Price Flexibility and Output «Persistence» in the Postwar U.S.

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by

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A great deal of evidence for the U.S. economy suggests that after changes in aggregate nominal demand (1) prices move "sluggishly" toward their eventual long-term values, that (2) output responds directly to these changes in demand, and (3) these output effects linger "persistently" over time. Most econometric evidence suggests that something of the order of four to six years must pass before the ultimate effects on prices and output will be reached. As commonly interpreted, this lag has profoundly disturbing implications about the functioning of markets and about the rate of agents' expectations in macro-economics.

The conventional interpretation of the output-price adjustment lag-- to borrow the label suggested recently by R.J. Gordon (1982) -- comes under the "Natural Rate Hypothesis and Gradual Adjustment of Prices" (NRH-GAP) approach. After a change in nominal demand, according to NRH-GAP, some combination of forecast inefficiency and institutional constraints on price setting prevents agents for a time from choosing the set of prices that would clear output markets at the "natural" level. In the meantime and because of this price stickiness aggregate output exhibits persistent deviations from its natural path.

The troubling aspect of this NRH-GAP explanation of output persistance and price sluggishness is the <u>length</u> of adjustment lags it is called upon to explain. It is difficult, for instance, to attribute four-to six-year adjustment lags to delays in the availability of information and at the some time incorporate in one's theory the notion of rational (or "just reasonable") agents. The literature has been focusing in recent years on constraints leading to price-stickiness. One strand of this literature makes these constraints external. Stickiness is introduced by means of institutional factors like contracts (e.q., Fischer (1977), Phelps and Taylor (1977), and Taylor (1979)). Another strand has been developing the consequences of decentralized (microeconomic) price setting, attempting to make price-stickiness a system-endogenous phenomenon.[1)] Each strand has suffered criticism, accentuated by the apparently high degree of price-stickiness that the theory is required to rationalize[2)]. Even if we accept these theories unhesstitatingly the long length if the adjustment lags still poses a disturbing question : what is the operational relevance of theories like rational expectations for short-term policy if agents succeed in changing prices no more than say 10 % of the "desired" adjustment per quarter ?

There is another explanation for the output-price lag, involving another sort of adjustment problem and which potentially circumvents these disagreeable implications of the NRH-GAP approach. I shall refer to the mechanism in this paper generally as "supply-side persistence ," although these are really two distinct processes. In one process, producers react to changes in demand by making commitments to new levels of productive stocks. These stock levels will in general be different from "natural," cannot be adjusted immediately, and for the time that they are different from natural the market-clearing level of output will also be different from natural. In a second process, sellers draw down (up) inventory levels when demand changes but can (or will) only restore inventory stocks gradually. For the time that these processes keep the market-clearing output away from the natural level, they will also keep the equilibrium price away from its longer-term value. Thus, all on part of what seems to be price-"stickiness" may in fact be an illusion brought about by a temporarily-"shifting" supply curve.

To date, supply-side persistence has made its appearance almost exclusively at the theoretical level and in models of the Lucas-Sargent-Wallace, rational expectations - "structural neutrality" type.[3)] These authors assume perfect price-adjustments to rational agents' forecasts, making supply-side persistence the only source of the output-price lag. There is however no reason a priori to restrict supply-side persistence to models involving neutrality or even rational expectations.

In this paper I propose and estimate a model of output and price adjustment which explicitly parameterizes both supply-side persistence and NRH-GAP price-stickness. The model is designed to incorporate general patterns of both phenomena and to reveal their relative importance. The rational expectations-neutrality and NRH-GAP approaches appear as limiting cases. The model is very similar in principle to the one employed recently by Gordon (1982). However, Gordon's empirical application of the model and resulting estimates appear to support NRH-GAP to the extreme and could hardly be different from the results of this paper (a matter to be reviewed in Section V).

In particular, the estimates of the model turn out to be consistent with the "perfect" short-run (in this case, one-quarter) price-flexibility requirement of the Lucas-Sargent-Wallace neutrality hypothesis and therefore also with the proposition that output persistence-price sluggishness is fully accounted for by supply-side persistence. Some less dramatic results concerning price flexibility are obtained if one loosens assumptions about the nature of the model that is being estimated, but even these indicate that supply-side persistence is the dominant reason for the long-lived nature of the output-price adjustment. Conservative interpretation of the evidence presented here suggests that (1) expectational elements (including possibly rational expectations) maintain an important role in influencing short-run macroeconomic adjustments, and that (2) NRH-GAP's role in creating output-persistence is either much less than commonly supposed or irrelevant.

