

Price Inertia and Policy Ineffectiveness in the United States, 1890-1980

Author(s): Robert J. Gordon

Source: *Journal of Political Economy*, Vol. 90, No. 6 (Dec., 1982), pp. 1087-1117

Published by: The University of Chicago Press

Stable URL: <https://www.jstor.org/stable/1830940>

Accessed: 23-04-2020 23:35 UTC

---

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact [support@jstor.org](mailto:support@jstor.org).

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at <https://about.jstor.org/terms>



JSTOR

*The University of Chicago Press* is collaborating with JSTOR to digitize, preserve and extend access to *Journal of Political Economy*

# Price Inertia and Policy Ineffectiveness in the United States, 1890–1980

Robert J. Gordon

*Northwestern University and National Bureau of Economic Research*

This paper introduces a new approach to the empirical testing of the Lucas-Sargent-Wallace (LSW) “policy ineffectiveness proposition,” which compares the LSW hypothesis with an alternative that states that prices respond fully in the long run, but only gradually in the short run, to nominal aggregate demand disturbances. The empirical equations, estimated for a new set of quarterly data extending back to 1890, exhibit uniformly high responses of real output and low responses of price changes to anticipated changes in nominal GNP. The paper compares and tests three alternative methods of introducing “persistence effects” into the LSW framework.

. . . it seems difficult to sustain the position that the policy ineffectiveness proposition is applicable to the U.S. economy. [Bennett T. McCallum]

I am grateful to the National Science Foundation and the John Simon Guggenheim Foundation for research support and to Jon Frye, Ross Newman, and Stephen King for research assistance. This research is part of the NBER’s research program in economic fluctuations. Any opinions expressed are those of the author and not the NBER. Earlier versions of this research benefited from the suggestions of Clive Bell, Robert Eisner, Stanley Fischer, Robert Hall, Fumio Hayashi, Rick Mishkin, Joel Mokyr, Charles Nelson, David Nickerson, Christopher Sims, Ken Singleton, David Small, Carl Walsh, and participants in the University of Chicago Money Workshop, the Research Meeting of the NBER 1979 Summer Institute in Macroeconomics, and the NBER Conference on Inventory Behavior in March 1980. I would like to acknowledge my special debts to Bennett McCallum, whose insightful comments on an earlier paper were indispensable in the development of the approach presented here, and to James Wilcox, whose insightful creation of a quarterly data file for the interwar years made possible the subsequent development of new data in this paper. The opening quote is from McCallum (1980, p. 738).

*[Journal of Political Economy, 1982, vol. 90, no. 6]*

© 1982 by The University of Chicago. All rights reserved. 0022-3808/82/9006-0004\$01.50

## 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 antiinflation 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. The LSW proposition, as it may also be designated, 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, which allows 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, the sample space here is extended to 90 years. The characterization of price and output behavior 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 three alternative methods of introducing persistence effects into the LSW model. Two of these, the direct dependence of current output on

lagged output and the introduction of an inventory and new orders mechanism, lead in our tests to the rejection of the LSW hypothesis. The third channel, the dependence of current output on lagged monetary innovations, is rejected on the basis of its theoretical implausibility and its poor empirical performance in tracking the time-series data.

### *Price Flexibility and Long-Run Neutrality*

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 to be tested 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.

Starting in equilibrium with real output at its natural level ( $Q^*$ ), let us consider the economy's response to an experiment in which there is a fully anticipated 5 percent acceleration in the growth rate of nominal GNP. The LSW proposition states that there would be no effect on real output, which would remain at the level  $Q^*$ . By definition, the full amount of the anticipated change in nominal GNP would immediately be reflected in an equiproportionate 5-percentage-point jump in the rate of inflation. This is consistent with Barro's interpretation of the LSW proposition: "perceived movements in the money stock . . . imply equiproportionate, contemporaneous movements in the price level" (1978, pp. 565–66).

The alternative hypothesis developed in this paper is that prices adjust gradually in the short run and fully in the long run to anticipated changes in nominal aggregate demand. Our label for this approach is 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 NRH-GAP view does not predict that the 5 percent experiment would leave the inflation rate unchanged. Instead, it predicts that initially the more rapid anticipated growth of nominal GNP would be reflected partly in faster inflation and partly in a temporary rise of real output above the equilibrium level  $Q^*$ . Eventually the gradual adjustment process would be completed, the inflation rate would rise by a full 5 percent amount, and real output would return to  $Q^*$ . Any factor that prevents prices from jumping instantaneously, for example, adjustment costs, long-term contracts, and the decentralization of decision making, can explain why the full adjustment of the inflation rate does not occur instan-

taneously. Thus the real issue separating proponents from critics of the LSW proposition is the importance of inertia in price adjustment; for LSW to be true, there can be no inertia, whereas inertia is the essence of the alternative NRH-GAP approach.

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. 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). 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.

## II. The Models to Be Tested

### *The Lucas Supply Function with a Lagged Output Term*

The point of departure for the analysis of the LSW proposition is a version of the Lucas supply function introduced by Lucas (1973). It states that the difference between log output ( $Q_t$ ) and log natural output ( $Q_t^*$ ), which we call the "output ratio" ( $\hat{Q}_t$ ), depends on the unanticipated component of price change and on the lagged output ratio:

$$\hat{Q}_t = Q_t - Q_t^* = \alpha U p_t + \lambda \hat{Q}_{t-1} + \epsilon_t, \quad (1)$$

where  $U p_t$  stands for the unanticipated component of price change ( $p_t - E p_t$ ), and  $\epsilon_t$  is a stochastic error term with mean zero and constant variance.<sup>1</sup> Because (1) allows the output ratio to depend on its own lagged values, it is consistent with the serial correlation or "persis-

<sup>1</sup>Throughout the present paper uppercase letters are used for logs of levels of variables and lowercase 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.

tence" observed in actual data on real output.<sup>2</sup> In this paper we derive general equations for output and price adjustment that subsume the supply function (1) and the gradual adjustment of prices approach as alternative special cases.

