, the paper develops a single empirical equation explaining price change that includes as special cases both the LSW proposition and an alternative hypothesis. The alternative, dubbed "NRH-GAP," states that prices respond fully in the long run, but only gradually in the short run, to nominal aggregate demand disturbances. A second innovation is the development of a quarterly data file for the period 1890-1980, thus opening up more than 200 new quarterly observations for analysis. A third innovation is the testing of three different methods of introducing "persistence effects" into the LSW analytical framework.

In conflict with the predictions of the LSW approach, the results here exhibit uniformly high coefficients of real output and low coefficients of price changes in response to anticipated nominal GNP changes. Further, price changes respond positively and output responds negatively to lagged changes in prices, reflecting the short-run inertia in price-setting that forms the basis for the alternative NRH-GAP approach. Evidence is also provided that velocity tends to respond negatively to anticipated changes in money, in contrast to the usual assumption in this literature of random serially independent velocity changes. Two shifts in the structure of the price-setting process are noted--a much higher degree of price responsiveness during World War I and its aftermath, and a longer mean lag in the influence of past price changes after 1953.

Of independent interest, beyond its treatment of the policy ineffectiveness debate, is the treatment in the paper of changes in monetary regimes, and of the impact of programs of government intervention. The money creation process exhibits a highly significant change in structure before and after World War I, and a marginally significant change in 1967. The results identify five episodes of government intervention that significantly displaced the time path of prices--the National Recovery Act of 1933-35, and price controls during the two world wars, Korea, and the Nixon era.

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" . . . it seems difficult to sustain the position that the policy ineffectiveness proposition is applicable to the U. S. economy"
—McCallum (1980, p. 738).

I. INTRODUCTION

A central question in modern macroeconomics is the speed of adjustment of the rate of inflation to the rate of change of nominal aggregate demand. The resolution of a wide variety of policy issues, including the costs of anti-inflation demand strategies, the effectiveness of systematic monetary rules, and the optimal degree of accommodation of supply shocks, hinges on empirical findings regarding the responsiveness of inflation to nominal demand. The most controversial issue whose resolution depends on such empirical research is the "policy ineffectiveness" proposition developed by Robert E. Lucas, Jr., Thomas J. Sargent, and Neil Wallace. Sometimes designated by the initials of its inventors (LSW), this proposition is based on the three theoretical assumptions of rational expectations, perfect market clearing, and a one-period aggregate information lag. It holds that real output responds only to unanticipated changes in the money supply, with no response of output to anticipated monetary changes, such as those that would be associated with a systematic feedback-type monetary rule. The corollary of the LSW proposition is that the inflation rate responds contemporaneously and proportionately to any such anticipated change in money, and it is the validity of this corollary that depends on the outcome of empirical research concerning the speed of adjustment of inflation.

This paper presents new empirical tests of the LSW policy ineffectiveness proposition that introduce three major improvements on previous studies. First and most important, unlike earlier papers that tested the LSW proposition in isolation from any plausible alternative, this paper explicitly compares the LSW characterization of price and output behavior with the major competing hypothesis underlying conventional analyses of monetary policy, that prices adjust gradually to nominal demand changes whether anticipated or not. A single reduced-form equation for the inflation rate is developed in which the LSW and gradual-price-adjustment hypotheses appear as special cases, allowing coefficient estimates to distinguish the two.

The second innovation here is a much expanded set of U.S. quarterly time series data extending over the entire period between 1890 and 1980. Unlike previous studies that have been limited to 30 years of postwar quarterly data, our extension of the sample space to 90 years allows a close examination of changes in monetary regimes, from the pure gold standard of 1890-1914, to the mixed standard of the interwar years, to the pure fiat money standard of the postwar United States. The characterization here of price behavior, and of changes in monetary regimes, in more than 200 new quarterly data observations is of independent interest outside of the context of the LSW debate.

The third contribution of the paper is explicit attention to alternative methods of introducing persistence effects into the LSW model. Three channels of persistence have been suggested. Two of these, the direct dependence of current output on lagged output, and the introduction of an inventory and new orders mechanism, in our tests lead to the rejection of the LSW hypothesis. The third channel, the dependence of current output on lagged monetary innovations, creates observational equivalence problems that preclude a definitive test. Rejection of this third version of the LSW hypothesis relies on its theoretical implausibility and its poor empirical performance in tracking the time-series data.

Price Flexibility and Long-run Neutrality

Previous studies have exhibited a lack of clarity regarding the alternative hypothesis against which the policy ineffectiveness proposition is being tested. Since the LSW hypothesis states that fully anticipated changes in the money supply can have no impact at all on real output, the alternative hypothesis states that those changes have at least *some* impact on real output *in the short run*. Because the debate is not about long-run responses, both the LSW and alternative views are fully compatible with the long-run neutrality of real output with respect to a permanent acceleration or deceleration in monetary growth.

The alternative hypothesis developed in this paper is that prices adjust gradually to changes in nominal aggregate demand in the short run but fully in the long-run. As a label for this approach we choose the hybrid acronym "NRH-GAP," standing for the combination of the long run Natural Rate Hypothesis with the short-run Gradual Adjustment of Prices. The implications of NRH-GAP can be compared to those of the LSW hypothesis in Figure 1, where the vertical axis represents the log of an aggregate price index (P) and the horizontal axis measures the log of real GNP (Q). The schedule marked "Y_0" is drawn for a hypothetical initial value of the log of nominal GNP (Y), has a slope of -1, and shows different possible combinations of P and Q into which nominal GNP can be divided. Initially it is assumed that the economy is in long-run equilibrium at point A, with real GNP equal to "natural" real GNP (Q^*), and with price level P_0. The question at issue is what happens when there is a fully anticipated change in nominal GNP (Ey) that shifts the level of nominal GNP to the upper schedule labelled Y_0 + Ey.[1]

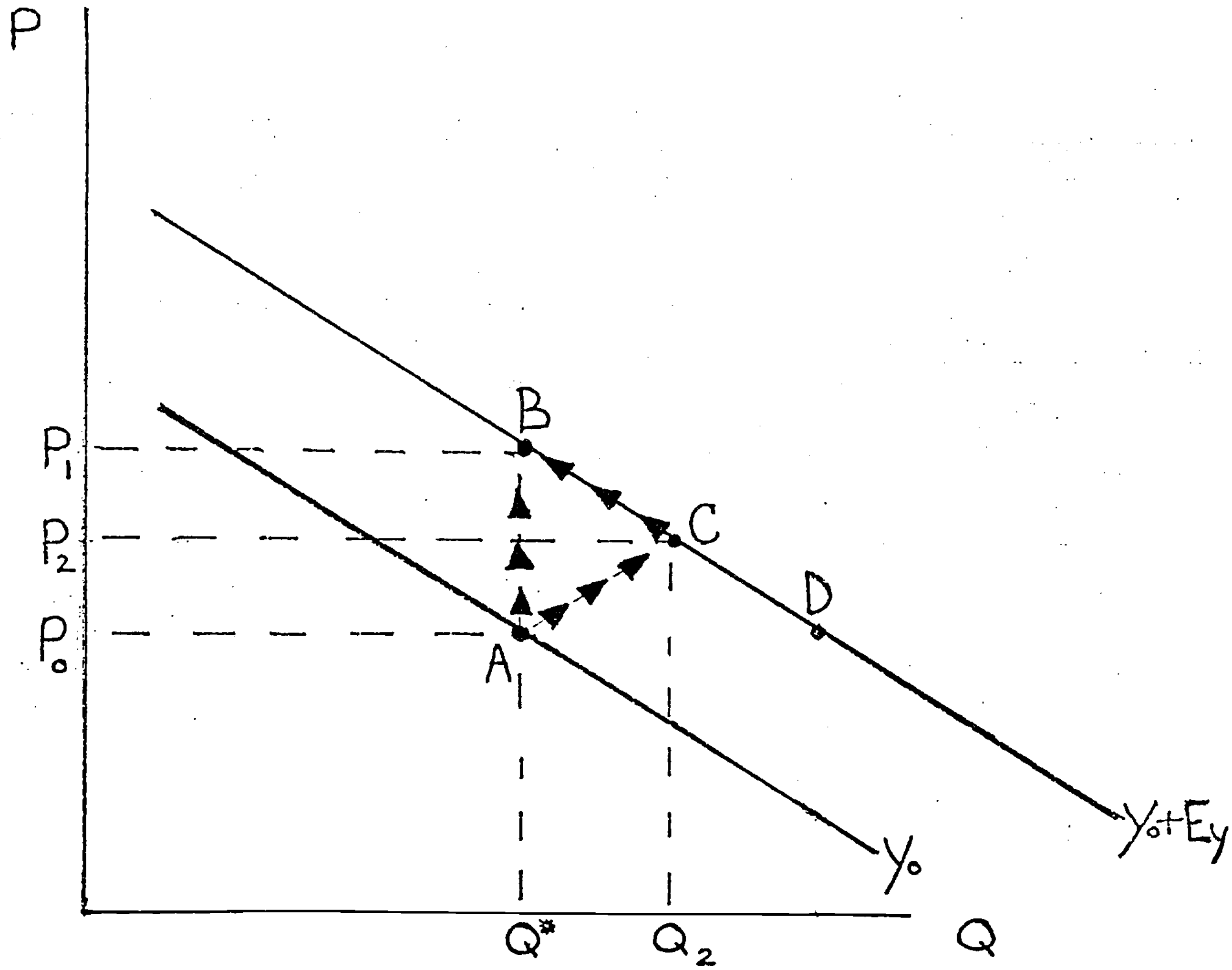

FIGURE 1

The LSW proposition that fully anticipated nominal changes have no effect on real output would predict a vertical movement from the initial position A to a new position B. Real GNP would remain at Q^*, and the price level would rise by exactly the same proportion as the fully anticipated increase in nominal GNP ($P_1 - P_0 = p_1 = Ey$). The alternative NRH-GAP view does *not* predict that the economy moves to point D, where all of the impact of the anticipated demand change falls on real output. Instead, it predicts an initial partial adjustment as represented by point C, where the effect of Ey is divided between an impact on the price level and on real output. Rejection of the LSW proposition in favor of the NRH-GAP approach does not imply a rejection of the long-run neutrality of aggregate demand shifts, since the economy could move initially to point C and then subsequently to point B. Any factor that prevents prices from jumping instantaneously, e.g., adjustment costs and the decentralization of decision-making, can explain why the economy moves along the path ACB rather than the vertical path AB.[2] Thus the real issue separating proponents from critics of LSW is the degree of instantaneous flexibility of the aggregate price level. Proponents regard prices as flexible without limit, so that "perceived movements in the money stock imply equiproportionate, contemporaneous movements in the price level" (Barro, 1978, pp. 565-6).

Because the central issue in dispute between the approaches is the degree of instantaneous price flexibility, it is misleading to label the LSW proposition the "rational expectations approach," as some have done. Individual economic agents can form expectations rationally in a world characterized by inertia in the response of prices to fully anticipated demand shifts. Aware of this inertia, agents form their rational expectations of price movements by incorporating information from past history on the serial correlation properties of the price series they are trying to predict, as well as any relevant past relationships between prices, money, and other variables.[3] It is also misleading to label the LSW policy ineffectiveness proposition as the "natural rate approach" and a model in which real output responds to anticipated monetary disturbances as the "unnatural rate approach," a usage introduced by Sargent (1976) and adopted by Barro (1981, pp. 62-64), and Parkin (1981). The alternative NRH-GAP approach adopted here is fully compatible with the Friedman (1968) "natural rate hypothesis" that the difference between the actual and natural rates of unemployment is independent in the long run of the growth rate of the money supply.

The alternative gradual price adjustment paradigm may be more appropriate for some times and places than others. American nominal wage behavior in the postwar years seems to be more sluggish and inertia-dominated--presumably due to the importance of multi-year staggered wage contracts--than in postwar Europe or in the U.S. before World War II. This paper extends the study of price responsiveness beyond the usual postwar quarterly data in order to examine changes in structure during a longer span of U.S. history.

II. THE MODELS TO BE TESTED

The Lucas Supply Function with a Lagged Output Term

The simplest version of the Lucas supply function states that the difference between log output (Q_t) and log natural output (Q_t^*), which we shall call the "output ratio" ($\hat{Q}_t$), depends on the unanticipated component of price change ($Up_t = p_t - Ep_t$):[4]

$$(1) \qquad \hat{Q}_t = Q_t - Q_t^* = \alpha Up_t + \varepsilon_t,$$

where ε_t is a stochastic error term with mean zero and constant variance. It is important to recognize that (1) *assumes* instantaneous market-clearing to occur and cannot by combined with mechanisms embodying gradual price adjustment, as has been attempted by McCallum.[5] Instead, in this paper we derive general equations for output and price adjustment that subsume the Lucas supply function and the gradual adjustment of prices approach as alternative special cases.