The sections are arranged as follows. In Section I, I set forth the price-adjustment model having no price-stickiness features or supply-side persistence affects. In Section II, I introduce price stickiness. The model is expanded further in Section III to allow for supply-side persistence. At this stage, the NRH-GAP and supply-side persistence parameters are identified, and I show the equations to be estimated. In Section IV I discuss parameter estimation, illustrate the results, and point out the implications. Section V includes a discussion of the Gordon estimates in which I demonstrate that estimation problems severely biased his estimates into the direction of NRH-GAP support. Corrected estimates agree with the conclusions stated in the last paragraph. Finally, I summarize in Section IV.

I. Output-Price Adjustment With Flexible Prices

I begin with a simple output equation of the Lucas (1973) type in which the discrepancy between current output, y^* (lower case denotes logs, "*" denotes a real value), and the "natural" equilibrium output, y_n^*, can be expressed as a function of the difference between the level of "anticipated" prices, $\hat{p}_t$, and their actual level :

$$(1) \qquad y_t^* = y_{n,t}^* + \alpha(p_t - \hat{p}_t) + e_{s,t}$$

where α is the "unanticipated-price elasticity" of aggregate supply and $e_{s,t}$ is a random error term. Alternatively, output deviations from natural can be expressed as a function of the forecast error in nominal demand $(y_t - \hat{y}_t)$. That is, since

$$(2) \qquad y_t - \hat{y}_t \equiv p_t - \hat{p}_t + y_t^* - y_{n,t}^* ,$$

(1) can be written

$$(3) \qquad y_t^* = y_{n,t}^* + \frac{\alpha}{1+\alpha} \ (y_t - \hat{y}_t) + \frac{e_{s,t}}{1+\alpha} \ .$$

Note also that (by identity)

$$(4) \qquad p_t = \hat{y}_t - y_{n,t}^* + \frac{1}{1+\alpha} (y_t - \hat{y}_t) - \frac{e_{s,t}}{1+\alpha} \ .$$

Changes in anticipated nominal demand $(\hat{y}_t)$ will not affect output (3) but will affect the price level and by equi-proportionate amounts (4). Unanticipated demand, represented in (3) and (4) by the log-difference $(y_t - \hat{y}_t)$, will have a less-then-proportionate effect on prices (4) and effects of the same sign on output (3).

In Luca's formulation the"^'$_d$" values represent rational forecasts - that is, forecasts made in t-1 and with all information that could have been known then, including serial correlation patterns in the factors determining y and in the error from $e_{s,t}$. It follows that in the Lucas formulation only serially-uncorrelated "news" is capable of producing the discrepancy $y_t - \hat{y}_t$, which is the only demand-side determinant of output. Among the various sources of information affecting agents' calculation of $\hat{y}$, systematic demand manipulation undertaken by authorities will be taken account of and therefore neutralized by price adjustments. Finally, while $y_t - \hat{y}_t$ will create output effects, these effects will not persist beyond the current period. Knowledge of $y_t - \hat{y}_t$ will be made by agents in making forecasts of the next period's demand level.

(1), (2) and (4) can be interpreted less strictly then in Lucas's framework by assuming that the "^'s" refer to "just reasonable" forecasts of their associated variables rather than rational forecasts. Learning lags and/or costs of information may make agents' forecasts less responsive to recent data than in the Lucas formulation. Such forecasts should be restricted to the class in which the variables forecasted would eventually approach steady-state values. An approach in point is the "adaptive expectations" one in which forecasts evolve as weighted averages of prior values of the variables in question.

Unlike the rational-forecast interpretation of the "^'s," the just-reasonable forecast interpretation implies that output can be effected by nominal demand that might have been forecasted (if forecasts had been more efficient). Moreover, the output response to demand change can be persistant and price response sluggish. The sluggishness of prices in this context is not due to constraints on their adjustment but to misperceptions on the part of agents as to their equilibrium values.

II. Constraints on Price Flexibility

The other NRH-GAP factor potentially responsible for output-price lags is not delay in information itself but institutional features of markets that prevent agents from acting quickly on their forecasts. The simplest scheme to impose (at least of the class that is faithful to the NRH-GAP notion of eventual natural-output equilibrium) is one in which agents manage to change the price level a constant fraction, λ, of the gap between the new market-clearing price level (p_t^c) and the price level that existed in the previous period :

$$(6) \qquad p_t - p_{t-1} = \lambda(p_t^c - p_{t-1}), \text{ where } 0 < \lambda < 1.$$

The clearing price, p_t^c, is the price that would clear markets given agents' expectations of prices where price adjustments not impeded - i.e., the price level p_t described in (4). Substituting that solution for prices into (6) for p_t^c, we have

$$(7) \qquad p_t - p_{t-1} = \lambda(\hat{y}_t - y^*_{n,t} - p_{t-1}) + \frac{\lambda}{1+\alpha}(y_t - \hat{y}_t) - \frac{\lambda e_{s,t}}{1+\alpha}.$$