The implications of (1) 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):

$$\begin{aligned} p_t &\equiv y_t - q_t \\ &\equiv \hat{y}_t - \hat{q}_t, \end{aligned} \quad (2)$$

where the "hats" on the lowercase 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 ( $\hat{q}_t \equiv \hat{Q}_t - \hat{Q}_{t-1}$ ), (2) is equivalent to:

$$p_t \equiv \hat{y}_t - \hat{Q}_t + \hat{Q}_{t-1}. \quad (3)$$

By rewriting (3) as a relationship between the unanticipated component of each variable and noting that with a one-period information lag the unanticipated component of the lagged output gap ( $U\hat{Q}_{t-1}$ ) is zero, we obtain:

$$\begin{aligned} Up_t &= Uy_t - U\hat{Q}_t \\ &= Uy_t - \alpha Up_t - \epsilon_t = \frac{1}{1 + \alpha}(Uy_t - \epsilon_t). \end{aligned} \quad (4)$$

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 (1). The resulting expression can be substituted back into (1) to provide a relationship between the actual output gap and the unanticipated component of nominal GNP change:

$$\hat{Q}_t = \frac{1}{1 + \alpha}(\alpha Uy_t + \epsilon_t) + \lambda \hat{Q}_{t-1}. \quad (5)$$

Thus (5) 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. We obtain a related expression for price change by re-

<sup>2</sup> Tobin (1980, p. 791) has criticized the appearance of the lagged output term in (1) as having a "very thin intrinsic justification."

writing the identity (3), splitting actual nominal GNP change between its expected and unexpected components, and then substituting (5) for the actual output gap:

$$\begin{aligned} p_t &\equiv E\hat{y}_t + U_{y_t} - \hat{Q}_t + \hat{Q}_{t-1} \\ &= E\hat{y}_t + \frac{1}{1 + \alpha}(U_{y_t} - \epsilon_t) + (1 - \lambda)\hat{Q}_{t-1}. \end{aligned} \quad (6)$$

Equation (6) 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  $\alpha/(1 + \alpha)$ .

### *Gradual Price Adjustment with Long-Run Monetary Neutrality*

Instead of starting from (1), in which the output ratio  $\hat{Q}_t$  is 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. 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:

$$p_t = a(L)p_{t-1} + b_0\hat{Q}_t + b_1\Delta\hat{Q}_t + b_2z_t + e_t, \quad (7)$$

where  $a(L)$  is a polynomial in 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 1981*b*). Equation (7) 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.<sup>3</sup> It 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

<sup>3</sup> A derivation of (7) 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 (1982). Tests of the influence of wage and price controls and guidelines within the same specification are presented in Frye and Gordon (1981).

equal to natural output ( $\hat{Q}_t = 0$ ) and when there are no supply shocks ( $z_t = 0$ ).

We can convert equation (7) into a form that is directly comparable with the LSW price-change equation (6) if we use the identity (3) 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  $Uy_t$ ):

$$p_t = \frac{1}{1 + b_0 + b_1} [a(L)p_{t-1} + (b_0 + b_1)(E\hat{y}_t + Uy_t) + b_0\hat{Q}_{t-1} + b_2z_t + e_t]. \tag{8}$$

We note that (6) and (8) 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 (8) in the form to be estimated:

$$p_t = c(L)p_{t-1} + d_0E\hat{y}_t + d_1Uy_t + d_2\hat{Q}_{t-1} + d_3z_t + u_t. \tag{9}$$

Now we see that the LSW equation (6) is just a special case of (9), which places explicit restrictions on coefficient estimates, as summarized in the following table (here  $\Sigma a_i$  and  $\Sigma c_i$  refer to the respective sums of the  $a[L]$  and  $c[L]$  lag coefficients).

Variable	Coefficient in NRH-GAP Hypothesis (8)	Coefficient in Special LSW Case (6)
$p_{t-1}$	$\Sigma c_i = \frac{\Sigma a_i}{1 + b_0 + b_1} > 0$	$\Sigma c_i = 0$
$E\hat{y}_t$	$d_0 = \frac{b_0 + b_1}{1 + b_0 + b_1} < 1$	$d_0 = 1$
$Uy_t$	$d_1 = \frac{b_0 + b_1}{1 + b_0 + b_1} < 1$	$d_1 = \frac{1}{1 + \alpha} < 1$
$\hat{Q}_{t-1}$	$d_2 = \frac{b_0}{1 + b_0 + b_1} < 1$	$d_2 = 1 - \lambda < 1$

There are three important differences between the gradual adjustment equation (8) and the LSW special case (6). First, since price inertia is the antithesis of the LSW proposition, the sum of coefficients on lagged price changes in (6) is zero, whereas the sum is positive in (8). Second, the LSW equation (6) implies that the elasticity of price change to an anticipated change in nominal demand is exactly unity, with other determinants of output held constant, whereas that coefficient must be less than unity in (8) if the sum of the level and



rate of change coefficients for the output terms in equation (7) 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 (8) but not in (6), 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 esp. McCallum 1979*b*). While correct, this conclusion is reached by substituting  $E\hat{y}_t$  out from (6). Lagged price change cannot appear in (6) 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 (6) and with a positive sum of coefficients (say,  $a$ ) 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 (8) 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 ( $E\hat{y}_t$ ) is exactly unity.