If expectations are rational and incorporate all past information, then the forecast error (Up_t) should be serially uncorrelated, leading to the criticism that equation (1) cannot explain the high degree of positive serial correlation or "persistence" observed in actual data on real output. The LSW hypothesis has been rescued from this line of criticism in several theoretical models. Lucas (1975) introduced a capacity variable that responds positively to a price shock and raises output in future periods until the excess capacity is corrected. While this variable introduces persistence into natural output Q_t^*, actual output Q_t responds in the same way, and there is no explanation of the observed persistence of the ratio $\hat{Q}_t$.

Sargent (1979, Chapter XVI) has developed a version of (1) in which the lagged dependent variable appears on the right-hand side in addition to the price surprise, based on the existence of costs of adjustment for employment. A related model that yields a richer set of testable propositions has been worked out by Blinder and Fischer (1981) and is discussed in section VI below. Lucas (1973) introduced, although did not formally derive, a version of (1) that is analogous to Sargent's and includes the lagged dependent variable. In our notation the 1973 Lucas equation can be written:

$$(2) \qquad \hat{Q}_t = \alpha Up_t + \lambda Q_{t-1} + \varepsilon_t .$$

This states that the output ratio responds positively both to a price surprise and to last period's value of the output ratio.

Of the various methods that have been proposed to explain persistence, (2) has the advantage that it allows us in the next section to develop a single comprehensive equation for the testing of the LSW and the alternative gradual-price-adjustment hypotheses. Nevertheless, the introduction of the lagged output term has been criticized:

> "This lagged output specification is an intrusion in the standard model; it has no relation to rational expectations, and so far as I can see very thin intrinsic justification. Its function is to 'explain' observed persistence in deviations from trend output . . . . the model cannot plausibly explain such persistence without assuming that capacity is limited by previous output, not just by capital and labor inputs. In other words, if unemployment is 9 percent in period *t*, this fact so lowers the productivity of labor in *t* plus 1 that unemployment cannot be reduced below, say, 8.5 percent, without a price surprise that fools workers and employers into doing more business than they want to" (Tobin, 1980, p. 791).

The implications of (2) for the response of price change to anticipated changes in nominal aggregate demand can be developed from a simple identity linking the rate of price change (p) to the difference between the growth rates of nominal and real GNP (y and q, respectively):

$$(3) \qquad p_t \equiv y_t - q_t$$

$$\equiv \hat{y}_t - \hat{q}_t,$$

where the "hats" on the lower-case symbols in the second line represent variables measured net of the trend (or "natural") growth rate of real GNP. Because $\hat{q}_t$, the deviation of actual output growth from natural output growth, is equal to the change in the log output ratio ($\hat{q}_t \equiv \hat{Q}_t - \hat{Q}_{t-1}$), (3) is equivalent to:

$$(4) \qquad p_t \equiv \hat{y}_t - \hat{Q}_t + \hat{Q}_{t-1}.$$

Our task is now to find an expression that links the unanticipated change in the price level, the variable appearing in the Lucas supply equation (2), to the change in aggregate demand. This is accomplished simply by rewriting (4) as a relationship between the unanticipated component of each variable, noting that with a one-period information lag the unanticipated component of the lagged output gap ($U\hat{Q}_{t-1}$) is zero:

$$(5) \qquad Up_t = Uy_t - U\hat{Q}_t$$

$$= Uy_t - \alpha Up_t - \varepsilon_t = \frac{1}{1+\alpha}(Uy_t - \varepsilon_t).$$

Here the second line is obtained by substituting for $U\hat{Q}_t$ in the top line the unanticipated component of the right-hand side of (2). The resulting expression can be substituted back into (2) to provide a relationship between the actual output gap and the unanticipated component of nominal GNP change:

$$(6) \qquad \hat{Q}_t = \frac{1}{1+\alpha}(\alpha Uy_t + \varepsilon_t) + \lambda\hat{Q}_{t-1}.$$

Thus (6) directly states the LSW policy ineffectiveness proposition that the real GNP gap depends only on the unanticipated component of nominal demand changes and is not affected by the anticipated component. Its corollary states that the rate of change of prices (p_t) is fully and instantly responsive to the anticipated component of nominal demand changes ($E\hat{y}_t$). We obtain the corollary by rewriting the identity (4), splitting actual nominal GNP change between its expected and unexpected components, and then substituting (6) for the actual output gap:

$$(7) \qquad p_t \equiv E\hat{y}_t + Uy_t - \hat{Q}_t + \hat{Q}_{t-1}$$

$$= E\hat{y}_t + \frac{1}{1+\alpha}(Uy_t - \varepsilon_t) + (1-\lambda)\hat{Q}_{t-1}.$$

(7) states that the anticipated component of nominal demand change ($E\hat{y}_t$) goes fully into price change, whereas the unanticipated component is divided between price and output change with respective weights $1/(1+\alpha)$ and $\alpha/(1+\alpha)$.

While it may seem unconventional to state the LSW proposition in terms of responses to unanticipated changes in *nominal GNP* rather than in the money supply, this device frees us from any need to adopt a particular theory of aggregate demand linking money to nominal GNP and thus concentrates our attention fully on the determinants of aggregate supply, which is what the policy ineffectiveness debate is about. It is also consistent with the treatment in Lucas (1973), which not only introduced the form of the supply equation written in (2) above, but also used nominal GNP rather than the money supply as its exogenous demand-shift variable.

As an alternative we could adopt the usual convention (Barro and Fischer, 1976, p. 151) of assuming that nominal GNP change is equal to the change in the money supply plus the change in velocity (ν_t), where ν_t is assumed to be a serially independent random variable with a mean of zero and a constant variance:

$$(8) \qquad y_t = m_t + \nu_t .$$

This converts the output equation in place of (6) to

$$(9) \qquad \hat{Q}_t = \frac{1}{1+\alpha}[(Um_t + \nu_t) + \varepsilon_t] + \lambda\hat{Q}_{t-1}$$

and the price change equation in place of (7) to

$$(10) \qquad p_t = E\hat{m}_t + \frac{1}{1+\alpha}(Um_t + \nu_t - \varepsilon_t) + (1-\lambda)\hat{Q}_{t-1} .$$

The advantage of testing equations (6) and (7) is that they are compatible with any theory of aggregate demand, whereas (9) and (10) represent joint tests of the LSW supply equation (2) and the assumption that velocity changes are serially independent. Persistence in velocity movements might lead to biased coefficient estimates in (9) and (10), even if the LSW approach in (6) or (7) were valid. Below in Part V we find that velocity changes are highly correlated with other determinants of p_t and $\hat{Q}_t$, and that equations using $\hat{m}_t$ as the exogenous demand shift variable yield misleading coefficients.

Gradual Price Adjustment with Long-run Monetary Neutrality

Instead of starting from (1), which assumes perfect market clearing and the determination of the output ratio $\hat{Q}_t$ as a choice variable, the alternative NRH-GAP approach starts from the determination of the rate of change of prices and derives the output ratio as a residual. We assume that price change deviates gradually from the inherited rate of price change in response to either demand or supply shocks, and that the failure of markets to clear instantaneously creates a sales constraint that controls the evolution of real GNP in the short run. The influence of demand on price adjustment is represented by the level ($\hat{Q}_t$) and change ($\Delta\hat{Q}_t$) of the output ratio, and the influence of supply is represented by a vector of "supply shock" variables (z_t) to be specified in more detail below. If we represent the influence of inherited price change by a general lag distribution on past prices, we have:

$$(11) \qquad p_t = a(L)p_{t-1} + b_0\hat{Q}_t + b_1\Delta\hat{Q}_t + b_2 z_t + e_t,$$

where (L) represents the lag operator and e_t is a serially independent error term with mean zero.

No theoretical underpinning is provided here for the assumption of gradual price adjustment, since this would require an entire separate paper (see Gordon, 1981b). Equation (11) can be viewed as the form that results when a Phillips-curve wage equation is augmented by the inclusion of supply-shock variables (z_t) and is substituted into a price-markup equation.[6] Equation (11) combines gradual price adjustment with long-run neutrality if the sum of the a(L) coefficients is unity, since in this case the rate of price change remains constant when real output is equal to natural output ($\hat{Q}_t = 0$) and when there are no supply shocks ($z_t = 0$).

We can convert equation (11) into a form that is directly comparable with the LSW price-change equation (7) if we use the identity (4) to eliminate the current output ratio variable ($\hat{Q}_t$), and if we split the actual rate of change of nominal GNP ($\hat{y}_t$) into its expected and unexpected components ($E\hat{y}_t$ and Uy_t):

$$(12) \quad p_t = \frac{1}{1+b_0+b_1}[a(L)p_{t-1} + (b_0+b_1)(E\hat{y}_t+Uy_t) + b_0\hat{Q}_{t-1} + b_2z_t + e_t].$$

We note that (7) and (12) display several important differences, despite the appearance of three variables in common, $E\hat{y}_t$, Uy_t and $\hat{Q}_{t-1}$. The differences can be highlighted if we rewrite (12) in the form to be estimated:

$$(13) \quad p_t = c(L)p_{t-1} + d_0E\hat{y}_t + d_1Uy_t + d_2\hat{Q}_{t-1} + d_3z_t + u_t.$$

Now we see that the LSW equation (7) is just a special case of (13), which places explicit restrictions on coefficient estimates, as summarized in the following table:

Variable	Coefficient in NRH-GAP Hypothesis (12)	Coefficient in Special LSW Case (7)
p_{t-1}	$c(L) = \frac{a(L)}{1+b_0+b_1} > 0$	$c(L) = 0$
$E\hat{y}_t$	$d_0 = \frac{b_0+b_1}{1+b_0+b_1} < 1$	$d_0 = 1$
Uy_t	$d_1 = \frac{b_0+b_1}{1+b_0+b_1} < 1$	$d_1 = \frac{1}{1+\alpha} < 1$
$\hat{Q}_{t-1}$	$d_2 = \frac{b_0}{1+b_0+b_1} < 1$	$d_2 = 1-\lambda < 1$

There are three important differences between the gradual adjustment equation (12) and the LSW special case (7). First, since price inertia is the antithesis of the LSW proposition, the coefficients on lagged price change in (7) are zero, whereas they are positive in (12). Second, the LSW equation (7) implies that the elasticity of price change to an anticipated change in nominal demand is exactly unity, holding constant other determinants of output, whereas that coefficient must be less than unity in (12) if the sum of the level and rate of change coefficients for the output terms in equation (11) is positive ($b_0 + b_1 > 0$). Finally, the coefficient on unanticipated demand changes in the LSW equation must be less than the unitary response to anticipated changes, whereas in the alternative approach the response of prices to anticipated and unanticipated changes is identical. We note that the estimated coefficient on the lagged output ratio is predicted to be less than unity in both approaches and thus cannot be used to distinguish between them. Although a vector of supply-shock variables appears in (12) but not in (7), this is not a crucial difference, since the explicit modeling of supply shocks is not inconsistent with the LSW approach.

Several proponents of the LSW proposition have argued that the perfect market clearing approach is consistent with a long distributed lag of actual price change on lagged price change (see especially McCallum, 1979b). While correct, this conclusion is reached by substituting $E\hat{y}_t$ out from (7). Lagged price change cannot appear in (7) *in addition to* $E\hat{y}_t$ without violating the long-run neutrality of money. With a unitary coefficient on $E\hat{y}_t$ in (7) and with a positive sum of coefficients (say $\underline{a}$) on lagged prices in the same equation, the long-run elasticity of p to a permanent change in $E\hat{y}_t$ would be $1/(1-a)$, not 1.0. Note that (12) is consistent with long-run neutrality if the sum of coefficients on lagged price change is $1/(1+b_0+b_1)$;

in this case the long-run elasticity of price change to a permanent increase in anticipated demand growth ($\hat{Ey}_t$) is exactly unity.

Just as the LSW output ratio equation (6) is "dual" to the LSW price change equation (7), since both are connected by an identity (4), so we can use the same identity to create an equation for the output ratio that is consistent with the NRH-GAP formulation. When we solve the identity (4) for $\hat{Q}_t$ and substitute the right-hand side of (13) for p_t, we obtain:

$$(14) \quad \hat{Q}_t = -c(L)p_{t-1} + (1-d_0)\hat{Ey}_t + (1-d_1)Uy_t + (1-d_2)\hat{Q}_{t-1} - d_3 z_t - u_t.$$

Since the LSW approach requires that $d_0=1$ in the price change equation, an equivalent test is that the coefficient on anticipated demand change $(1-d_0)$ is zero in the output gap equation (14). In addition, the LSW approach requires that the negative lag coefficients on past price changes do not appear in (14)

Contrast with Other Studies

Equation (14) highlights the contrast between this paper and previous studies. In papers by Barro (1977)(1978) the central focus is on equations in which a real variable (unemployment or output) is on the left-hand side, and a distributed lag of current and past values of unanticipated monetary change is on the right-hand side. The testing of an alternative hypothesis involves the addition of *actual* monetary change as a right-hand side variable, and the insignificance of this extra variable is the only evidence provided to support the validity of the LSW proposition. We can assess this test by rewriting (14) in terms of actual rather than expected nominal GNP, using the identity $\hat{y}_t \equiv \hat{Ey}_t + Uy_t$:

$$(15) \qquad \hat{Q}_t = -c(L)p_{t-1} + (1-d_0)\hat{y}_t + (d_0-d_1)Uy_t + (1-d_2)\hat{Q}_{t-1} - d_3z_t - u_t.$$

Barro's equation differs from (15) in three ways that have no bearing on the validity of his test based on the statistical significance of the $\hat{y}_t$ variable (the use of changes in money rather than nominal GNP; the omission of supply shock variables; and the representation of persistence through lagged unanticipated demand terms rather than through the lagged output ratio). But there is one difference that represents a key defect in Barro's test, and that is the omission of the distributed lag on past price changes, $c(L)p_{t-1}$. The NRH-GAP hypothesis does *not* imply that actual nominal demand change influences real output permanently, since that would represent a permanent relation between a nominal variable ($\hat{y}_t$) and a real variable ($\hat{Q}_t$) that would violate long-run monetary neutrality. Instead, real output depends on the *excess* of nominal demand change over lagged price change, an excess that is zero in the long run. Since nominal demand changes and lagged price changes are positively correlated over the postwar period taken as a whole, the omission of the lagged price change term (which should enter with a negative coefficient) biases toward zero the coefficient on nominal demand change ($\hat{y}_t$).