From the identity that $p_t \equiv y_t - y_t^*$ and breaking y_t into its parts, $\hat{y}_t$ and $(y_t - \hat{y}_t)$, note that

$$(8) \qquad y_t^* - y^*_{n,t} = (1-\lambda)\ (\hat{y}_t - \hat{y}_{t-1} - g) + (1-\lambda)\ (y^*_{t-1} - y^*_{n,t-1})$$

$$+ \{\frac{1+\alpha-\lambda}{1+\alpha}\}\ (y_t - \hat{y}_t) - (1-\lambda)\ (y_{t-1} - \hat{y}_{t-1}) + \frac{\lambda}{1+\alpha} e_{s,t}$$

where g is the growth rate of natural output. Equation (7), and more explicitly equation (8), suggest that when price adjustment is constrained (i.e, $0 < \lambda < 1$) the gap between current and natural output will depend upon current and lagged values of both $\hat{y}_t$ and $(y_t - \hat{y}_t)$. Demand-induced output persistance can be fully accounted for by $(1-\lambda)$ and would have to be so if forecasts were rational. $(1-\lambda)$ will be just a contributing factor if expectations are not rational. For later reference note that, however expectations are formed, the coefficient on $\hat{Y}_t$ in (7) should be larger then that of $(y - \hat{y}_t)$ (so long as $\alpha > 0$), and the opposite should hold in (8).

The price-adjustment mechanism proposed in (6) has expositional advantages and is relatively easy to estimate, but it has an analytical shortcoming of potential importance. It constrains the current price such to be a geometrically-decaying, weighted-average of past market-clearing prices (i.e., of the form $p_t = \lambda\, p_t^c + (1 - \lambda)\, \lambda\, p_{t-1}^c + (1 - \lambda)^2\, \lambda\, p_{t-2}^c + \ldots$). This has the unacceptable (to NRH-GAP) theorists) implication that changes in the rate of growth of y will produce permanent deviations of output from the natural level. The problem is that if for example the growth of y increased, and prices did not increase proportionately and instantly, then it would be necessary for the growth rate of prices to increase temporarily by an amount exceeding the increase in y-growth. This is necessary in order for the price level to rise high enough to eliminate the output gap, but this movement is not permitted by (6).[4)]

The more general specification is

$$p_t = \sum_{i=0}^{\infty} a_i\, p_{t-i}^c \;. \tag{9}$$

The NRH-GAP long-run, natural output condition requires that $\sum_{i=0}^{\infty} = 1$, but in this case the early a's are free to sum to a value greater than unity to reflect temporary "overshooting" of prices. Like (7) and (8), the adjustment in (9) implied that prices and output are distributed-lag functions of both $\hat{y}_t$ and $(y_t - \hat{y}_t)$ (provided that $a_0 < 1$) but with a more general distributed form than that implied by (7) and (8). The implications regarding the effects of changes in $\hat{y}_t$ and $(y_t - \hat{y}_t)$ are similar to those of (7) and (8). If expectations are rational, $a_0 < 1$ is a necessary condition for demand-induced output persistance. If expectations are not rational, $a_0 < 1$ will contribute to output persistance. Whatever the a_i-pattern and manner of expectations formation, the coefficients on $(y - \hat{y})$'s will be greater then those of the $\hat{y}$'s for output and the opposite will hold for prices.

III. Supply-Side Persistence and Its Identification

The previous section placed the NRH-GAP approach into parameter form. In this section I add parameters which identify a supply-side persistance process, the rationale for which is based on a third set of adjustment lags. One of these centers on agents' adjustments of productive stocks like fixed capital, the other has to do with sellers' inventory adjustments.

The argument in the case of productive stocks is that demand change induces producers to invest "too little" or "too much" in durable stocks relative to these stocks' natural equilibrium values. In part these investment decisions represent "mistakes" and are due to imperfect information. (A model of this type appears in Lucas (1975)). In general, however, producers may hold "excess" stocks deliberately and correctly so long as they have forecasts that output will for a significant time be greater than natural.[5] The inventory-adjustment mechanism is different that the current stock change in at least in part a passive response to demand change. The lag is in producers' subsequent reestablishment of desired stock levels, adjustments which in turn require output level changes. (A model of this type appears in Blinder and Fisher (1981)). Those postulating the existence of these supply-side effects have done so in the context of rational expectations-neutrality models, but as noted in the introduction there is no reason *a priori* to restrict the process to models which do not include NRH-GAP features.