Just as the LSW output-ratio equation (5) is "dual" to the LSW price change equation (6), since both are connected by an identity (3), 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 (3) for  $\hat{Q}_t$  and substitute the right-hand side of (9) for  $p_t$ , we obtain:

$$\begin{aligned} \hat{Q}_t = & -c(L)p_{t-1} + (1 - d_0)E\hat{y}_t + (1 - d_1)Uy_t \\ & + (1 - d_2)\hat{Q}_{t-1} - d_3z_t - u_t. \end{aligned} \quad (10)$$

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 (10). In addition, the LSW approach requires that the negative lag coefficients on past price changes do not appear in (10).

### III. Econometric Issues

The remainder of this paper is concerned with the econometric estimation of the dual equations (9) for price change and (10) for the

output ratio, 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  $Uy_t$ ) and the selection of proxy variables to represent systematic supply shocks ( $z_t$ ). But another more general econometric issue has been discussed in the literature and must be treated here.

### *Observational Equivalence*

Sargent (1976) has posed an identification problem that occurs when the Lucas supply hypothesis is represented by the following in place of (5):

$$\hat{Q}_t = \sum_{i=1}^N \gamma_i U y_{t-i} + \epsilon_t. \quad (11)$$

This alternative formulation explains persistent deviations of the output ratio from zero by introducing lagged values of the expectational error. The observational equivalence problem is evident when anticipated nominal demand changes depend mainly on lagged actual changes in nominal demand. Substitution of these lagged values into (11) would make the output ratio depend only on current and lagged changes in actual nominal demand. Yet this distributed lag relationship between the output ratio and current and past actual nominal changes is just the same as would be obtained when equation (10) is solved recursively. 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 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.<sup>4</sup> McCallum (1979a) has proposed excluding lagged values of  $Uy_t$  from output equations, which would thus constrain 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 (5) excludes lagged demand innovations from influencing output directly.

Four factors argue in favor of McCallum's suggestion. First, the essential features of (11) are captured by (5). The only difference is that (5), by forcing the lagged influence to operate through the lagged

<sup>4</sup> Included are the papers by Barro (1977, 1978), Small (1979), Barro and Rush (1980), Leiderman (1980), Makin (1981), and Mishkin (1982).

dependent variable, constrains the distributed lag on  $Uy_t$  to be the same as on  $\epsilon_t$ , which seems reasonable given that both are serially independent variables that by construction cannot be predicted one period in advance.

Second, it does not make any sense for lagged surprises to influence current output: “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  $[\hat{Q}_t]$ ” (McCallum [1979a, p. 398]; my notation substituted for his).

Third, our results based on (5) avoid the problems of serial correlation of residuals that have plagued previous studies based on (11).<sup>5</sup> Fourth, as demonstrated in table 5 below, the lagged innovation approach based on (11) 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, (9) and (10), 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 ( $E\hat{y}_t$ ). 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); the fitted values of this equation are used as a proxy for  $E\hat{y}_t$  in the second-stage equations explaining price change and the output ratio, and the residuals of this equation are used as a proxy for  $Uy_t$ . To avoid measurement error and achieve consistent estimation, procedures followed in the first stage obey the following conditions:

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

2. The output-ratio equation (10) supports the LSW proposition only if  $E\hat{y}_t$  does not “Granger-cause” the output ratio, that is, if it makes no significant contribution to the fit of (10) when the lagged dependent variable is included. For such a test to be valid, the under-

<sup>5</sup> Without a correction for serial correlation, the D-W statistic in the basic Barro-Rush quarterly output and price-level equations is 0.4 (1980, tables 2.1, 2.2). Mishkin (1982) is also forced to correct for significant serial correlation in his residuals. See also table 5.

lying aggregate supply equation cannot include lagged innovations, and its error term must be a white-noise disturbance (McCallum 1979*b*). 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. This source of mis-measurement is avoided here by including only lagged variables in the first-stage equation.<sup>6</sup>

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 1970:4 is based on a regression fitted to data for 1967:3–1980:4, which allows the coefficient used to forecast in 1970 to be based on information for 1971–80. A solution, 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  $1-t$ . But 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. 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 subperiods 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 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 govern-

<sup>6</sup> 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.

ment 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.<sup>7</sup> 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.<sup>8</sup> 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 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. 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.<sup>9</sup>

<sup>7</sup> A more complete explanation of postwar inflation (Gordon 1982) 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 (9) and (10) 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.

<sup>8</sup> On World War I controls, see Taussig (1919).

<sup>9</sup> 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.

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, respectively including and excluding food and energy, has the advantage of weighting food and energy prices in proportion to final expenditures.<sup>10</sup> When relative prices are constant, the variable assumes a value of zero.<sup>11</sup>

#### *The New Quarterly Data File, 1890–1980*

The empirical results in the paper are based on a new quarterly data file for nominal GNP, actual and natural real GNP, the GNP deflator, the money supply (M2), and the short-term interest rate covering the years 1890–1980. Details of the construction of these variables are contained in the Appendix, and a printout of the file is available by mail from the author. An important feature of the data set is the new series on natural real GNP ( $Q_t^*$ ); unlike previous studies in this area,  $Q_t^*$  is not forced to follow a single time trend. Estimated decadal growth rates of our new  $Q_t^*$  series range from 2.5 percent per annum (1910–20) to 4.5 percent per annum (1890–1900). The output-ratio series, the difference between the logs of actual and natural real GNP ( $Q_t$ ), displays a range between –53.9 percent (1933:1) and 21.1 percent (1945:1).