Recently Mishkin (1981) has proposed testing separately the validity of two aspects of the LSW approach, the rationality of expectations and the neutrality of money. Rationality is tested by examining cross-equation restrictions that the variables entering the first-stage money equation (that generates the proxy for "anticipated money"), but not entering the second-stage output equation, also enter a single reduced-form version of the output equation with the same implied structural coefficients. Neutrality is validated if expected monetary change does not enter the output equation with a coefficient significantly greater than zero, when a distributed lag of current and past monetary innovations is also included.

While Mishkin's tests are technically innovative, his procedure misses the main point of the debate between the LSW and gradual-price-adjustment approach, in which neither rationality nor neutrality are at issue. Rationality does not distinguish the LSW approach, since rational agents can form expectations using all available information on the actual degree of inertia in the price-setting process. Long-run neutrality is not an issue, since the NRH-GAP hypothesis makes output independent of anticipated monetary growth in the long run.

III. ECONOMETRIC ISSUES

The remainder of this paper is concerned with the econometric estimation of the "dual" equations, (13) for price change and (14) for the output gap, to determine whether the estimated *c* and *d* coefficients are consistent with the LSW hypothesis. The main practical estimation problems include the decomposition of aggregate demand growth into its anticipated and unanticipated components ($E\hat{y}_t$ and Uy_t), the selection of proxy variables to represent systematic supply shocks (z_t), and the measurement of the growth rate of equilibrium or natural output (needed to convert measured y_t into adjusted $\hat{y}_t$). But another more general econometric issue has been discussed in the literature and must be treated here.

Observational Equivalence

Sargent (1976) has demonstrated that it is impossible in principle to distinguish between the structure of LSW-type models and the alternative "Keynesian" hypothesis using only parameter estimates from a single policy regime. His identification problem can be best understood if we compare two different formulations of the Lucas supply hypothesis:

$$(6) \qquad \hat{Q}_t = \frac{1}{1+\alpha}(\alpha Uy_t + \varepsilon_t) + \lambda \hat{Q}_{t-1}.$$

$$(16) \qquad \hat{Q}_t = \sum_{i=0}^{N} \gamma_i Uy_{t-i} + \varepsilon_t.$$

Both equations contain one or more terms, in addition to the current demand surprise (Uy_t), in order to explain persistent deviations of the output ratio from zero. In (6) persistence is explained by the lagged dependent variable, whereas in (7) the additional terms are lagged values of the expectational error.

The observational equivalence problem is evident when form (16) is used. Suppose that anticipated nominal demand changes depend mainly on last period's actual change:

$$(17) \qquad E\hat{y}_t = \phi \hat{y}_{t-1};\ Uy_t \equiv \hat{y}_t - E\hat{y}_t = \hat{y}_t - \phi \hat{y}_{t-1}.$$

Substitution of (17) into (16) makes the output ratio depend only on current and lagged changes in actual nominal demand ($\hat{y}_t$):

$$(18) \qquad \hat{Q}_t = \gamma_0 \hat{y}_t + \sum_{i=1}^{N} (\gamma_1 - \gamma_{i-1}\phi) \hat{y}_{t-i} + \varepsilon_t.$$

Yet this distributed lag relationship between the output ratio and current and past actual nominal demand changes is just the same as would be obtained when equation (14) is solved recursively, using (12) to eliminate the lagged price change terms. Since both approaches predict that output responds to a distributed lag of actual values of $\hat{y}_t$, how is one to distinguish them?

Most of the previous empirical work in this area by Barro and others has attempted to identify the coefficients in equations for unemployment and output by constraining particular variables to influence expected monetary growth but not to affect output directly.[7] McCallum (1979a) has proposed excluding lagged values of Uy_t from output equations, thus constraining lagged values of $\hat{y}_t$ to enter only to the extent that they are significant in the first-stage equation used to predict $E\hat{y}_t$. This paper accepts McCallum's suggestion and in (6) excludes lagged demand innovations from influencing output directly. As is evident in (14), this constraint allows lagged values of actual nominal demand changes to influence the current output ratio only through the lagged output ratio ($\hat{Q}_{t-1}$) and the current anticipated demand change ($E\hat{y}_t$), and interprets a significant coefficient on the latter variable, i.e., $(1-d_0) > 0$, as evidence against the LSW position.

A critic who believed that (16) is the true model explaining persistent fluctuations in output might find our empirical tests to be unconvincing, and might claim that tests of the LSW proposition are impossible without introducing Barro-type exclusion restrictions. Our first response is that the essential features of (16) are captured by (6). The only difference is that (6), by forcing the lagged influence to operate through the lagged dependent variable, forces the distributed lag on Uy_t to be the same as on ε_t, which seems reasonable given that both are serially independent variables that by construction cannot be predicted one period in advance.

A second response, that it does not make any sense for lagged surprises to influence current output, was suggested by McCallum:

> "More generally, it is hard to imagine ways in which past expectational errors could have direct effects on current behavior--bygones are, after all, bygones. Because of adjustment costs, past errors might be expected to have indirect effects working through state variables--that is, past values of [$\hat{Q}_t$]" (1979a, p. 398, my notation substituted for his).

Thus our tests, based on (6) as the supply equation underlying the LSW proposition, are valid to the extent that past expectational errors affect current output *indirectly* through their influence on lagged output, but do not *directly* influence current output decisions when lagged output is held constant. This seems a more plausible identifying restriction than Barro's, which amounts to constraining government expenditures to influence money creation but not to influence output decisions.

A third response is that tests using the lagged-innovation specification yield ambiguous results; Mishkin (1981) accepted the LSW proposition when seven lags were included but rejected it when twenty lags were included. Our results based on (6) avoid both this source of ambiguity and also the problems of serial correlation of residuals that have plagued previous studies based on (16).[8] A fourth and final response, demonstrated in Table 9 below, is that the lagged-innovation approach provides an abysmal fit to postwar data on real output.

Consistent Estimation and the Measurement of Anticipations

Once we accept the exclusion of lagged innovations from the price-change and output ratio equations, (13) and (14), the construction of a test that distinguishes the LSW proposition from the NRH-GAP approach hinges on forming an accurate proxy for expected aggregate nominal demand change ($E\hat{y}_t$), since we have proposed to reject the LSW proposition if the coefficient on this variable is significantly less than unity in the price-change equation (13) and greater than zero in the output ratio equation (14). As in most previous papers on this topic, estimation takes place in two stages. A first-stage equation is fitted in which the dependent variable is actual nominal GNP change (or money change), and the fitted values of this equation are used as a proxy for $E\hat{y}_t$ (or $E\hat{m}_t$) in the second-stage equations explaining price-change and the output ratio. Procedures followed in the first stage must obey the following conditions if measurement error is to be avoided and consistent estimation achieved:

1. For $E\hat{y}_t$ to be orthogonal to the other predetermined variables in the second-stage equations, the first-stage equation must contain all of those variables. For instance, since the lagged output ratio and supply shock variables appear in both of the second-stage equations, they must appear in the first-stage equation explaining changes in nominal demand (McCallum, 1979b).

2. The output ratio equation (14) supports the LSW proposition only if $E\hat{y}_t$ does not "Granger-cause" the output ratio, i.e., if it makes no significant contribution to the fit of (14) when the lagged dependent variable is included. For such a test to be valid, the underlying aggregate

supply equation cannot include lagged innovations, and its error term must be a white-noise disturbance (McCallum, 1979b). We have already ruled out the appearance of lagged innovations for the reasons stated above, and we see no reason to presume that the error term is other than white noise. The serial correlation evident in the recent work of other investigators is absent in our estimates presented below.

3. The first-stage equation must not include any predictor of anticipated nominal demand growth that was not actually employed by economic agents in forming their anticipations. Mishkin (1981), for instance, has criticized Barro for including the current value of a government expenditure variable in his equation used to forecast the growth rate of money. This practice implies that part of the mismeasured anticipated demand series is really a surprise and could legitimately have caused changes in output if the LSW proposition is correct; such mismeasurement would bias the coefficient on $E\hat{y}_t$ in the output equation away from zero and lead to an erroneous rejection of the LSW proposition. This source of mismeasurement can be avoided by including only lagged variables in the first-stage equation.

4. Even though our equations explaining nominal GNP and money growth obey the previous condition, they err in estimating coefficients from observations after the anticipations were formed. For instance, the fitted value for 1970:Q4 is based on a regression fitted to data for 1967:Q3 through 1980:Q4, allowing the coefficient used to forecast in 1970 to be based on information for 1971-80. Two solutions are available to avoid the use of coefficients based on future information. The first, which is both obvious and expensive, is to follow Sheffrin (1979) and estimate a separate

regression for every observation. The coefficients used to forecast nominal demand growth in period *t+1* would be based on an equation estimated for data from time period *1* to *t*. The second solution, introduced by Mishkin, is to use a nonlinear least-squares procedure to estimate the first and second-stage equations simultaneously. Thus, instead of entering the Uy_t and $\hat{E}y_t$ variables directly into the second-stage equation, the second-stage equation contains a distributed lag on actual money changes and on the explanatory variables from the first-stage, and iterative estimation forces the two equations together to yield the same set of first-stage coefficients.

The use of future information to estimate coefficients in the two-stage approach is a more important problem in principle than in practice. Makin (1981, Table 2) compared quarterly second-stage results using three series for anticipated money, a simple ARIMA model, the Barro-Rush series based on a single equation for the entire sample period, and the Sheffrin series based on separate equations for each observation. All three series were highly correlated, and all yielded very similar results. Mishkin (1981, footnote 26) also found that his technique of joint estimation yielded similar first-stage coefficients to direct estimation of the single first-stage equation.

The approach taken in this paper goes a small distance in the direction of Sheffrin's procedure by estimating equations explaining nominal GNP change for eight separate sub-periods, and nominal money change for seven periods. Thus, instead of basing anticipations for, say, 1896 on coefficients estimated for 1892-1980, the coefficients are based on the period 1892-1907. The division among the sub-periods not only reduces the extent to which coefficients use future information, but also allows the identification of changes in monetary regimes. Otherwise, our first-stage equations are specified to avoid the potential defects outlined above. Consistent estimation is achieved by including all of the explanatory variables that appear in the second-stage output and price-change equations. Measurement error is minimized by including only lagged values of explanatory variables, plus other variables (especially interest rates) that are relevant for the formation of expectations about future changes in nominal GNP or money but that are not relevant for the adjustment of prices.[9]

The Representation of Supply Shocks

In previous papers I have stressed the role of supply shocks, particularly changes in the relative prices of food and energy and government intervention in the form of the Nixon price controls, in explaining why price changes in the 1970s were so variable compared to--and were sometimes negatively correlated with--changes in nominal GNP and money.[10] In four earlier episodes government intervention had a major impact in distorting the evolution of prices relative to changes in nominal GNP and money. In addition to the Nixon episode, partial price controls in World War I, an artificial attempt to raise prices in the National Recovery Act in 1933-35, relatively complete price controls in World War II, and partial price controls during the Korean war, all require explicit treatment.[10a] In a detailed study of this issue, Frye and Gordon (1981) have found that the simple device of introducing dummy variables for periods influenced by the imposition and removal of price controls is as effective as any other method of handling their impact. Each of these intervention episodes involved both an initial period of impact when price changes were held down (raised in the case of NRA), followed by a "rebound" period when most or all of the impact of the program on the price level was reversed after its termination. The need to adjust for the termination as well as the imposition of controls is most obvious in the case of World War II, when the "rebound" phenomenon caused an annual rate of inflation of 52 percent in the third quarter of 1946, with single-digit inflation in the following quarter.