The productive stock and inventory adjustment mechanisms both imply the existence of lagged adjustment of short-period equilibrium output independent of demand. A general way to represent this equilibrium output is as the natural level itself plus a distributed lag on past deviations from natural : $y^*_{n,t} + \sum_{i=1}^{\infty} \theta_{t-i} (y^*_{t-i} - y^*_{n,t-i})$. For theoretical frameworks employing natural output equilibrium we would expect the process to be damped, though the productive stock mechanism suggests a possibility of temporary, accelerator-like build-ups of the output "gap" in absolute terms.

When $y^*_{n,t} + \sum_{i=1}^{\infty} \theta_{t-i} (y^*_{t-i} - y^*_{n,t-i})$ is substituted for $y^*_{n,t}$ in (7) and in the less-restricted counterpart (9), we have

$$(10) \qquad p_t - p_{t-1} = \lambda(\hat{y}_t - y^*_{n,t} - p_{t-1}) + \frac{\lambda}{1+\alpha}(y_t - \hat{y}_t) - \lambda\{\sum_{i=1} \theta_{t-i}(y^*_{t-i} - y^*_{n,t-i})\} - \frac{e_{s,t}}{1+\alpha}$$

or

$$(11) \qquad p_t = \sum_{i=0} a_i(\hat{y}_{t-i} - y^*_{n,t-i}) - \sum_{i=0} a_i \sum_{i=1} \theta_{t-i}(y^*_{t-i} - y^*_{n,t-i}) + \sum_{i=0} a_i(\frac{1}{1+\alpha})(y_t - \hat{y}_t) - \frac{e_{s,t}}{1+\alpha}$$

Estimates of λ (or the a_i's) and the θ_{t-i}'s offer. the means of assessing the relative importance of NRH-GAP and supply-side persistence The θ_{t-i}'s times their respective $(y^*_{t-i} - y^*_{n,t-i})$ - terms indicate those levels of output that would have prevailed in the hypothetical absence of current restraints on price flexibility on information problems. Put in textbook language, they indicate the current position of the short-run, "vertical" aggregate supply curve. Given the discrepancies between these short-term hypothetical levels of output and nominal demand, λ (or the a_i's) measure(s) the rate(s) at which prices will move to clear markets. Failure of prices to move instantly (λ or $a_0 < 1$) will create components of output discrepancy from natural that will exist in addition to those produced by the θ_{t-i}'s. The limiting cases are of course $\{\theta_{t-i}\text{'s} = 0,\ a_0 \text{ or } \lambda < 1\}$ for pure NRH-GAP (and where "^" may refer to less-than-optimal forecasts) and $\{a_0 \text{ or } \lambda = 1,\ \theta_{t-i} \neq 0\}$ for the price Lucas-Sargent-Wallace case (and where "^" refers exclusively to rational forecasts).

IV. Estimation

A conceptual problem to be faced in estimating (10) and (11) is how to represent agents' forecasts of nominal demand, $\hat{y}_t$. For theories which employ rational expectations, $\hat{y}_t$ is reasonably well defined and in principle its generation can be simulated retrospectively. Under NRH-GAP, however, agents' forecasting mechanism is not defined and may even be highly inefficient. For went of a better procedure, I shall assume that equations (10) and (11) where $\hat{y}_t$ is defined as the rational forecast can be used to represent all Lucas-Sargent-Wallace and NRH-GAP models including the forecast-inefficient versions of NRH-GAP. This means that in general λ (or the a_i's) measures the effects, if any, of some (unspecified) combination of forecast inefficiencies and price strickiness.[6)]

I shall assume that the rational forecast $\hat{y}_t$ can be adequately represented by a least squares regression on past economic data. y is defined as the log of nominal G.N.P. and it is "forecast" with an equation having seven lagged y's, seven lagged (log) M1's, and a time trend dummy y_n^*, the natural (log) real income level is the estimated trend value. Other data, in logs, include p : the G.N.P. deflator ; and y^* : real G.N.P. The estimating period is 1955 : QI through 1979 : QIV.

Placing $\hat{y}$ from a forecast equation in the price adjustment equations (10) and (11) involves cross-equation restrictions, and there other reasons to expect the $\hat{y}$-equation and corresponding price equation from the same sample to be related. This requires joint estimation of each price equation and its corresponding y-forecast equation with a procedure that takes the cross-equation effects into account. I have used FIML (Full Information Maximum Likelihood) for the results of this section. Results from a two-step OLS procedure by which one first estimates of the y-equation, and subsequently employs the $\hat{y}$'s in an OLS price equation for prices, turn out to have some substantial differences. I reserve those estimates for the comparison in Section V of my results and those of Gordon (1982), who used the two-step approach.