#### **IV. Nominal GNP, Money, and Changes in Regimes**

##### *The Equations Predicting Nominal GNP and Money Change*

The first-stage equations used to split up observed changes in nominal GNP and money into expected and unexpected components are based on an identical specification. The right-hand variables include four lagged values of changes in nominal GNP, money, and the GNP deflator and two lagged values of the commercial paper rate. Also included are the supply-shift variables for the relevant subsample periods, which begin, respectively, in 1891:2, 1908:4, 1915:1,

<sup>10</sup> No similar variable is available prior to 1947. Our 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.

<sup>11</sup> Following the procedure outlined in Gordon (1980, p. 246), the lagged dependent variables in the equations estimated below in tables 3 and 5 are entered “net” of the influence of the supply-shift variables. Thus, if a supply variable  $z_t$  is included in quarter  $t$  and has an estimated coefficient of  $\alpha$  in a first iteration, in a subsequent iteration the lagged dependent variable applying to quarter  $t$  is entered in the form  $p_t^y = p_t - \alpha z_t$ . This procedure essentially purges the inertia variable of the influence of special historical factors that agents are unlikely to extrapolate into the future.

TABLE 1  
 MEANS AND STANDARD DEVIATIONS OF KEY VARIABLES,  
 EIGHT SUBPERIODS BETWEEN 1891:2 AND 1980:4

	$\hat{y}$	$E\hat{y}$	$Uy$	$\hat{m}^a$	$E\hat{m}^a$	$Um^a$	$p$	$\hat{q}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Means								
1891:2-1908:3	.2	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .	.6	-.4
1908:4-1914:4	1.3	. . . . .	. . . . .	2.8	. . . . .	. . . . .	1.9	-.6
1915:1-1922:4	7.4	. . . . .	. . . . .	7.3	. . . . .	. . . . .	6.1	1.3
1923:1-1929:3	.5	. . . . .	. . . . .	.6	. . . . .	. . . . .	.1	.4
1929:4-1941:4	-1.0	. . . . .	. . . . .	-1	. . . . .	. . . . .	.0	-.9
1942:1-1953:4	5.6	. . . . .	. . . . .	5.5	. . . . .	. . . . .	4.8	.8
1954:1-1967:2	2.4	. . . . .	. . . . .	2.0	. . . . .	. . . . .	2.2	.2
1967:3-1980:4	5.9	. . . . .	. . . . .	5.6	. . . . .	. . . . .	6.4	-.5
1891:2-1980:4	2.7	. . . . .	. . . . .	3.4	. . . . .	. . . . .	2.7	.0
Standard Deviations								
1891:2-1908:3	21.6	12.8	17.4	. . . . .	. . . . .	. . . . .	6.0	21.6
1908:4-1914:4	8.3	7.4	3.8	2.9	2.6	1.2	4.3	6.4
1915:1-1922:4	21.4	17.8	11.7	10.1	9.3	3.8	15.4	14.4
1923:1-1929:3	9.9	8.5	4.9	4.1	3.4	2.2	3.7	9.0
1929:4-1941:4	24.1	19.0	15.0	12.3	10.5	6.4	7.8	19.4
1942:1-1953:4	11.6	9.3	6.9	8.5	7.6	3.8	8.1	11.4
1954:1-1967:2	3.9	2.9	2.7	2.6	2.1	1.5	2.0	3.8
1967:3-1980:4	3.9	2.5	3.0	3.5	3.0	1.8	2.2	4.0
1891:2-1980:4	15.8	11.8	10.6	7.8	6.9	3.5	7.3	13.8

NOTE.—All data are quarterly percentage changes at annual rates.

<sup>a</sup> The starting date for all statistics involving money is 1908:4.

1929:4, 1942:1, 1954:1, and 1967:3. The estimated coefficients themselves are not presented here, because they play no role in our subsequent analysis.

Table 1 displays for each subperiod 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. Several important facts stand out in the bottom half of the table. 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 standard deviation 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.

*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 for quarterly data for 1949–74 and monthly data for 1920–40. Using our first-stage nominal GNP and money equations estimated for overlapping sample periods, we can identify shifts in structure for the entire 1890–1980 period. As shown in table 2, 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.

The main difference with the Neftci-Sargent results here is the absence of a split in the money-supply process 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). Overall, it seems remarkable that the processes generating changes in nominal GNP and money have remained so stable for so long, at least according to the Neftci-Sargent criterion, in view of the numerous major changes in policy attitudes and financial institutions that have occurred over the past century. This

TABLE 2  
CHOW TESTS FOR CHANGES IN REGIME,  
EIGHT SUBPERIODS BETWEEN 1891:2 AND 1980:4

Date of Split	$y_t$	$m_t$
1908:4	$F(12,71) = .41$	. . .
1915:1	$F(17,23) = .54$	$F(17,23) = 3.03***$
1923:1	$F(17,25) = .63$	$F(17,25) = 2.76**$
1929:4	$F(17,42) = .72$	$F(17,42) = .56$
1942:1	$F(20,61) = 1.56^*$	$F(20,61) = .99$
1954:1	$F(19,64) = .75$	$F(19,64) = 1.27$
1967:3	$F(18,72) = 1.53^*$	$F(18,72) = 1.54^*$

SOURCE.—The formula for the  $F$ -ratio is from Maddala (1977, p. 198).

\* 10% significance.

\*\* 5% significance.