This paper imposes the restriction that in each episode the rebound period completely eliminated the initial impact of the controls on the price level. This is implemented by defining a set of dummy variables that sum to 4.0 during the period of impact of the controls, and to -4.0 during the rebound period (the sum of 4.0 rather than 1.0 reflects the fact that all quarterly changes have been multiplied by 4.0 to express them on an annual rate basis). The coefficient on each dummy variable thus indicates the cumulative displacement of the price *level* during the controls episode, all of which is assumed to have been eliminated during the rebound interval. Rather than arbitrarily setting the dummy variable at the same value during each quarter of the period of impact (e.g., 4/N for a controls program lasting N quarters), the exact timing of the dummy variables during the period of impact, and the period of termination, is allowed to reflect the verdict of the data. Thus in the case of the post-World War II rebound, -2.8 of the -4.0 point total is assigned to 1946:Q3, reflecting the concentration of the rebound in that single quarter, with the remaining -1.2 points assigned to adjacent quarters.[11] The dummy variables entered into the output-ratio equations are exactly the same as those used in the price-change equations and, if the specification is correct, should emerge with the same coefficients and the opposite signs.

The only other supply-shock variable entered into the price-change and output-ratio equations in this paper is the change in the relative prices of food and energy. This variable, the difference between the national income accounts deflators for consumption expenditures including and excluding food and energy, has the advantage of weighting food and energy prices in proportion to final expenditures. When relative prices are constant, the variable assumes a value of zero.[12] No similar variable is available for the period before 1947, but there is no reason to believe that the evolution of price changes was influenced in an important way by relative price changes before that date.[13]

The Growth Rate of Natural Real GNP

Virtually all previous papers in this area have constrained natural real GNP (Q_t^*) to follow a single time trend. This can lead to serious error if the true growth rate of natural real GNP has varied. There is widespread agreement, for instance, that the growth rates of U.S. productivity and natural real GNP have decelerated in the 1970s as compared to the period between 1948 and 1973. Use of a single time trend for Q_t^* yields a large and growing negative output ratio ($\hat{Q}_t = Q_t - Q_t^*$) after 1973, thus creating a spurious negative correlation between the low output ratio and high anticipated nominal demand growth rate ($E\hat{y}_t$) and biasing toward zero its (presumably positive) coefficient.

This problem becomes potentially more important over the full 90-year period included in this study. The use of a single time trend would disregard decades of research by Denison (1979), Kendrick (1961), and others, indicating that the trend growth rate of real GNP has exhibited major variations when periods of one or two decades are compared. The procedure used here establishes seven benchmark years having roughly similar unemployment rates (1890, 1901, 1912, 1923, 1929, 1950, and 1955) and defines natural real GNP for 1890-1954 as a trend connecting the actual level of real GNP in those years.[14] After 1954 natural real GNP is based on a detailed study of the postwar inflation process and is defined as the level of real GNP that would have been consistent in each quarter with a constant inflation rate in the absence of supply shocks and government intervention, and with a constant foreign exchange rate of the dollar (Gordon, 1981c, Appendix B). The resulting natural real GNP series displays the following annual percentage rates of change over the nine decades covered in this study:

1890-1900	4.5	1940-1950	2.7
1900-1910	3.6	1950-1960	3.2
1910-1920	2.5	1960-1970	3.8
1920-1930	3.1	1970-1980	3.4
1930-1940	2.8		

The conversion of the annual series to a quarterly series for this paper is performed by linear interpolation. The resulting quarterly natural real GNP variable can be combined with a quarterly series on real GNP, described in the next section, to yield an estimate of the output ratio ($\hat{Q}_t$), defined as 100 times the log of the ratio of actual to natural real GNP. Some of the extreme quarterly values of the output ratio observed during our sample period are:

Recessions		Booms	
1896:Q4	-20.9	1906:Q4	9.0
1908:Q2	-8.0	1918:Q3	6.8
1922:Q1	-12.9	1926:Q3	6.7
1933:Q1	-53.9	1945:Q1	21.1
1949:Q4	-9.4	1953:Q2	4.5
1958:Q2	-4.5	1966:Q1	5.5
1975:Q1	-5.9	1973:Q1	3.6

The Quarterly Data File, 1890-1980

All quarterly variables used in this paper for the period since 1947 come from conventional sources and take account of the National Income and Product Account revisions of December, 1980. In addition to the series on natural real GNP, described above, the study is based on five key quarterly series for the period before 1947. Two of these, the change in the money supply and the level of the commercial paper rate, are available monthly and require no further processing. Monthly data for the money supply, the old concept of M2, are available in Friedman and Schwartz (1963) beginning in 1907. In order to avoid shifting concepts in 1914 when M1 data become available, this study uses M2 throughout.[15] The series on the 4-6 month commercial paper rate, used as an explanatory variable in the nominal GNP and money equations but not in the inflation or output ratio equations, comes from historical Federal Reserve publications and is chosen because of its homogeneity over the full period between 1890 and 1980.

The other three series required in the study are nominal GNP, real GNP, and the GNP deflator. Any two of these can be used to compute the third.

Our procedure is to use the generalized least-squares technique suggested by Chow and Lin (1971) to interpolate existing annual series on real GNP and the GNP deflator using, as interpolators, available monthly data on closely related series. The technique amounts to the use of correlations from annual data on, say, real GNP and industrial production to guide the intra-year interpolation. Thus if detrended real GNP in annual data tends to vary only one half as much as detrended industrial production, the intra-year variance of the interpolated real GNP series will be half as much as that of industrial production. For the period after 1919 the monthly series are the Index of Industrial Production and Retail Sales deflated by the Consumer Price Index for the interpolation of real GNP, and both the Consumer and Wholesale Price Indexes for the interpolation of the GNP deflator. Prior to 1919 the interpolation is based only on the Index of Industrial Production and the Wholesale Price Index. The quarterly series for the period 1919 to 1941 have previously been used for an analysis of the temporal relations between money, nominal GNP, real GNP, and price changes in Gordon and Wilcox (1981).

Two questions can be raised about the use of interpolated quarterly data. First, why not directly use the published monthly data, as in recent papers on the Great Depression by Sims (1980) and Schwartz (1981)? While the study of the direct relationships in monthly data among money, production and wholesale prices is a useful activity, use of the raw monthly data has limitations as well. Industrial production and wholesale prices are both more volatile than real GNP and the GNP deflator, respectively, and in addition refer to a relatively narrow sector of the economy. In addition the Wholesale Price Index tends to overweight crude materials. Our interpolation procedure is a compromise, using information from annual data on the whole economy to determine the intra-year variance of the interpolated series, while using the raw monthly data to determine the timing of intra-year output and price movements.

Second, how comparable are the pre- and post-1947 data for real GNP and the deflator? This question has been answered in an ingenious and detailed study of interpolation procedures by Wilcox (1980), who constructed artificial quarterly series for postwar real GNP and the GNP deflator by the Chow-Lin technique using the same monthly series as were used to create our data for 1919 to 1941. He found that the interpolated series possess time- and frequency-domain characteristics which are very similar to those of the official quarterly series, and that they also yield very similar parameter estimates when the interpolated and official series are used alternatively in a standard equation explaining the real demand for money. This comparison suggests that measurement error in our interpolated series may not be appreciably larger than in the official quarterly series available for the postwar period.

IV. NOMINAL GNP, MONEY, AND CHANGES IN REGIMES

The Equations Predicting Nominal GNP and Money Change

Several common features stand out in the estimated equations for changes in nominal GNP and the money supply (M2), as displayed in Tables 1 and 2. To simplify the presentation, only four lagged values of changes in nominal GNP, money, and prices are entered, and only two lagged values of the commercial paper rate. The separate sub-period equations differ substantially in

TABLE 1

Regression Equations Explaining
Nominal GNP Change, 1891:Q2-1980:Q4

	1891:Q2 -1908:Q3	1908:Q4 -1914:Q4	1915:Q1 -1922:Q4	1923:Q1 -1929:Q3	1929:Q4 -1941:Q4	1942:Q1 -1953:Q4	1954:Q1 -1967:Q2	1967:Q3 -1980:Q4
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	45.0**	22.8	103.8**	33.6	26.3*	4.81	3.58**	6.85*
y_{t-1}	0.06	1.04*	-0.54	0.22	-0.06	0.55**	0.18	-0.19
y_{t-2}	0.02	0.34	-0.35	0.34	-0.55**	0.10	-0.14	-0.01
y_{t-3}	-0.13	1.56**	-0.42*	0.32*	0.11	-0.07	0.23*	0.22
y_{t-4}	-0.06	0.28	-0.31	0.27	-0.32*	0.12	-0.41**	0.25*
m_{t-1}	---	0.01	0.01	0.70	-0.09	0.33	-0.15	0.22
m_{t-2}	---	-1.13	-0.44	-0.51	1.65**	0.03	0.48*	0.09
m_{t-3}	---	-1.29*	0.60	0.05	-0.26	-0.10	0.10	0.10
m_{t-4}	---	-0.99*	-0.42	-0.29	0.87**	0.25	0.74**	-0.38*
p_{t-1}	0.87**	-1.28*	0.81*	-0.13	1.22*	0.22	0.08	0.80*
p_{t-2}	-0.38	-0.35	-0.30	-0.88*	0.79	-0.28	0.51*	0.35
p_{t-3}	-0.44	-1.71*	0.30	-0.19	-0.64	-0.04	0.41	-0.48
p_{t-4}	0.68*	-1.10*	0.87**	0.94*	-0.13	-0.19	0.61**	0.02
$Rate_{t-1}$	-8.14**	-.57	-1.74	2.38	3.19	-15.1	-4.43**	-0.08
$Rate_{t-2}$	0.20	-2.61	-14.6*	-8.14*	-1.42	13.9	2.60	-0.94*
$\hat{Q}_{t-1}$	-0.69*	-2.00	1.13	-3.37**	-0.94**	-0.76**	0.37*	-0.34
WW I Dummy	---	---	11.5	---	---	---	---	---
NRA Dummy	---	---	---	---	15.3**	---	---	---
WW II Dummy	---	---	---	---	---	-0.50	---	---
Korea Dummy	---	---	---	---	---	-0.93	---	---
Controls Dummy	---	---	---	---	---	---	---	2.60
Food-Energy Effect		---	---	---	---	1.60	0.68	0.54
R^2	.349	.791	.699	.751	.616	.650	.533	.417
SEE	19.03	6.22	16.87	7.56	18.33	8.72	3.19	3.59

Note: Asterisks indicate significance at the levels of 10 percent (*), and 5 percent (**).

TABLE 2

Regression Equations Explaining Changes in Money Supply (M2)

1908:Q4-1980:Q4

	1908:Q4 -1914:Q4	1915:Q1 -1922:Q4	1923:Q1 -1929:Q3	1929:Q4 -1941:Q4	1942:Q1 -1953:Q4	1954:Q1 -1967:Q2	1967:Q3 -1980:Q4
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	8.32	73.9**	-20.4*	-6.08	9.99*	-0.66	5.11**
m_{t-1}	-0.68**	-0.73**	-0.04	0.73**	0.10	0.43**	0.18
m_{t-2}	-0.75**	-0.46**	0.61**	-0.07	0.32*	0.18	0.09
m_{t-3}	-0.53**	-0.06	0.67**	0.05	-0.18	-0.35**	0.10
m_{t-4}	-0.36*	-0.67**	0.51	0.11	-0.27*	0.40**	-0.30**
y_{t-1}	0.76**	-0.08	-0.20*	0.01	0.19*	0.11	0.11
y_{t-2}	0.30	-0.06	-0.11	-0.06	-0.07	-0.07	0.14
y_{t-3}	0.38*	-0.13	-0.14	0.08	0.13	-0.01	0.13
y_{t-4}	0.19	-0.09	-0.09	-0.10	0.10	-0.13*	0.15*
p_{t-1}	-0.79**	0.39**	-0.39	0.27	-0.04	-0.38*	-0.42
p_{t-2}	-0.24	0.03	-0.44*	-0.14	0.02	-0.03	0.36
p_{t-3}	-0.41	0.48**	-0.60*	-0.25	0.12	0.27*	-0.47*
p_{t-4}	-0.36	0.35**	-0.22	0.62**	-0.09	0.01	-0.30
$Rate_{t-1}$	0.16	-4.76**	0.05	2.08	-20.8*	-1.38	-1.28**
$Rate_{t-2}$	0.05	-4.58*	4.21	-1.21	15.7	1.96*	1.37**
$\hat{Q}_{t-1}$	-1.64**	1.55**	0.02	-0.22*	0.41**	-0.13	-0.61**
WWI Dummy	---	-13.3**	---	---	---	---	---
NRA Dummy	---	---	---	4.39	---	---	---
WW II Dummy	---	---	---	---	-1.62	---	---
Korea Dummy	---	---	---	---	2.62	---	---
Controls Dummy	---	---	---	---	---	---	1.83*
Food-Energy Effect	--	---	---	---	0.44	-0.11	-0.07
R^2	.823	.857	.690	.730	.801	.669	.737
SEE	1.96	5.48	3.53	7.80	4.84	1.80	2.19

Note: Asterisks indicate significance at the levels of 10 percent (*), and 5 percent (**).

the fit of the equations, and in the estimated coefficients themselves. In almost every period at least one coefficient on the lagged dependent variable is significant. Significant feedback from money to nominal GNP occurs in only some of the periods, especially in the Great Depression and 1954-67. Significant positive feedback in the reverse direction from nominal GNP to money is evident in only a few coefficients in Table 2, with significance at the 5 percent level achieved only in 1908-14. This result does not, of course, rule out positive contemporaneous feedback, which is not measured in Tables 1 and 2, because current variables are omitted. Strong positive feedback from prices to nominal GNP occurs in 1892-1908, 1915-22, and 1954-67, and in 1915-22 and 1929-41 from prices to money.