I imposed two other constraints, one for computational convenience and one that is required by the model. For convenience, I restricted the number of θ_{t-i}'s to two. Estimates of (10) using the OLS, two-stop procedure indicated that θ_{t-i}'s beyond two had small and insignificant coefficients. Further, the $\hat{\theta}_{t-1}$ and $\hat{\theta}_{t-2}$ estimates appeared to be insensitive to whether

OLS or FIML was used. Limiting the number of θ_{t-i}'s reduced considerably the complications involved in the second set of restrictions. The form of (11) requires non-linear restrictions among the a_i's, θ_{t-i}'s and $\frac{1}{1+\alpha}$[7]. Table 1 presents the resulting FIML estimates of (10) and (11).

The Results I : The NRH-GAP Effect

At least with respect to the issue of price-flexibility, the results illustrated in Table 1 are one-sided in their support of the Lucas-Sargent-Wallace approach and against NRH-GAP. For both estimates (10) and (11) the first-quarter adjustment of prices to $\hat{y}$ is close to the "perfect" unity value. The value of $\hat{\lambda}$ in estimate (10) is 1.14 - a value slighty but less than one standard error (.21) from 1.0. The $\hat{a}_0$ - value in (11) is also close to 1.0 (estimate = .988, standard error = .16) and a_1 and a_2 are not significantly different from zero at the .05 level. Since the first-quarter price adjustment coefficients (λ, a_0) are so close to unity, there is little substantive difference between the specifications of (10) and (11) and the "overshooting" of prices issue is moot.

An implication of both Lucas-Sargent-Wallace and NRH-GAP is that the coefficient on the forecast error $y - \hat{y}_t$ be smaller than that of $\hat{y}_t$. This condition is met at the .01 level in both (10) and (11). This evidence does not help distinguish one approach from the other, but it at least supports the general class of models and the specification of (10) and (11).

The Results II : Supply-Side-Persistance

To the extent that output persistance-price sluggishness exists, therefore, it must be accounted for by supply-side adjustment lags. The estimates of the identifying parameters $(\hat{\theta}_{t-1}, \hat{\theta}_{t-2})$ as obtained in (10) and (11) are quite close :

	Estimate (10)	Estimate (11)
$\hat{\theta}_{t-1}$	1.31	1.29
	(s.e. = .07)	(s.e. = .12)
$\hat{\theta}_{t-2}$	-.36	-.35
	(s.e. = .08)	(s.e. = .13)

I have not identified the particular mechanism behind this lag, but there are two particularly interesting features of these estimates. First, the adjustment pattern is, as expected, a long one. As illustrated in Chart 1, the "half-life" of a given hypothetical output deviation from natural is fourteen quarters. Second, the combination of parameters produces a kind of damped accelerator having a temporily cumulations buildup of $y^{*} - y_{n}^{*}$ is the first year. This is more suggestive of a mechanism involving fixed productive stocks than an inventory mechanism.[8)]

V. The Gordon Estimates

In his recent paper on price adjustments Gordon (1982) estimates equations for subperiods ranging over 1890 through 1980 that are similar in principle to (10) and (11). The implications of the estimates, however, could hardly be different (and still belong to the class of natural equilibrium models). For each of his subperiods -- including one for 1954 : QI through 1980:QIV which is close to the 1955:QI through 1979:QIV sample used for Table 1 -- the first-quarter impact of Gordon's $\hat{y}$-variable falls far short of unity and the subsequent adjustments appear to be spread over a several years. In the 1955-1980 estimate the impact coefficient is only .06 and final effects on prices are not complete until after twenty quarters.[8a)] The Gordon results support the NRH-GAP explanation of output persistence-price sluggishness to a polar extreme. What is the difference between Gordon's and this paper's models or estimation procedures that produces such a drastic difference in results ?

In this section I show that there are no substantive differences in the basic models, but that (1) Gordon imposes hard-to-justify restrictions on the functional form of his NRH-GAP price-adjustment mechanism, and that (2) his method of estimation involves possible estimation bias due to the presence of lagged dependent variables. When the Gordon formulation is relieved of problems (1) and (2) and re-estimated (in effect, making the model a close variant of my (11)), the price adjustment parameters increase from his original low values to high (but imperfect) values. A final statistical issue to be considered in this section is over the issue of the two-steps, OLS procedure used by Gordon or the cross-equation procedure I used for Section IV. It is apparently the use of the latter that moves the price adjustment parameters from high to the "perfect" values exhibited in Table 1.