\*\*\* 1% significance.



suggests that the Sargent idea of studying the stability of output determination models across regime changes may have little payoff, simply because regime changes have been so few and far between.<sup>12</sup>

## V. The LSW and NRH-GAP Hypotheses as Explanations of Price and Output Behavior

### *The Response of Prices and Output to Nominal GNP Changes*

The paper's central results on price and output behavior may now be presented. Table 3 exhibits estimates of equation (9) for the rate of price change and of its dual, equation (10) 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.<sup>13</sup> 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 the NRH-GAP hypotheses regarding two sets of coefficients. The LSW proposition predicts that the coefficient on anticipated nominal GNP change (table 3, 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 in  $E\hat{y}_t$  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.

The results seem unambiguously to reject the LSW proposition and to confirm the NRH-GAP approach for all sample periods displayed in table 3. 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,

<sup>12</sup> An extensive discussion of the implications of regime changes for econometric practice is contained in Sims (1982). The difficulty of identifying the 1967 monetary regime change with contemporaneous data is illustrated in Gordon and King (1982).

<sup>13</sup> The choice of dates for the subperiods, which inevitably must be somewhat arbitrary, corresponds to the dates chosen in Gordon (1980) in order to facilitate comparisons between the two papers.

TABLE 3

REGRESSION EQUATIONS EXPLAINING QUARTERLY PRICE CHANGES AND THE OUTPUT RATIO, SELECTED INTERVALS, 1892:4-1980:4

	1892:4-1929:3		1929:4-1953:4		1954:1-1980:4		1892:4-1980:4	
	$p_t$	$\hat{Q}_t$	$p_t$	$\hat{Q}_t$	$p_t$	$\hat{Q}_t$	$p_t$	$\hat{Q}_t$
1. Constant	.82	-.82	.92***	-.92***	-.34	.34	.79***	-.79***
2. Lagged ratio ( $\hat{Q}_{t-1}$ )	.08***	.93***	.01	.99***	.06***	.94***	.01**	.99***
3. Expected nominal GNP change ( $E_t^e \hat{y}_t$ )	.09**	.91***	.12***	.88***	.09**	.91***	.11***	.88***
4. Unexpected nominal GNP change ( $U_t \hat{y}_t$ )	.09**	.91***	.17***	.83***	.25***	.75***	.12***	.88***
5. $E_t^e \hat{y}_t$ , 1915-22	.47***	-.47***					.35***	-.35***
6. $U_t \hat{y}_t$ , 1915-22	.25**	-.25***					.23***	-.23***
7. $\sum_{i=0}^{10} c_i p_{t-i}$	.40***	-.40***	.60***	-.60***			.49***	-.49***
8. $\sum_{i=0}^{20} c_i p_{t-i}$ , 1954-80	-9.02***	9.02***			1.06***	-1.06***	.25***	-.25***
9. World War I dummy							-9.52***	9.52***
10. NRA dummy			6.00***	-6.00***			5.94***	-5.94***
11. World War II dummy			-15.21***	15.21***			-15.22***	15.22***
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			.37	-.37	.54***	-.54***	.63**	-.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
Durbin $h$ statistic	-.30	-.30	-.01	-.01	.55	.55	...	...

NOTE.—Quarterly change variables expressed as annual percentage rates.

<sup>a</sup> Cannot be computed in this case.

\*\* 5% significance.

\*\*\* 1% significance.

1982) 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 subsample 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. 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 (Gordon 1981*b*) 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's distinction between aggregate and local information. Lines 9–14 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 5–8.

We can use the results in table 3 to recover the  $b_0$ ,  $b_1$ , and  $\sum a_i$  coefficients from the original NRH-GAP equation (7). 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	1929–53	1954–80	1892–1980
Current output ratio, $b_0$	.08	.01	.07	.01
Change in output ratio, $b_1$	.02	.12	.03	.11
Lagged inflation, $\sum a_i$	.44	.68	1.17	.83

While their sum is quite stable over the subperiods,  $b_0$  and  $b_1$  in the preceding table jump around substantially, with the “level effect” dominant in the first and third subperiods and the “rate-of-change effect” dominant in the second subperiod. This shift in coefficients is similar to, but more drastic than, that previously identified in annual data in Gordon (1980).

The increase over time in the sum of coefficients on lagged inflation

corresponds to the diagnosis of a growing role of inertia in the price-adjustment process. This may have 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 from the introduction of 3-year staggered wage contracts at about the same time. The main difference between my previous study of annual data (1980) and the present results for quarterly data is the greater extent of positive serial correlation evident here for the pre-1929 period; this short-lag inertia process is disguised when the data are aggregated to an annual basis, as in that earlier paper.

### *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, that is, 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 ( $Ev_t = E\hat{y}_t - E\hat{m}_t$ ;  $Uv_t = Uy_t - Um_t$ ). Table 4 presents the coefficients on  $E\hat{m}_t$  and  $Ev_t$  that result when each equation of table 3 is reestimated with nominal GNP change divided between changes in money and velocity (see lines 1*b* and 2*b*).

If only money mattered and velocity were truly a random variable, then the coefficients on velocity changes 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 coefficients are generally of the same order of magnitude in each equation, *F*-tests 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 1 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  $E\hat{m}_t$ . Since the NRH-GAP hypothesis implies that prices respond more to anticipated permanent than anticipated transitory demand shifts, the pattern of coefficients in table 4 seems consistent with that hypothesis.