Interest rate effects in both tables are relatively weak, with a few periods exhibiting a significant zig-zag from a negative to a positive coefficient, indicating that a positive *change* in the interest rate was followed by a slowdown in the growth of nominal GNP and money. A number of the coefficients on the lagged output ratio are significant, but the signs are both positive and negative. Most of the significant coefficients during peacetime periods are negative, indicating countercyclical policy, but there are significant positive coefficients in the money equations for both World Wars I and II, supporting the general presumption of a monetary policy that accommodated fiscal deficits by supporting bond prices.

Basic Characteristics of the Expected Nominal GNP and Money Series

Table 3 displays for each sub-period means and standard deviations of the various rate of change variables--actual, expected, and unexpected changes in nominal GNP and money, and actual changes in prices and real GNP. The "hats"

TABLE 3

Means and Standard Deviations of Key Variables,
Eight Subperiods Between 1891:Q2 and 1980:Q4

(all data are quarterly percentage changes at annual rates)

	$\hat{y}$	$E\hat{y}$	Uy	$\hat{m}$	$E\hat{m}$	Um	p	$\hat{q}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Means								
1891:Q2-1908:Q3	0.2	---	---	---	---	---	0.6	-0.4
1908:Q4-1914:Q4	1.3	---	---	2.8	---	---	1.9	-0.6
1915:Q1-1922:Q4	7.4	---	---	7.3	---	---	6.1	1.3
1923:Q1-1929:Q3	0.5	---	---	0.6	---	---	0.1	0.4
1929:Q4-1941:Q4	-1.0	---	---	-0.1	---	---	0.0	-0.9
1942:Q1-1953:Q4	5.6	---	---	5.5	---	---	4.8	0.8
1954:Q1-1967:Q2	2.4	---	---	2.0	---	---	2.2	0.2
1967:Q3-1980:Q4	5.9	---	---	5.6	---	---	6.4	-0.5
1891:Q2-1980:Q4[a]	2.7	---	---	3.4	---	---	2.7	0.0
Standard Deviations								
1891:Q2-1908:Q3	21.6	12.8	17.4	---	---	---	6.0	21.6
1908:Q4-1914:Q4	8.3	7.4	3.8	2.9	2.6	1.2	4.3	6.4
1915:Q1-1922:Q4	21.4	17.8	11.7	10.1	9.3	3.8	15.4	14.4
1923:Q1-1929:Q3	9.9	8.5	4.9	4.1	3.4	2.2	3.7	9.0
1929:Q4-1941:Q4	24.1	19.0	15.0	12.3	10.5	6.4	7.8	19.4
1942:Q1-1953:Q4	11.6	9.3	6.9	8.5	7.6	3.8	8.1	11.4
1954:Q1-1967:Q2	3.9	2.9	2.7	2.6	2.1	1.5	2.0	3.8
1967:Q3-1980:Q4	3.9	2.5	3.0	3.5	3.0	1.8	2.2	4.0
1891:Q2-1980:Q4[a]	15.8	11.8	10.6	7.8	6.9	3.5	7.3	13.8

Note: a. The starting date for all statistics involving money is 1908:Q4.

indicate that the nominal GNP, money, and real GNP changes have all been adjusted by subtracting out the growth rate of natural real GNP. This accounts for the fact that the mean rate of change of adjusted real GNP ($\hat{q}$) is so close to zero in most of the sub-periods. As a result, price changes in each period mimic the adjusted rate of change of nominal GNP. The close correspondence between the average rates of change of nominal GNP and money calls attention to the remarkable long-run stability of the velocity of M2, with a substantial decline in velocity occurring only during 1908-14 and 1929-41. Friedman and Schwartz (1963) called attention to the secular decline in M2 that had occurred before 1908 and at a slower rate during much of the period between 1908 and World War II. But this phenomenon, which led to their theory of the demand for money as a luxury good having an income elasticity greater than unity, seems to have disappeared in the data for 1942-80.

Several important facts stand out in the bottom half of Table 3. First, fluctuations in all variables are greater before 1954 than after, although monetary growth in 1908-14 and 1923-29 displays a stability roughly comparable to the post-1954 era. Second, the variance of expected money change is greater than that of unexpected money change in every period, and in all periods but two for nominal GNP change. The LSW proposition does not require that the expected money series have a low variance, but only that its movements are completely reflected in price changes and uncorrelated with output movements. Thus it is interesting to note that the variance of output changes was double or triple that of price changes in some of the periods, and was lower only in 1915-22. Finally, nominal GNP was much more volatile than money before 1954, but only moderately more variable thereafter.

The Choice Between Nominal GNP and Money as the Demand Shift Variable

This paper includes results for both nominal GNP and money as exogenous demand shift variables. The appeal of nominal GNP is its direct definitional connection with prices and real GNP. Any change in nominal GNP must be accompanied simultaneously by a change in one or both of its two components, and from this fact emerges our test of the LSW proposition as requiring a unitary coefficient on expected nominal GNP change in an equation explaining the output ratio (14). The defect of the money supply variable is the nature of its connection with nominal GNP; velocity may not be a random variable but may display systematic movements that influence the test results. For instance, if fully anticipated changes in money are partially offset by changes in velocity in the opposite direction, as happened in the 1929-53 period, then neither nominal GNP nor price changes will move equiproportionately with anticipated money even if the LSW proposition is true.

The disadvantage of nominal GNP is the fact that it is not directly controlled by policymakers. Ignore any current-quarter feedback from nominal GNP to money, and assume that policymakers can control the money supply perfectly. If changes in money are offset completely by shifts in velocity in the opposite direction, then the authorities can influence neither nominal nor real GNP. Indeed the LSW proposition--that real GNP is independent of anticipated monetary policy--would be correct. But, ironically, this verdict would not result from any insight of Lucas, Sargent, or Wallace, but rather from an old-fashioned liquidity trap! If nominal GNP responds at least partially to monetary changes, and if policymakers can control money, then results with nominal GNP as the exogenous demand shift variable can provide a clear test of the LSW hypothesis regarding the behavior of aggregate supply. Below in Tables 7 and 8 we present results on the interrelation of money and velocity changes.

Some of the partial correlations among our key variables for the eight subperiods are displayed in Table 4. Output changes are consistently more highly correlated with anticipated nominal GNP change than with anticipated money change, as would be expected if velocity responds negatively and with a lag to monetary changes. On the other hand, the correlation between $E\hat{y}$ and p is very similar to that between $E\hat{m}$ and p, as would be true if nominal GNP and money move together in the long run. A striking finding is the extremely low correlation between price changes and both anticipated variables after 1942, as compared to relatively high correlations between 1915 and 1941. This may make that interval more likely to provide support for the LSW proposition than the postwar interval that has dominated recent research.

Changes in Nominal GNP and Monetary Regimes

Following Sargent's (1976) suggestion that observational equivalence problems can be avoided by examining the stability of alternative hypotheses of output determination across monetary regimes, Neftci and Sargent (1978) present evidence on this issue. They find, using a conventional Chow test, that a monetary-feedback equation fitted to quarterly data for M1 and real GNP between 1949:Q2 and 1974:Q4 exhibits a shift in structure in 1964:Q2. In interwar monthly data for M1 and industricl production between June, 1920, and December, 1940, they find a shift in structure in January, 1930. Then, contrasting two output equations containing alternatively lagged

TABLE 4

Contemporaneous Correlations Among Key Variables,

Eight Subperiods Between 1891:Q2 and 1980:Q4

	$\hat{Ey}$, $\hat{q}$	$\hat{Ey}$, p	$\hat{Em}$, $\hat{q}$	$\hat{Em}$, p	$\hat{Ey}$, $\hat{Em}$	Uy, Um
	(1)	(2)	(3)	(4)	(5)	(6)
1891:Q2-1908:Q3	0.61	-0.07	---	---	---	---
1908:Q4-1914:Q4	0.84	0.49	0.62	0.24	0.67	0.01
1915:Q4-1922:Q4	0.48	0.71	0.08	0.76	0.72	0.06
1923:Q1-1929:Q3	0.74	0.50	-0.06	0.43	0.12	-0.67
1929:Q4-1941:Q4	0.70	0.69	0.35	0.66	0.63	0.47
1942:Q1-1953:Q4	0.62	0.28	0.18	0.01	0.23	0.44
1954:Q1-1967:Q2	0.73	0.02	0.35	-0.08	0.41	-0.14
1967:Q3-1980:Q4	0.60	0.06	0.48	-0.22	0.57	0.13
1891:Q2-1980:Q4[a]	0.60	0.48	0.25	0.52	0.58	0.32

Note: a. The starting date for all statistics involving money is 1908:Q4.

levels of *actual* money (M_{t-i}) and lagged *unanticipated* money (UM_{t-i}), the authors find more structural stability over their postwar and interwar sample periods for the latter "natural rate" output equation than the former "Keynesian" equation.

While the Neftci-Sargent output equations do not allow a legitimate test of the NRH-GAP hypothesis, for reasons set out in the discussion of equation (15) above (p. 16), their identification of monetary regimes is of independent interest. Using the nominal GNP and money equations displayed in Tables 1 and 2, and fitting identical equations to overlapping sample periods, we can identify shifts in structure for the entire 1890-1980 period. As shown in Table 5, the nominal GNP equations exhibit shifts in structure in 1942 and 1967 that are only marginally significant. The money equations exhibit highly significant shifts in structure before and after World War I (in 1915 and 1923), and a weakly significant shift in 1967. Because this paper uses M2 exclusively, there is no conflict with the Neftci-Sargent results, and in fact the F ratio for the 1967 split in Table 5 is 1.54, as compared to their 1.52. Instead, the main difference here is the absence of a split in 1929. The greater stability of our money equation during the interwar period could result from any of the numerous differences between the two tests (our M2 vs. their M1, our use of first differences compared to their use of levels, and the inclusion of numerous additional variables in our feedback equations).

How can the 1967 shift in the money feedback rule be characterized? Comparing columns (6) and (7) of Table 2, one difference seems to be a reduction in the positive serial correlation of the money series itself. Perhaps more important, there was a major jump in the size of the negative

TABLE 5

Chow Tests for Changes in "Regime,"

Eight Subperiods Between 1891:Q2 and 1980:Q4

Date of "split"	y_t	m_t
1908:Q4	F(12,71) = 0.41	- -
1915:Q1	F(17,23) = 0.54	F(17,23) = 3.03***
1923:Q1	F(17,25) = 0.63	F(17,25) = 2.76**
1929:Q4	F(17,42) = 0.72	F(17,42) = 0.56
1942:Q1	F(20,61) = 1.56*	F(20,61) = 0.99
1954:Q1	F(19,64) = 0.75	F(19,64) = 1.27
1967:Q3	F(18,72) = 1.53*	F(18,72) = 1.54*

Notes:

Asterisks indicate significance at the levels of 10 percent (*), five percent (**), and 1 percent (***).

The formula used is from Maddala (1977, p. 198).

$$F(k, n_1 + n_2 - 2k) = \frac{\{RSS(R) - [RSS_1(U) + RSS_2(U)]\}/k}{[RSS_1(U) + RSS_2(U)]/(n_1 + n_2 - 2k)},$$

where: k equals the number of parameters
n_1 and n_2 are the number of observations in the two sample periods divided by the "split"
$RSS_1(U)$ and $RSS_2(U)$ are the unrestricted residual sums of squares in the two periods divided by the "split"
RSS(R) is the restricted sum of squares when a single equation is estimated for the two periods divided by the "split"

coefficient on the output ratio ($\hat{Q}_{t-1}$), indicating a shift to a more aggressively countercyclical monetary policy. After 1967 there was also less of a tendency to accommodate price changes and to stabilize short-term interest rates.

V. THE LSW AND NRH-GAP HYPOTHESES AS EXPLANATIONS OF PRICE AND OUTPUT BEHAVIOR

The Response of Prices and Output to Nominal GNP Changes

With the methodology, data, and series on Ey, Uy, Em, and Um in place, the paper's central results on price and output behavior may now be presented. Table 6 exhibits estimates of equation (13) for the rate of price change and of its "dual," equation (14) for the output ratio. Because the two equations are linked by an identity, the statistical properties of adjacent pairs of price and output equations in the table are identical. Four such pairs of equations are displayed, for subperiods divided in 1929 and 1953, and for the entire 1892-1980 interval.[16] The four pairs are estimated over, respectively, 148, 97, 108, and 353 observations.