Gordon's adjustment mechanisms (1982, p.1092) is (notation changed wherever necessary to be consistent with this paper's) :

$$(G.1) \qquad p_t - p_{t-1} = a(L)\,(p_{t-1} - p_{t-2}) + b_o(y^*_t - y^*_{n,t}) + b_1\,\Delta(y^*_t - y^*_{n,t}) + b_2 z_t + e_t ,$$

where z_t is a vector of supply-"shocks" (phenomena such as the "Nixon" price controls), a(L) is a polynominal in the lag operator which Gordon says is designed to account for the influences of "inherited price change;" and e_t is the error term. b_0 and b_1 are expected to be positive.

Gordon then uses the identity that

$$\text{(G.2)} \qquad y_t - y_{t-1} \equiv p_t - p_{t-1} + y^*_t - y^*_{n,t-1} - y^*_{t-1} + y^*_{n,t-1} + g,$$

where g is the trend rate of natural output growth, in order to write (G.1) as :

$$\text{(G.3)} \qquad p_t - p_{t-1} = \frac{1}{1 + b_0 + b_1} \{a(L)\ (p_{t-1} - p_{t-2}) + (b_0 + b_1)\ (\hat{y}_t - y_{t-1} - g) + b_0(y^*_{t-1} - y^*_{n,t-1}) + b_2 z_t + e_t\}.$$

As an allowance for rational expectations, $y_t - y_{t-1}$ is divided into anticipated $(\hat{y}_t - y_{t-1})$ and unanticipated $(y_t - \hat{y}_t)$ parts so that the estimated equation takes the form (1982, p.1093) :

$$\text{(G.4)} \qquad p_t - p_{t-1} = c(L)\ (p_{t-1} - p_{t-2}) + d_0(\hat{y}_t - y_{t-1} - g) + d_1(y_t - \hat{y}_t) + d_2(y^*_{t-1} - y^*_{n,t-1}) + d_3 z_t + \mu_t\ ,$$

where d_0, $d_2 > 0$.

Now (G.4) is not an implausible price-adjustment mechanism. If the lagged $(p_t - p_{t-1})$'s are eliminated by substitution (G.4) implies, like (10) and (11), a distributed lag on the other explanatory variables. This distributed lag however imposes a restriction that the coefficients at each lag be in the same ratio to each other. If the true coefficient distributions on demand variables and lagged output $(y^* - y^*_n)$ terms have distinctive shapes (as implied by estimates (10) and (11)) this could not be revealed by an estimate of (G.4). A second problem arises not from the form of (G.4) but from Gordon's direct estimate of it in a form having lagged dependent variables. In general, coefficients of equations in which lagged dependent variables are present will be biased.[9]

Whatever the relative and combined importance of these estimation problems, the means to avoid both is to estimate the same model without the offending constraints and in direct, reduced-form. In Table 2, I present re-estimates of the Gordon formulation for 1954-1979.[10] The first estimate (G.4.1) essentially reproduces the Gordon result of low demand impacts and long adjustment lags. The second (G.4.2) is a direct, reduced-form version estimated on the same data.[11] The coefficients in (G.4.2) on the current $(\hat{y}_t - y_{t-1} - g)$ and lagged demand variables sum to .93 (standard error = .08), indicating imperfect but considerably faster price adjustment than suggested by Gordon's estimates and by my re-estimate (G.4.1).

The overall implications of the reduced-form (G.4.2) are similar to those I obtained when estimating (10) and (11) using the two-step, OLS procedure rather than FIML. An estimate of equation (11) is shown in Table 2 with the label (11.a). (11.a) was corrected for serial correlation with a constraint that required the error term to follow a second-order process.[12]

The similarity between the revised-Gordon (G.4.2) and my own two-step - OLS estimate (11.a), as well as the difference these estimates have in common with Table 1's, raises a more difficult question of judgment. If we assume (10) or (11) together with its associated y-forecast equation represents "the" correct model, then a cross-equation procedure like FIML is clearly required. In consequence, the results favoring Lucas-Sargent-Wallace implications which appear in Table 1 are the preferred ones. On the other hand, if we view the estimated system as an approximation in which misspecification is likely[13] the OLS reduced-form results in Table 2 should be retained on the ground that they may be more robust to specification error. Whichever result one wishes to emphasize, it should be clear that the issue is over "relatively" rapid vs. "perfect" price adjustment and not over these and the extraordinarily slow price adjustment implied by Gordon's original estimates.

VI. Summary and Conclusions

There is little doubt that nominal demand changes often produce long-lasting effects on output and that prices often adjust sluggishly to changes in demand. The disagreement is over the cause(s) of this joint phenomenon. The conventional NRH-GAP approach attributes these lags to informational inefficiencies and/or institutional constraints on price adjustments. The length of observed output-price adjustment lags, under the NRH-GAP interpretation, raises awkward questions about the functioning of the price system and the relevance of agents' expectations in affecting short-term economic activity.