Along these lines, it seems plausible to interpret the shrinking coefficients on  $E\hat{m}_t$  in columns 1, 2, and 3 of table 4 as reflecting a gradual reduction in the responsiveness of prices to anticipated per-

TABLE 4

ANALYSIS OF DIFFERENCES BETWEEN THE EFFECTS ON PRICES AND OUTPUT  
OF ANTICIPATED CHANGES IN NOMINAL GNP AND MONEY

	1908:4– 1929:3	1929:4– 1953:4	1954:1– 1980:4	1908:4– 1980:4
	(1)	(2)	(3)	(4)
1. Equations explaining $p_t$ , coefficient when included anticipated variable is:				
$E\hat{y}_t$ (table 3)	.28***	.12***	.09**	.18***
$E\hat{m}_t$	.57**	.26***	.12	.32***
$E v_t$	.24**	.10***	.07	.12***
$E\hat{m}_t$ alone	.57**	.21***	.13	.33***
2. Equations explaining $\hat{Q}_t$ , coefficient when included anticipated variable is:				
$E\hat{y}_t$ (table 3)	.72***	.88***	.91***	.82***
$E\hat{m}_t$	.44**	.74***	.88***	.68***
$E v_t$	.76***	.90***	.93***	.88***
$E\hat{m}_t$ alone	.22	.22	.43***	.56***
3. Equations explaining $v_t$ , coefficient on $E\hat{m}_t$	-.20	-.56**	-.44***	-.12

NOTE.—All regressions also include constant terms and the variables other than  $E\hat{y}_t$  listed in table 3.

\*\* 5% significance.

\*\*\* 1% significance.

manent demand disturbances. The relative constancy of the  $E\hat{y}_t$  coefficients in the price-change equations of table 4 reflects the influence of a growing share of the variance of  $E\hat{y}_t$  taking the form of permanent changes, offset against a shrinking responsiveness of price changes to those permanent demand shifts.

Despite the higher responsiveness of prices to  $E\hat{m}_t$  exhibited before 1954, every equation in table 4, line 2b, displays a significant positive response coefficient of the output ratio ( $\hat{Q}_t$ ) to anticipated monetary changes. An important flaw in previous work has been that the estimated coefficients of price and output response to anticipated changes in money have been estimated in equations omitting velocity changes. This approach inevitably confuses 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). The coefficients in table 4, lines 1c and 2c, show the responses of price change and the output ratio to anticipated monetary changes, when the equations are 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 4, which lists fitted coefficients on  $E\hat{m}_t$  in equations that regress the change in velocity on the same right-hand variables appearing in table 3 (with money changes substituted for nominal GNP changes). 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.<sup>14</sup> 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 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.

## 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 (1) above, where persistence effects are introduced by entering the lagged output variable. 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 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 ( $O_t$ ).

Our version of 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 ( $O_t - O_{t-1}$ ):

$$\hat{Q}_t = \alpha U y_t + \lambda(N_t^* - N_{t-1}) - \mu(O_t^* - O_{t-1}) + \epsilon_{1t}, \quad (12)$$

$$N_t - N_{t-1} = \theta(N_t^* - N_{t-1}) - \beta U y_t + \epsilon_{2t}, \quad (13)$$

$$O_t - O_{t-1} = \phi(O_t^* - O_{t-1}) + \gamma U y_t + \epsilon_{3t}. \quad (14)$$

<sup>14</sup> Note that the coefficient on line 2c, minus that on line 3, approximately equals the coefficient on line 2b, as is to be expected from the elementary econometric analysis of specification errors in the presence of a left-out variable—in this case  $v_t$ , which is omitted in line 2c.

Here (12) 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 ( $O_t^*$ ) over actual unfilled orders. Equations (13) and (14) 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, which reflects 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.<sup>15</sup> 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 (13) and (14) can be solved for the actual change in  $N$  and  $O$  and then substituted back into (12):

$$\hat{Q}_t = \left( \alpha + \frac{\lambda\beta}{\theta} + \frac{\mu\gamma}{\phi} \right) Uy_t + \frac{\lambda n_t}{\theta} - \frac{\mu o_t}{\phi} + \epsilon_{1t} - \frac{\lambda\epsilon_{2t}}{\theta} + \frac{\mu\epsilon_{3t}}{\phi}, \quad (15)$$

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

Equation (15) 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 (10), which makes no mention of inventories or unfilled orders, but which shares in common the demand-surprise variable. Equation (10) also includes several variables not in (15), 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 (10) 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 (9) is a dual to (10), so we can test a price-change equation that is identical to (9) when the  $n_t$  and  $o_t$  variables are added, with signs predicted to be, respectively, negative and positive.

<sup>15</sup> The steps required to replace  $Up_t$  by  $Uy_t$  are set out above in eqq. (3)–(5).

The results are reported in table 5. Columns 1 and 2 exhibit coefficients when the inventory and unfilled orders variables are added to (12) and when nominal GNP and money are used as alternative demand-shift variables. The results are almost identical to those reported in tables 3 and 4. The coefficients on the inventory and unfilled orders variables have the predicted signs, and that on inventory change ( $n_t$ ) is highly significant in column 1. In column 2 the inventory change and unfilled orders variables are not significant.

Columns 5 and 6 list the results for the equivalent equations explaining the output ratio. As in table 3, the identity relating equations (12) and (13) guarantees that the output-ratio equation using nominal GNP as the demand-shift variable will yield the same 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 4, 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 (15), 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 (9) and (10) but not in the Blinder-Fischer equation (15), supports the general approach taken in this paper. The significance of the inventory change variable in columns 1 and 5 of table 5 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 3.