As outlined above, the test procedure is based on the different predictions made by the LSW and NRH-GAP hypotheses regarding two sets of coefficients. The LSW proposition predicts that the coefficient on anticipated nominal GNP change (Table 6, line 3) will be unity in the price equation and zero in the output equation. The sum of coefficients on lagged price change (lines 7 and 8) is predicted to be zero in both equations. In contrast, the NRH-GAP hypothesis predicts that the coefficient on $\hat{Ey}_t$ will be less than unity in the price equation and greater than zero in the output equation, and that the sum of coefficients on lagged price change will be positive in the price equation and negative in the output equation.

TABLE 6

Regression Equations Explaining Quarterly Price Changes and the Output Ratio, Selected Intervals, 1892:Q4-1980:Q4

(quarterly change variables expressed as annual percentage rates)

	1892:Q4-1929:Q3		1929:Q4-1953:Q4		1954:Q1-1980:Q4		1892:Q4-1980:Q4	
	p_t	$\hat{Q}_t$	p_t	$\hat{Q}_t$	p_t	$\hat{Q}_t$	p_t	$\hat{Q}_t$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Constant	0.82*	-0.80*	0.92***	-0.92***	-0.34	0.34	0.79***	-0.79***
2. Lagged Ratio ($\hat{Q}_{t-1}$)	0.08***	0.93***	0.01	0.99***	0.06***	0.94***	0.01**	0.99***
3. Expected Nominal GNP Change ($E\hat{y}_t$)	0.09**	0.91***	0.12***	0.88***	0.09**	0.91***	0.11***	0.88***
4. Unexpected Nominal GNP Change (Uy_t)	0.09**	0.91***	0.17***	0.83***	0.25***	0.75***	0.12***	0.88***
5. $E\hat{y}_t$, 1915-22	0.47***	-0.47***	---	---	---	---	0.35***	-0.35***
6. Uy_t, 1915-22	0.25**	-0.25***	---	---	---	---	0.23***	-0.23***
7. $\sum_{i=1}^{10} c_i p_{t-i}$	0.40***	-0.40***	0.60***	-0.60***	---	---	0.49***	-0.49***
8. $\sum_{i=1}^{20} c_i p_{t-i}$, 1954-80	---	---	---	---	1.06***	-1.06***	0.25***	-0.25***
9. World War I Dummy	-9.02***	9.02***	---	---	---	---	-9.52***	9.52***
10. NRA Dummy	---	---	6.00***	-6.00***	---	---	5.94***	-5.94***
11. World War II Dummy	---	---	-15.21***	15.21***	---	---	-15.2***	15.2***
12. Korean War Dummy	---	---	-3.39**	3.39**	---	---	-3.49**	3.49**
13. Nixon Control Dummy	---	---	---	---	-3.32***	3.32***	-3.23**	3.23***
14. Food-Energy Effect	---	---	0.37	-0.37	0.54***	-0.54***	0.63**	-0.63**
R^2	.608	.950	.855	.998	.800	.985	.672	.991
SEE	5.59	5.59	3.33	3.33	1.39	1.39	4.30	4.30

Note: Asterisks indicate significance at the levels of 10 percent (*), 5 percent (**), and 1 percent (***).

The results seem unambiguously to reject the LSW proposition and to confirm the NRH-GAP approach for all sample periods displayed in Table 6. The coefficient on $E\hat{y}_t$ in the price change equation ranges only between 0.09 and 0.12, and in the output equation is highly significant in the narrow range between 0.88 and 0.91. Lagged prices are highly significant in all equations, with signs as predicted by NRH-GAP, and with a tendency of the sum of the lagged price coefficients to increase over time from 0.40 in 1892-1929 to 1.06 in 1954-80. The number of lagged price terms included is raised from 10 to 20 after 1953, in light of evidence provided in Gordon (1980, 1981c) that longer lags have been important in the postwar period. In the equation for the entire 1892-1980 period, the longer lag distribution is entered interactively with a dummy variable equal to zero before 1954 (i.e., two lag distributions are included for the 1954-80 portion of the sample period, and a single 10-quarter lag distribution for 1892-1953). The results in columns (7) and (8) indicate a significant role for the extra lag distribution in the postwar period. The three pairs of equations for the sub-sample periods yield mean lags on the past inflation variable of, respectively, 3.8, 1.0, and 5.7 quarters.

Other aspects of these results may be briefly noted. In line 2 the coefficient on the lagged output ratio is significant in every column but one. In line 4 the unanticipated nominal GNP change variable is always significant and indicates that the fraction of a nominal GNP "surprise" taking the form of price change gradually increased from 9 percent in the first subperiod to 25 percent in the last subperiod. Lines 5 and 6 display the special coefficients for the World War I period that show a much higher share of both anticipated and unanticipated nominal GNP change going into price change;

in a recent paper (1981b) I view this coefficient shift as a challenge for theorists attempting to explain gradual price adjustment and suggest that it may be related to Lucas' distinction between aggregate and local information. Finally, lines 9 through 14 of the table display the coefficients on the supply shift variables. The coefficients on the government-intervention dummies indicate the cumulative impact of each program on the price level, all of which is assumed to be erased after the program is terminated, ranging from a -3.3 percent cumulative impact of the Nixon controls, to a -15.2 percent impact of the World War II controls. The food-energy variable is significant in the expected direction in columns (5) through (8).

If Table 6 is viewed as validating the NRH-GAP approach, we can use the results to recover the b_0, b_1, and a(L) coefficients from the original NRH-GAP equation (11). These three coefficients represent, respectively, the influence on the inflation rate of the current output ratio, the change in the output ratio, and lagged inflation.

	1892-1929	1929-1953	1954-1980	1892-1980
Current output ratio, b_0	.08	.01	.07	.01
Change in output ratio, b_1	.02	.12	.03	.11
Lagged inflation, a(L)	.44	.68	1.17	.83

While their sum is quite stable over the sub-periods, b_0 and b_1 jump around substantially, with the "level effect" dominant in the first and third sub-periods, and the "rate-of-change effect" dominant in the second sub-period. This shift in coefficients is similar to, but more drastic than, that previously identified in annual data in Gordon (1980). When the Table 6 equations are estimated for the shorter sub-sample periods displayed in Table 1, we find that the "level effect," that is, the coefficient on the lagged output ratio in the price-change equation, is significant only before 1922 and after 1953. The highest coefficients on this variable are found during the 1908-22 and 1954-67 sub-periods.

The increase over time in the coefficient on lagged inflation correspondends to the diagnosis of a growing role of inertia in the price-adjustment process. I have previously conjectured (1980) that this resulted from a change in attitude in the first postwar decade toward recognition of a fundamental change in the stabilizing role of government policy, and the introduction of three-year staggered wage contracts at about the same time. The main difference in the present results for quarterly data is the greater extent of positive serial correlation before 1929; this short-lag inertia process is disguised when the data are aggregated to an annual basis.

The relatively low a(L) coefficients prior to 1954 may appear to deny the neutrality of money, that is, the "natural rate hypothesis" (NRH) portion of the NRH-GAP hypothesis. However, as Sargent (1971) pointed out in a perceptive comment, the set of coefficients a(L) represents the product of two unobservable sets of coefficients, (1) the response of inflation to expected inflation, which must be unit-elastic if the NRH is to be confirmed, and (2) the response of expected inflation to lagged inflation, which need not be unit-elastic. As I have stressed before (1980), in the gold standard era, when agents expected an expansion in nominal GNP to be short-lived and quickly reversed, optimal forecasting of price change would require regressive expectations and small weights on lagged price changes, not the larger coefficients appropriate under the postwar regime of fiat money and extrapolative expectations.

The Response of Prices and Output to Money-Supply Changes

Most previous tests of the LSW proposition have included, as the exogenous demand shift variable, only levels or changes in the money supply, without any attention to nominal GNP. This procedure requires the implicit assumption that changes in velocity have no systematic effect on prices or output, i.e., that velocity is a random serially uncorrelated variable. We can test the validity of this assumption by using the previously described series on anticipated and unanticipated changes in nominal GNP and money to create an equivalent pair of variables for velocity changes ($Ev_t = Ey_t - Em_t$; $Uv_t = Uy_t - Um_t$). Table 7 presents results when each equation of Table 6 is re-estimated with nominal GNP change divided between changes in money and velocity (the earliest observation in Table 7 is in 1908:Q4, as contrasted with 1892:Q4 in Table 6, due to the limited availability of the quarterly money series).

If only money mattered, and velocity were truly a random variable, then the coefficients on velocity changes in Table 7 would be equal to zero. That is clearly not the case. There are actually a slightly greater number of significant velocity coefficients than significant money coefficients. Although the money and velocity coefficinets are generally of the same order of magnitude in each equation, the F ratios listed at the bottom of the table indicate that the use of the separate $\hat{m}_t$ and v_t variables, in place of $\hat{y}_t$, significantly improves the fit of the pre-1954 equations. This improvement in fit may be related to our previous finding in Table 3, that anticipated velocity changes are much more variable than anticipated monetary changes prior to 1954, but not afterward. Thus relatively more of the variance of Ev_t consists of a transitory component than that of $E\hat{m}_t$.

TABLE 7

Regression Equations Explaining Quarterly Price Changes and the Output Ratio, Selected Intervals, 1908:Q4-1980:Q4

(quarterly change variables expressed as annual percentage rates)

	1892:Q4-1929:Q3		1929:Q4-1953:Q4		1954:Q1-1980:Q4		1892:Q4-1980:Q4	
	p_t	$\hat{Q}_t$	p_t	$\hat{Q}_t$	p_t	$\hat{Q}_t$	p_t	$\hat{Q}_t$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Lagged Ratio ($\hat{Q}_{t-1}$)	0.11***	0.89***	0.00	1.00***	0.06***	0.94***	0.01	0.99***
2. Expected Money Change ($E\hat{m}_t$)	0.56***	0.44**	0.26***	0.74***	0.12**	0.88***	0.32***	0.68***
3. Expected Velocity Change (Ev_t)	0.24***	0.76***	0.10***	0.90***	0.07	0.93***	0.12***	0.88***
4. Unexpected Money Change (Um_t)	0.34	0.66	0.06	0.94***	0.34***	0.66***	0.10*	0.90***
5. Unexpected Velocity Change (Uv_t)	0.19	0.81***	0.19***	0.81***	0.25***	0.75***	0.19***	0.81***
6. $E\hat{m}_t$, 1915-22	0.19	-0.19	---	---	---	---	0.30***	-0.29***
7. Uv_t, 1915-22	0.22**	-0.22**	---	---	---	---	0.28***	-0.28***
8. Um_t, 1915-22	-0.81*	0.80	---	---	---	---	-0.52***	0.59***
9. Uv_t, 1915-22	0.16	-0.16*	---	---	---	---	0.18***	-0.18***
10. $\sum_{i=1}^{10} c_i p_{t-i}$	0.38***	-0.38***	0.46***	-0.46***	---	---	0.40***	-0.40***
11. $\sum_{i=1}^{20} c_i p_{t-i}$, 1954-80	---	---	---	---	1.05***	-1.05***	0.20*	-0.20*
R^2	.793	.947	.875	.998	.802	.985	.798	.995
SEE	5.05	5.05	3.16	3.16	1.39	1.39	3.53	3.53
F for m,v split	F(4,67)=4.06***		F(2,83)=5.79***		F(2,96)=0.74		F(4,296)=10.63***	

Note: Asterisks indicate significance at the levels of 10 percent (*), 5 percent (**), and 1 percent (***). All regressions also include constant terms and the same supply shift variables listed in Table 6.

Since the NRH-GAP hypothesis implies that prices respond more to anticipated permanent than anticipated transitory demand shifts, the pattern of coefficients in Table 7 seems entirely consistent with that hypothesis.

Along these lines, it seems plausible to interpret the shrinking coefficients on $\hat{Em}_t$ in columns (1), (3), and (5) of Table 7 as reflecting a gradual reduction in the responsiveness of prices to anticipated permanent demand disturbances. The relative constancy of the $\hat{Ey}_t$ coefficients in the price-change equations of Table 6 reflects the influence of a growing share of the variance of $\hat{Ey}_t$ taking the form of permanent changes, offset against a shrinking responsiveness of price changes to these permanent demand shifts.

Despite the higher responsiveness of prices to $\hat{Em}_t$ exhibited before 1954, every equation in Table 7 displays a significant positive response coefficient of the output ratio ($\hat{Q}_t$) to anticipated monetary changes. Otherwise, the results in Table 7 duplicate those of Table 6. Unanticipated demand disturbances cause much larger changes in output than in prices. A peculiar result is that the Um_t coefficients in the postwar price-change equations are larger than the $\hat{Em}_t$ coefficients, whereas before 1954 the reverse is true. This might be explained by the combined influence of pre-1954 measurement errors and the impact of the three-year wage contracts in cutting the responsiveness of prices to anticipated monetary disturbances. (The coefficients on the supply-shift variables included in the equations of Table 7 are not displayed, both to save space, and to reflect the fact that there are no important changes as compared with the coefficients exhibited in Table 6.)