A competing explanation of the output-price adjustment lag - I have called it "supply-side persistence" - involves lags in the adjustment of productive stocks rather than in expectations or price-setting. This approach is capable in theory of explaining part or all of the observed output-price adjustment lags and can do so even if there is high or "perfect" degrees of expectations-rationality and price-flexibility.

The empirical results of this paper suggest that the importance of NRH-GAP is explaining output persistence and price sluggishness ranges between "very little" and "none." Implicitly, and according to my estimates, the supply-side mechanism is predominantly to totally responsible for the output-price lag. The "perfect" price-flexibility results, obtained with the FIML procedure, turn out to be in accord with the Lucas-Sargent-Wallace neutrality hypothesis. I have also retained and reported some less dramatic results obtained with a two-step, OLS procedure. The most conservative interpretation of the evidence is that prices are at least reasonably flexible and that supply-side persistence is powerful and long-lasting.

If the results are correct, they may reduce the pressure that is currently being placed on theories of contracts and other forms of macroeconomic disequilibrium theories to produce a convincing NRH-GAP explanation for price stickiness. At the same time, these results point to the need to expand our knowledge of supply-side persistence.

Table 1

Price Equation Estimates

1955 : QI through 1979 : QIV

Equation (10)

Dep. Var. = $p_t - p_{t-1}$

Coef	Estimate	t-statistic
λ	1.144	5.54
$\frac{\lambda}{1+\alpha}$	.118	2.69
θ_{t-1}	1.35	18.58
θ_{t-2}	-.363	-4.68
(const.)	-.0010	-.48

D.W. = 2.19

Log of likelihood
Function : 718.68

Equation (11)

Dep. Var. = p_t

Coef	Estimate	t-statistic
a_0	.988	6.34
a_1	.186	.99
a_2	-.174	-1.89
$\frac{1}{1+\alpha}$	.318	5.15
θ_{t-1}	1.296	10.91
θ_{t-2}	-.348	-2.72
(const.)	-.00213	-.08

D.W. = 1.97

Log of likelihood
Function = 721.74

Chart 1

Supply-Side Persistence

Hypothetical Adjustment of $y^{*} - y_{n}^{*}$ to a One-Unit Deviation Beginning at Time $\underline{t}$

(Perfect Information and Flexible Prices)