### *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 3 and 4 with those obtained when persistence effects are incorporated by a method adopted in most previous studies. This third method involves the inclusion in the output equation of a long distributed lag of 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 Section III due to the obser-



TABLE 5  
REGRESSION EQUATIONS EXPLAINING QUARTERLY PRICE CHANGES AND THE OUTPUT RATIO, 1954:1-1980:4

	PRICE CHANGE			OUTPUT RATIO				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. $\dot{Q}_{t-1}$	.09***	.06**	. . .	.03	.91***	.76***	. . .	.96***
2. $\dot{E}y_t$	.14**	. . .	. . .	. . .	.86***	. . .	. . .	. . .
3. $\dot{E}m_t$	. . .	.11	.39***	.44***	. . .	.18	-1.44***	.26**
4. $\dot{U}y_t$	.28***	. . .	. . .	. . .	.72***	. . .	. . .	. . .
5. $U m_t$	. . .	.05	.05	.04	. . .	.07	.33	. . .
6. $\sum_{i=1}^{20} \omega_i U m_{t-i}$	. . .	. . .	.96	.69	. . .	. . .	9.08***	1.34
7. $\sum_{i=1}^{20} d_i p_{t-i}$	1.05***	1.08***	. . .	. . .	-1.05***	-.74***	. . .	. . .
8. $n_t$	-.88***	-.30	. . .	. . .	.88***	2.96***	. . .	. . .
9. $o_t$	.09	.17**	. . .	. . .	-.09	.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	.44***	.44***	1.34***	1.27***	-44***	-.08	1.45	-.50
$R^2$	.816	.748	.476	.485	.986	.986	.323	.903
SEE	1.34	1.57	2.23	2.23	1.34	2.87	9.18	3.50
D-W	. . .	. . .	1.21	1.24	. . .	. . .	.36	. . .
Durbin $h$ -statistic	.38	-.14	. . .	. . .	.38	-.14	. . .	.21

NOTE.—Quarterly change variables expressed at annual percentage rates. All regressions also include a constant term.  
\*\* 5% significance.  
\*\*\* 1% significance.

vational 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 5, 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 D-W statistic signals the presence of severe positive serial correlation, which, for reasons set forth by Flood and Garber (in press), 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 D-W statistic.<sup>16</sup>

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 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.

<sup>16</sup> Numerous detailed differences between column 7 and the basic Barro-Rush output equation (1980, table 2.1, col. 3) seem to make little difference in the fit of the equation and its severe problem of serial correlation. The Barro-Rush standard error, when multiplied by 4 to be comparable with our dependent variable, is 7.48 compared with 9.18; the D-W is 0.4 as compared with 0.36; and the sum of coefficients on the lagged money residuals is 11.50 compared with 9.08.

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 gradually in the short run and fully in the long run to nominal aggregate demand disturbances.

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 subperiods, find uniformly high coefficients of real output and low coefficients of price changes in response to anticipated nominal GNP changes. Further, in every subperiod 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.

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 (Gordon 1980, 1981*b*), 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 analysis 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. 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 canceled 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, which thus inhibits or completely precludes a statistical analysis of cause and effect.

## Appendix

### 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 Accounts revisions of December 1980. In addition to the series on natural real GNP, described below, 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. 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 Board 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 intrayear interpolation. The monthly series include the Index of Industrial Production, Retail Sales, the Consumer Price Index, and the Wholesale Price Index. The quarterly series for the period 1919–41 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). A preliminary analysis of the data set for 1890–1980 is contained in Gordon (1981*b*, pp. 500–502).

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 1919–41. He found that the interpolated series possess time- and frequency-domain characteristics that 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.

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 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.<sup>17</sup> After

<sup>17</sup> 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

1954 natural real GNP 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 1982, app. B). The conversion of the annual series to a quarterly series for this paper is performed by linear interpolation.

### *Details on Sources*

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*.—1907–58: Friedman and Schwartz (1963) M2 series, spliced to Federal Reserve “old” M2 series in 1947. 1959–80: Federal Reserve “new” M2 series, as revised January 1980.

*Interest rate*.—1890–1980: 4–6-month commercial paper rate, from Federal Reserve *Historical Statistics*.

*Inventory change*.—1947–80: in constant 1972 dollars, from National Income and Product Accounts, table 1.2.

*Unfilled orders*.—1947–80: manufacturers’ unfilled orders, durable-goods industries, *Business Conditions Digest*, series 98.

*Natural real GNP*.—1900–1953: Gordon (1981*a*, app. B); 1954–80: Gordon (1982, app. B).

*Actual real GNP*.—1890–1908, annual: U.S. Commerce Department, *Long-Run Economic Growth (LREG)*, series A1; 1909–28, annual: *LREG*, series A2; 1929–46, annual, and 1947–80, quarterly: National Income and Product Accounts, table 1.2; incorporates 1981 revisions. Quarterly interpolations based on method of Chow and Lin (1971). Interpolators: 1890–1918: Index of Industrial Production. 1919–46: Index of Industrial Production and Retail Sales Deflated by the CPI.

*GNP deflator*.—1890–1908, annual: *LREG*, series A7 divided by series A1; 1909–28, annual: *LREG*, series A8 divided by series A2; 1929–46, annual, and 1947–80, quarterly: National Income and Product Accounts, table 7.1; incorporates 1981 revisions. Quarterly interpolations based on method of Chow and Lin (1971). Interpolators: 1890–1918: WPI for farm products; WPI for nonfarm products; 1919–46: WPI and CPI.

*Nominal GNP*.—1890–1946, quarterly: Real GNP times the GNP deflator. 1947–80, quarterly: National Income and Product Accounts, table 1.1.