An important flaw in previous work has been that the estimated coefficients of price and output response to anticipated changes in money, in equations omitting velocity changes, confuse aggregate supply behavior (i.e., the fraction of nominal GNP change taking the form of price change) with aggregate demand behavior (i.e., the fraction of monetary changes that, sooner or later, cause changes in nominal GNP in the same direction). Table 8 helps to distinguish supply and demand behavior as separate sources of weak output responses to anticipated monetary disturbances. The four sample periods are the same as in Table 7. Lines 1a, 1b, 2a, and 2b repeat the coefficients on anticipated changes in nominal GNP, money, and velocity from Tables 6 and 7. New information is provided in lines 1c and 2c, where the coefficients show the responses of price change and the output ratio to anticipated monetary changes, when the equations of Table 7 are re-estimated with velocity changes omitted. It is evident that the omission of velocity changes makes little difference for the monetary coefficients in the price-change equations, but causes a substantial decline in the monetary coefficients in the output-ratio equations.

The source of this shift in coefficients is identified in line 3 of Table 8, which lists fitted coefficients on $\hat{Em}_t$ in equations that regress the change in velocity on the same right-hand variables appearing in Table 7 (with velocity changes omitted). It is clear that the response of velocity changes to anticipated monetary changes is uniformly negative. Thus the low and insignificant coefficient of output on anticipated monetary change on line 2c for the 1908-29 and 1929-53 sample periods combines a *high* response of output to changes in nominal GNP, with a *negative* response of velocity to money. To the extent that output was insulated from the impact of anticipated monetary changes during those two sample periods, this occurred more because of a restricted impact of money on spending than because of any independence

TABLE 8

Analysis of Differences Between the Effects on Prices and Output of Anticipated Changes in Nominal GNP and Money

	1908:Q4 -1929:Q3	1929:Q4 -1953:Q4	1954:Q1 -1980:Q4	1908:Q4 -1980:Q4
	(1)	(2)	(3)	(4)
1. Equations explaining p_t, coefficient when included anticipated variable is:				
a. $\hat{Ey}$ (Table 6)	0.28***	0.12***	0.09**	0.18***
b. $\hat{Em}$ (Table 7)	0.57**	0.26***	0.12*	0.32***
Ev (Table 7)	0.24**	0.10***	0.07	0.12***
c. $\hat{Em}$ alone	0.57**	0.21***	0.13*	0.33***
2. Equations explaining $\hat{Q}_t$, coefficient when included anticipated variable is:				
a. $\hat{Ey}$ (Table 6)	0.72***	0.88***	0.91***	0.82***
b. $\hat{Em}$ (Table 7)	0.44**	0.74***	0.88***	0.68***
Ev (Table 7)	0.76***	0.90***	0.93***	0.88***
c. $\hat{Em}$ alone	0.22	0.22	0.43***	0.56***
3. Equations explaining v_t, coefficient on $\hat{Em}$	-0.20	-0.56**	-0.44***	-0.12

Note: Asterisks indicate significance at the levels of 10 percent (*), 5 percent (**), and 1 percent (***). All regressions also include constant terms and the same supply shift variables listed in Table 6.

of real output from anticipated changes in spending. In other words, policy ineffectiveness between 1908 and 1953 is more related to factors set forth in early-postwar Keynesian models than those advanced by Lucas, Sargent, and Wallace.

The significant negative response of velocity to anticipated monetary changes also denies the claim by Barro (1978, p. 565-6) that "perceived movements in the money stock imply equiproportionate, contemporaneous movements in the price level." Even if the LSW proposition were true as a statement about aggregate supply, and real output were completely independent of changes in nominal GNP, the negative correlation between velocity and monetary changes would invalidate the Barro quote, since nominal GNP and prices would both respond with less than unit elasticity to changes in money.

VI. TESTS OF OTHER CHANNELS OF PERSISTENCE

Inventories and Unfilled Orders

To this point in the paper the empirical tests have been based on the version of the Lucas supply function written in (2) above, where persistence effects are introduced by entering the lagged output variable. The basis for this form was its use by Lucas (1973), and the derivation by Sargent (1979) of a version of (2) based on the existence of costs of adjustment for employment. A related model that yields a richer set of testable propositions has been worked out by Blinder and Fischer (1981). Any types of costs of adjusting production, including Sargent's employment adjustment costs, would motivate firms to meet only a fraction of an unanticipated increase in sales by increasing production. The remainder of the sales increase would be met by a reduction in inventories of finished goods (N_t) or by an increase in unfilled orders (O_t).[17]

The Blinder-Fischer model can be written in three equations, the first to determine the output ratio ($\hat{Q}_t$), the second to characterize the change in the stock of inventories during the current period ($N_t - N_{t-1}$), and the third to characterize the change in unfilled orders ($O_t - O_{t-1}$):

$$(19) \qquad \hat{Q}_t = \alpha Uy_t + \lambda(N_t^* - N_{t-1}) - \mu(O_t^* - O_{t-1}) + \varepsilon_{1t},$$

$$(20) \qquad N_t - N_{t-1} = \theta(N_t^* - N_{t-1}) - \beta Uy_t + \varepsilon_{2t},$$

$$(21) \qquad O_t - O_{t-1} = \phi(O_t^* - O_{t-1}) + \gamma Uy_t + \varepsilon_{3t}.$$

Here (19) states that the output ratio responds positively to an unanticipated change in nominal aggregate demand (Uy_t), positively to an excess of desired inventories (N_t^*) over actual inventories, and negatively to an excess of desired unfilled orders (O_t^*) ovaer actual unfilled orders. (20) and (21) govern the change in actual inventories and unfilled orders by a stock adjustment equation that allows for a direct response of inventories and orders to sales, reflecting assumed costs of adjusting production.

These three equations introduce only two changes into equations (4.1) and (4.2) of Blinder and Fischer. First, the addition of an extra equation providing a symmetric treatment of unfilled orders is consistent with their approach. Second, unanticipated demand enters directly into each equation rather than unanticipated prices, saving several steps in the subsequent exposition without changing any substantive conclusions.[18] Third, nominal GNP is used as an exogenous variable rather than money.

Since we are interested in the extent to which the adjustment of inventories and unfilled orders can explain the output ratio ($\hat{Q}_t = Q_t - Q_t^*$), we shall interpret "N_t" and "O_t" respectively as the ratio of the real inventory stock and real unfilled orders to equilibrium real output (Q_t^*). Equations (20) and (21) can be solved for the actual change in N and O and then substituted back into (19):

$$(22) \qquad \hat{Q}_t = (\alpha + \frac{\lambda\beta}{\theta} + \frac{\mu\gamma}{\phi})Uy_t + \frac{\lambda n_t}{\theta} - \frac{\mu o_t}{\phi} + \varepsilon_{1t} - \frac{\lambda\varepsilon_{2t}}{\theta} + \frac{\mu\varepsilon_{3t}}{\phi},$$

where n_t and o_t represent the first difference of N_t and O_t, respectively, and where each first difference is expressed as a ratio to Q_t^*.

Equation (22) represents a hypothesis that the level of the output ratio depends on the demand surprise, and the change in inventories and unfilled orders. It can be compared with our basic output equation (14), which makes no mention of inventories nor unfilled orders, but which shares in common the demand surprise variable. (14) also includes several variables not in (22), including the anticipated change in demand, the lagged output ratio, lagged price changes, and supply shifts. It seems appropriate to combine the two equations, since the alternative sets of exclusion restrictions can then be tested. The combined equation is not written separately here, since it is identical to (14) when the n_t and o_t variables are added, with signs predicted to be, respectively, positive and negative. Just as the price-change equation (13) is a "dual" to (14), so we can test a price-change equation that is identical to (13) when the n_t and o_t variables are added, with signs predicted to be, respectively, negative and positive.

The results are reported in Table 9. Columns (1) and (2) exhibit coefficients when the inventory and unfilled orders variables are added to (13) and when nominal GNP and money are used as alternative demand-shift variables. The results are almost identical to those reported in Table 6 and 7. The coefficients on the inventory and unfilled orders variables have the predicted sign, and that on inventory change (n_t) is highly significant in column (1). In column (2) the inventory change variable is not significant, and the unfilled orders variable only marginally so.

Columns (5) and (6) list the results for the equivalent equations explaining the output ratio. As in Table 6, the identity relating equations (13) and (14) guarantees that the output ratio equation using nominal GNP as the demand shift variable will yield an identical fit as the corresponding price-change equation. The output ratio equation in column (6), where monetary changes are used as the demand shift variable, differs substantially. Now expected monetary change is only marginally significant, and changes in inventories and unfilled orders become highly significant in explaining the output ratio. The low response of output to anticipated monetary changes in column (6) can be explained by the strong negative correlation between money and velocity during the 1954-80 interval observed in Table 8, together with the role of inventories and unfilled orders in helping to track changes in velocity. In terms of the Blinder-Fischer hypothesis as written in equation (22), the coefficient on the unfilled orders variable has the wrong sign.

Overall, the high level of significance of variables included in the NRH-GAP hypothesis, as written in equations (13) and (14), but not in the Blinder-Fischer equation (22), supports the general approach taken in this

TABLE 9

Regression Equations Explaining Quarterly Price Changes and the Output Ratio, 1954:Q1-1980:Q4

(quarterly change variables expressed at annual percentage rates)

	Price Change				Output Ratio			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. $\hat{Q}_{t-1}$	0.09***	0.06**	---	0.03*	0.91***	0.76***	---	0.96***
2. $\hat{Ey}_t$	0.14**	---	---	---	0.86***	---	---	---
3. $\hat{Em}_t$	---	0.11*	0.39***	0.44***	---	0.18*	-1.44***	0.26**
4. Uy_t	0.28***	---	---	---	0.72***	---	---	---
5. Um_t	---	0.05	0.05	0.04	---	0.07	0.33	0.07
6. $\sum_{i=1}^{20} \omega_i Um_{t-i}$	---	---	0.96	0.69	---	---	9.08***	1.34
7. $\sum_{i=1}^{20} d_i p_{t-i}$	1.05***	1.08***	---	---	-1.05***	-0.74***	---	---
8. n_t	-0.88***	-0.30	---	---	0.88***	2.96***	---	---
9. o_t	0.09	0.17*	---	---	-0.09	0.49***	---	---
10. Nixon Control Dummy	-3.22***	-3.35***	-3.99***	-4.40***	3.22***	3.41***	18.1***	6.10***
11. Food-energy Effect	0.44***	0.44***	1.34***	1.27***	-0.44***	-0.08	1.45*	-0.50
R^2	.816	.748	.476	.485	.986	.936	.323	.903
SEE	1.34	1.57	2.23	2.23	1.34	2.87	9.18	3.50
D-W	1.94	2.02	1.25	1.24	1.94	1.65	0.36	1.53

Notes: Asterisks indicate significance at the levels of 10 percent (*), 5 percent (**), and 1 percent (***). All regressions also include a constant term.

paper. The significance of the inventory change variable in columns (1) and (5) of Table 9 seems to be of minor importance, in view of the fact that the coefficients on the other variables are almost identical to those in columns (5) and (6) of Table 6.

The Role of Lagged Monetary Surprises

This paper has rejected the LSW hypothesis in favor of the alternative "NRH-GAP" approach that combines long-run monetary neutrality with the gradual adjustment of prices in the short run. As a final step it is appropriate to compare our basic empirical results in Tables 6 and 7 with those obtained when persistence effects are incorporated by a method adopted in most previous studies. This third method (an alternative to the use of the lagged output ratio variable as in (2) or inventory and unfilled-orders changes as in (22)) involves the inclusion in the output equation of a long distributed lag on past monetary surprises (Um_t). Pioneered by Barro (1977) (1978) and used by Barro and Rush (1980) in a study of postwar quarterly data, this third method was rejected above in Part III, due to the observational equivalence problem discussed there, and McCallum's argument that "bygones are bygones."

There is an additional reason, other than purely methodological considerations, to avoid the "lagged surprise" technique. This is the fact that the method provides an abysmal fit to the data on real output, as is evident in column (7) of Table 9, where we omit the persistence variables used previously (the lagged output ratio, and changes in inventories and unfilled orders) and the lagged price-change terms suggested by the NRH-GAP hypothesis. The resulting equation has a standard error seven times that in column (5) and more than triple that in column (6). Further, the Durbin-Watson statistic signals the presence of severe positive serial correlation, which, for reasons set forth by Flood and Garber (1981), cannot be corrected in the normal way by the Cochrane-Orcutt procedure. Column (7) duplicates the essential features of the specification used by Barro and Rush in their basic output equation, and the results are almost identical, including the low Durbin-Watson statistic.[19]

The misspecification in column (7) involves the omission of both the lagged output ratio variable and the lagged price change variables. The first omission is crucial, as is clear in column (8), where $\hat{Q}_{t-1}$ is added to the specification of column (7). The t-ratio on the additional variable is a mammoth 24.3. The drastic decline in the size and significance of the coefficients on the lagged surprise terms in comparing columns (7) and (8), together with the change from an incorrect to a correct sign of the coefficients on the anticipated change in money and on the food-energy variables, can be cited as evidence of the misleading results that are yielded by the Barro-Rush specification.

Finally, for completeness columns (3) and (4) present parallel specifications for equations explaining price change. Here the omission of $\hat{Q}_{t-1}$ makes little difference; the omission of the lagged price-change variables causes the fit to deteriorate and the coefficients on anticipated money change to jump. What is important, however, is that the lagged-surprise method of incorporating persistence effects seems soundly rejected, since the associated sums of coefficients in columns (3), (4), and (8) are uniformly insignificant.

VII. SUMMARY AND CONCLUSION

This paper has introduced a new approach to the empirical testing of the Lucas-Sargent-Wallace (LSW) "policy ineffectiveness proposition." Instead of testing that hypothesis in isolation from any plausible alternative, the paper develops a single empirical equation explaining price changes, and a parallel equation explaining real output behavior. Both of these include as special cases the LSW proposition, and an alternative hypothesis, dubbed "NRH-GAP," that prices respond fully in the long run, but only gradually in the short run, to nominal aggregate demand disturbances. A second innovation is the development of a quarterly data file for the period 1890-1980, thus opening up more than 200 new quarterly observations for analysis, over and above the postwar data that have been the sole focus of previous research. The third innovation is the testing of three different methods of introducing "persistence effects" into the LSW analytical framework--use of a lagged output variable, the Blinder-Fischer approach based on inventories as a buffer stock, and the Barro approach based on the inclusion of lagged monetary surprises.

The LSW proposition predicts that real output is independent of anticipated changes in nominal GNP, and that prices move equiproportionately and contemporaneously with those anticipated changes. In contrast, our results over the entire 1890-1980 period, and over separate sub-periods, find uniformly high coefficients of real output and low coefficients of price changes in response to anticipated nominal GNP changes. Further, in every sub-period price changes respond positively and output responds negatively to lagged changes in prices, reflecting the short-run inertia in price-setting that forms the basis of the alternative NRH-GAP approach.

These results are confirmed when nominal GNP changes are subdivided between changes in money and in velocity, with some additional evidence provided that the apparent constancy in the response of price changes to anticipated nominal GNP changes confounds a *growing* share over time of anticipated nominal GNP changes that are regarded as permanent rather than transitory, offset against a *shrinking* responsiveness of prices to those permanent changes.

Price-setting behavior exhibits a remarkable constancy over the entire period between 1890 and 1980 in its main features, which are a small elasticity to anticipated nominal GNP changes, and a substantial coefficient on lagged price changes. Nevertheless, there are two shifts over time, to which I have previously called attention (1980, 1981b), and which are confirmed here. These are the much higher degree of price responsiveness during the period of World War I and its aftermath (1915-22), and the presence of a longer mean lag on past price changes after 1953.

Only one piece of evidence is provided to support the notion of "policy ineffectiveness." The elasticity of real output with respect to anticipated changes in the money supply is small and insignificant before 1954, when the impact of velocity changes is omitted. However, this result does not support the LSW interpretation of ineffectiveness, which requires instantaneous flexibility of prices to anticipated changes in nominal GNP. Instead, this result stems from the negative response of velocity to changes in money, which makes the response of real output to changes in money substantially smaller than to changes in nominal GNP. Thus, to the extent that ineffectiveness of monetary policy is exhibited before 1954, it occurs for old-fashioned Keynesian reasons rather than the new-fangled reasons set forth by Lucas, Sargent, and Wallace.

The basic empirical results allow the LSW approach to incorporate "persistence effects" through the presence of the lagged dependent variable in the output equation. An alternative technique, suggested by Blinder and Fischer, takes account of the role of inventories as a buffer stock. Results indicate that inventory changes are significant in the basic postwar price change and output equations, but cause only minor changes in the other coefficients. In particular, lagged price changes and lagged output continue to be highly significant in equations containing inventory change, confirming the specification on which the central results of the paper for the full 1890-1980 period are based. A third technique for incorporating persistence, the Barro method of adding lagged money surprise terms, is rejected both on methodological grounds, and for its poor performance in explaining the postwar data.

Of independent interest, beyond its treatment of the policy ineffectiveness issue, is the characterization in the paper of changes in monetary regimes, and of the impact of programs of government intervention. The equations used to split nominal GNP and money into their anticipated and unanticipated components exhibit highly significant shifts in structure before and after World War I (for money, not nominal GNP), and a marginally significant shift in 1967 (for both variables). The results identify five episodes of government intervention that significantly displaced the time path of prices--the National Recovery Act of 1933-35, and price controls during the two world wars, Korea, and the Nixon era. In each case the results are consistent with the hypothesis that in these episodes the initial impact of the government intervention was cancelled by a subsequent offsetting movement in the price level when the particular program was terminated. The results also suggest a significant impact after 1953 of changes in the relative prices of food and energy in shifting the aggregate price level in the same direction, and real output in the opposite direction.

Like many studies, this one leaves several questions as unsettled items for a future research agenda. There is a noticeable shift in the structure of the price adjustment process during the Great Depression, as contrasted with the period before 1929 or after 1953. During the 1930s the *level* of output played a much smaller role, and the *change* in output a greater role, than before or after. Further, the lag distribution on past price changes in our basic equations was much shorter during the Depression than before 1929 or after 1953. This confirms the conclusion of Gordon and Wilcox (1981) that movements of all important aggregate variables--money, nominal GNP, prices, and output--were essentially simultaneous in the Great Depression, thus inhibiting or completely precluding a statistical analysis of cause and effect. Finally, there are numerous detailed aspects of the process of gradual price adjustment during the post-1953 era, outside of the context of the policy-ineffectiveness debate, that are best treated in a separate analysis (see Gordon 1981c).

FOOTNOTES

1. Throughout the present paper upper-case letters are used for logs of levels of variables, and lower-case letters for percentage rates of change. The prefix "E" stands for the expectation of a variable based on information available last period, and the prefix "U" stands for the difference between the realization of a variable and its expectation.
2. A detailed analysis of alternative theoretical explanations of gradual-price adjustment is contained in Gordon (1981b).
3. The proposition that the expectations of agents depend on the serial correlation properties of the variable being forecast was originally applied to the U.S. Phillips curve literature by Sargent (1971). The relevance of known serial correlation properties to the formation of rational price expectations within the context of the policy ineffectiveness proposition was first set forth in Gordon (1976, pp. 203-4).
4. A perceptive analysis of the Lucas supply function and a number of conceptual difficulties associated with it is presented by Bull and Frydman (1980).
5. See McCallum (1977)(1978) and the critiques by Gordon (1977), Frydman (1981), and Nickerson (1981).
6. A derivation of (11) from wage and price markup equations, detailed testing over the 1954-80 period, and comparison with equations that directly enter money as a variable explaining inflation, are contained in Gordon (1981c). Tests of the influence of wage and price controls and guidelines within the same specification are presented in Frye and Gordon (1981).

7. Included are the papers by Barro (1977)(1978), Barro and Rush (1980), Leiderman (1980), Makin (1981), Mishkin (1981), and Small (1979).

8. Without a correction for serial correlation, the Durbin-Watson statistic in the basic Barro-Rush quarterly output and price level equations is 0.4 (1980, Tables 2.1 and 2.2). Mishkin is also forced to correct for significant serial correlation in his residuals.

9. The only current values of explanatory variables included in the money and nominal GNP equations are the dummy variables for government intervention. We assume that people were capable of knowing that a particular government program was in effect during the current quarter but did not know the current value of money, nominal GNP, etc., until after the quarter was over.

10. A more complete explanation of postwar inflation (1981c) also introduces as explanatory variables deviations of productivity growth from trend, changes in the foreign exchange rate of the dollar, and changes in the effective minimum wage and effective social security payroll tax rate. These variables are omitted from the basic equations (13) and (14) in this paper, both to simplify the presentation and to maintain comparability with the period before 1947 when data series on these variables are not available.

10a. On World War I controls, see Taussig (1919).

11. The implementation of this approach requires an iterative technique in which the residuals of the price-change equation are used to define the timing pattern of the dummy variables.

12. The variable is only roughly appropriate in equations explaining the GNP deflator, because an adjustment is needed to correct for the impact of food and energy exports and imports. Nevertheless, this approximation

seems to be adequate to capture the impact of supply shock inflation during the postwar period. The conceptually correct variable was constructed and tested in Gordon (1975). Its coefficient, however, is very close to that of the variable described in the text for a subperiod extending from 1954 to 1975.

13. Following the procedure outlined in Gordon (1980, p.246), the lagged dependent variables in the equations estimated below in Tables 1, 2, 6, and 7, are entered "net" of the influence of the supply-shift variables. Thus, if a dummy variable D_t is included in quarter "t", and has an estimated coefficient of α in a first iteration, in a subsequent iteration the lagged dependent variable applying to quarter t is entered in the form $P_t^N = P_t - \alpha D_t$. For instance, in explaining an observation like 1948:Q3, the 8th lag on the dependent variable, referring to 1946:Q3, would subtract out that portion of the 52 percent annual inflation rate in 1946:Q3 attributed to the "special factor" of a post-controls rebound (in Table 6, 43 points of the 52 points is subtracted). This procedure essentially purges the inertia variable of the influence of special historical factors that agents are unlikely to extrapolate into the future. As such, it represents a partial tion to the problem I have posed regarding the role of special factors in the formation of expectations (Gordon, 1973).

14. The technique is slightly more involved than a simple trend-through-peaks-method. An adjustment is made for the effect on unemployment of the shrinking importance of farmers and self-employed proprietors, and for differences among the adjusted unemployment rates observed in benchmark years. See Gordon (1981a, Appendix C, pp. xxii-xxiii).

15. The growth rate of M2 refers to the old concept for 1907-58, and for 1959-80 to the new concept, introduced in early 1980, that includes saving deposits at thrift institutions.

16. The choice of dates for the sub-periods, which inevitably must be somewhat arbitrary, corresponds to the dates chosen in Gordon (1980), in order to facilitate comparisons between the two papers.

17. The Blinder-Fischer paper does not include any explicit treatment of unfilled orders, but the symmetric treatment of inventories and unfilled orders in equations (19)-(21) seems entirely consistent with their approach.

18. The steps required to replace Up_t by Uy_t are set out above in equations (4) through (6).

19. Numerous detailed differences between column (7) and the basic Barro-Rush output equation (1980, Table 2.1, column (3)) seem to make little difference in the fit of the equation, and its severe problem of serial correlation. The differences include the use by Barro-Rush of a different set of variables to decompose money into Em_t and Um_t; a different sample period (1947:Q1-1978:Q1); a natural output series represented as a single trend line; one additional variable in the output equation, current real government spending on goods and services; and the omission of our Nixon controls and food-energy variables. The Barro-Rush standard error, when multiplied by four to be comparable with our dependent variable, is 7.48 compared to 9.18; the Durbin-Watson is 0.3 as compared to 0.36; and the sum of coefficients on the lagged money residuals is 11.50 compared to 9.08.

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DATA APPENDIX

Note: The references listed below identify the source of data in levels. When data are spliced from more than one source, quarterly rates of change are calculated by using overlapping data, in order to avoid jumps in levels between two sources.

Money. 1907-1958. Friedman and Schwartz (1963) M2 series, spliced to Federal Reserve "old" M2 series in 1947.

1959-1980. Federal Reserve "new" M2 series, as revised in January 1980.

Interest Rate. 1890-1980. 4-6 month commercial paper rate, from Federal Reserve Historical Statistics.

Inventory Change. 1947-1980. In constant 1972 dollars, from National Income and Product Accounts, Table 1.2.

Unfilled Orders. 1947-1980. Manufacturers unfilled orders, durable goods industries, Business Conditions Digest series 98.

Natural Real GNP. 1900-1953. Gordon (1981a, Appendix B).
1954-1980. Gordon (1981c, Appendix B).

Actual Real GNP. 1890-1908, annual. U.S. Commerce Department, Long-run Economic Growth (LREG), series A1.
1909-1928, annual. LREG, Series A2.
1929-1946, annual, and
1947-1980, quarterly. National Income and Product Accounts, Table 1.2, incorporates 1981 revisions.

Quarterly interpolations, based on method of Chow-Lin (1971).
Interpolators: 1890-1918. Index of Industrial Production.
1919-1946. Index of Industrial Production and Retail Sales Deflated by the CPI.

GNP Deflator. 1890-1908, annual. LREG, series A7 divided by series A1.
1909-1928, annual. LREG, series A8 divided by series A2.
1929-1946, annual, and 1947-80, quarterly. National Income and Product Accounts, Table 7.1, incorporates 1981 revisions.

Quarterly interpolations, based on method of Chow-Lin (1971).
Interpolators: 1890-1918. WPI for farm products, WPI for nonfarm products.
1919-1946. WPI and CPI.

Nominal GNP. 1890-1946, quarterly. Real GNP times the GNP deflator.
1947-1980, quarterly. National Income and Product Accounts, Table 1.1