### References

- Barro, Robert J. “Unanticipated Money Growth and Unemployment in the United States.” *A.E.R.* 67 (March 1977): 101–15.
- . “Unanticipated Money, Output, and the Price Level in the United States.” *J.P.E.* 86, no. 4 (August 1978): 549–80.
- Barro, Robert J., and Rush, Mark. “Unanticipated Money and Economic

---

importance of farmers and self-employed proprietors and for differences among the adjusted unemployment rates observed in benchmark years (see Gordon 1981*a*, app. C, pp. xxii–xxiii).

- Activity." In *Rational Expectations and Economic Policy*, edited by Stanley Fischer. Chicago: Univ. Chicago Press (for Nat. Bur. Econ. Res.), 1980.
- Blinder, Alan S., and Fischer, Stanley. "Inventories, Rational Expectations, and the Business Cycle." *J. Monetary Econ.* 8 (November 1981): 277-304.
- Chow, Gregory C., and Lin, An-loh. "Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series." *Rev. Econ. and Statis.* 53 (November 1971): 372-75.
- Flood, Robert P., and Garber, Peter M. "A Pitfall in Estimation of Models with Rational Expectations." *J. Monetary Econ.* (in press).
- Friedman, Milton. "The Role of Monetary Policy." *A.E.R.* 58 (March 1968): 1-17.
- Friedman, Milton, and Schwartz, Anna. *A Monetary History of the United States, 1867-1960*. Princeton, N.J.: Princeton Univ. Press (for Nat. Bur. Econ. Res.), 1963.
- Frye, Jon, and Gordon, Robert J. "Government Intervention in the Inflation Process: The Econometrics of 'Self-Inflicted Wounds.'" *A.E.R. Papers and Proc.* 71 (May 1981): 288-94.
- Gordon, Robert J. "A Consistent Characterization of a Near-Century of Price Behavior." *A.E.R. Papers and Proc.* 70 (May 1980): 243-49.
- . *Macroeconomics*. 2d ed. Boston: Little, Brown, 1981. (a)
- . "Output Fluctuations and Gradual Price Adjustment." *J. Econ. Literature* 19 (June 1981): 493-530. (b)
- . "Inflation, Flexible Exchange Rates, and the Natural Rate of Unemployment." In *Workers, Jobs, and Inflation*, edited by Martin N. Baily. Washington: Brookings Inst., 1982.
- Gordon, Robert J., and King, Stephen R. "The Output Cost of Disinflation in Traditional and Vector Autoregressive Models." *Brookings Papers Econ. Activity*, no. 1 (1982), pp. 205-42.
- Gordon, Robert J., and Wilcox, James A. "Monetarist Interpretations of the Great Depression: Evaluation and Critique." In *The Great Depression Revisited*, edited by Karl Brunner. The Hague: Nijhoff, 1981.
- Leiderman, Leonardo. "Macroeconometric Testing of the Rational Expectations and Structural Neutrality Hypotheses for the United States." *J. Monetary Econ.* 6 (January 1980): 69-82.
- Lucas, Robert E., Jr. "Some International Evidence on Output-Inflation Tradeoffs." *A.E.R.* 63 (June 1973): 326-34.
- McCallum, Bennett T. "On the Observational Inequivalence of Classical and Keynesian Models." *J.P.E.* 87, no. 2 (April 1979): 395-402. (a)
- . "Topics Concerning the Formulation, Estimation, and Use of Macroeconomic Models with Rational Expectations." In *Proceedings of the Business and Economics Statistics Section, American Statistical Association*. Washington: American Statis. Assoc., 1979. (b)
- . "Rational Expectations and Macroeconomic Stabilization Policy: An Overview." *J. Money, Credit and Banking* 12, no. 4, pt. 2 (November 1980): 716-46.
- Maddala, G. S. *Econometrics*. New York: McGraw-Hill, 1977.
- Makin, John H. "Anticipated Money, Inflation Uncertainty, and Real Economic Activity." Working paper. Seattle: Univ. Washington, 1981.
- Mishkin, Frederic S. "Does Anticipated Monetary Policy Matter? An Econometric Investigation." *J.P.E.* 90, no. 1 (February 1982): 22-51.
- Neftci, Salih, and Sargent, Thomas J. "A Little Bit of Evidence on the Natural Rate Hypothesis from the U.S." *J. Monetary Econ.* 4 (April 1978): 315-19.
- Sargent, Thomas J. "The Observational Equivalence of Natural and Un-

- natural Rate Theories of Macroeconomics." *J.P.E.* 84, no. 3 (June 1976): 631-40.
- Sargent, Thomas J., and Wallace, Neil. " 'Rational' Expectations, the Optimal Monetary Instrument, and the Optimal Money Supply Rule." *J.P.E.* 83, no. 2 (April 1975): 241-54.
- Sheffrin, Steven M. "Unanticipated Money Growth and Output Fluctuations." *Econ. Inquiry* 17 (January 1979): 1-13.
- Sims, Christopher A. "Policy Analysis with Econometric Models." *Brookings Papers Econ. Activity*, no. 1 (1982), pp. 107-52.
- Small, David H. "Unanticipated Money Growth and Unemployment in the United States: Comment." *A.E.R.* 69 (December 1979): 996-1003.
- Taussig, Frank W. "Price-Fixing as Seen by a Price-Fixer." *Q.J.E.* 33 (February 1919): 205-41.
- Tobin, James. "Are New Classical Models Plausible Enough to Guide Policy?" *J. Money, Credit and Banking* 12, no. 4, pt. 2 (November 1980): 788-99.
- Wilcox, James A. "The Character of Temporally Disaggregated Time Series Derived from Related Series." Working paper. Berkeley: Univ. California, July 1980.