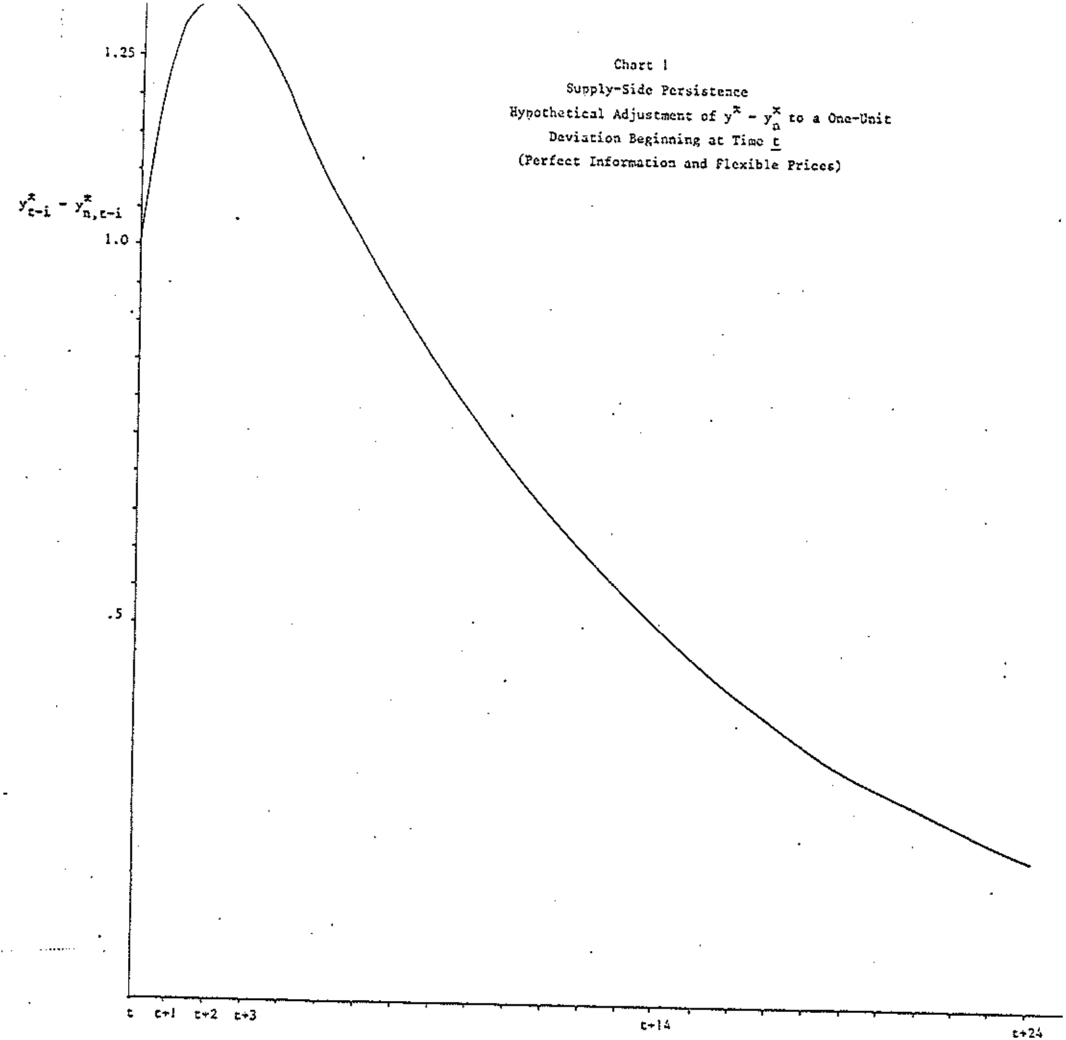

Table 2

Alternative Two-Step OLS Estimates

1951:QI through 1979:QIV

"Gordon"
Equation (G.4.1)
Dep.Var. = $p_t - p_{t-1}$

Expl. var.	coef.	t-statistic
$(\hat{y}_t - y_{t-1} - g)$	.0987	2.18
$(y_t - \hat{y}_t)$	.145	4.16
NIXCON(*)	-.00796	-6.15
$(p_{t-1} - p_{t-2})$	.106	1.13
$(p_{t-2} - p_{t-3})$	.165	1.88
$(p_{t-3} - p_{t-4})$	.209	2.30
$\sum_{i=0}^{14} (p_{t-4} - p_{t-5-i})$	.466	3.49
$y^*_{t-1} - y^*_{t-2}$	.060	5.69
(const.)	.000448	.76

$R^2 = .85$

D.W. = 1.87

s.e. = .00256

"Gordon"
Equation (G.4.2)
Dep.Var. = $p_t - p_{t-1}$

Expl. var.	coef.	t-statistic
$(\hat{y}_t - y_{t-1} - g)$	.20	3.27
$(y_{t-1} - y_{t-2} - g)$	.242	2.28
$(y_{t-2} - y_{t-3} - g)$	.218	2.12
$(y_{t-3} - y_{t-4} - g)$	.222	2.14
$(y_{t-4} - y_{t-5} - g)$	.072	.75
$(y_{t-5} - y_{t-6} - g)$	-.0257	-.29
$(y_t - \hat{y}_t)$	.132	3.25
$(y^*_{t-1} - y^*_{n,t-1})$	-.206	-1.86
$(y^*_{t-2} - y^*_{n,t-2})$	.0176	.10
$(y^*_{t-3} - y^*_{n,t-3})$	.0101	.06
$(y^*_{t-4} - y^*_{n,t-4})$	.162	.96
$(y^*_{t-5} - y^*_{n,t-5})$	.106	.69
$(y^*_{t-6} - y^*_{n,t-6})$	-.0545	-.60
NIXCON(*)	-.00649	-4.46
(const.)	-.00526	-4.34

$R^2 = .82$

D.W. = 1.85

s.e. = .00291

Equation (11.a)
Dep. Var. = p_t

Expl. var.	coef.	t-statistic
$(\hat{y}_t - y^*_{n,t})$ (**)	.367	3.93
$(y_{t-1} - y^*_{n,t-1})$	.221	9.59
$(y_{t-2} - y^*_{n,t-2})$	.148	5.10
$(y_{t-3} - y^*_{n,t-3})$	.127	4.74
$(y_{t-4} - y^*_{n,t-4})$	.0885	2.59
$(y_{t-5} - y^*_{n,t-5})$	.0548	1.76
$(y_t - \hat{y}_t)$	.0942	2.22
$(y^*_{t-1} - y^*_{n,t-1})$	-.352	-3.19
$(y^*_{t-2} - y^*_{n,t-2})$	.048	1.26
(const.)	.00157	.131
ρ^1	.957	6.01
ρ^2	.124	.70

D.W. = 1.89

s.e. = .00334

(*) This is a dummy variable used by Gordon to account for the effects of the Nixcon price controls of the early 1970's. The values are : 1971:QIII through 1972:QIV - 4/6 ; 1974:QII through 1975:QI - (-1).

(**) The "$\hat{y}$" in this equation is computed in a manner that is described in Section IV. (The $\hat{y}$ calculation for (G.4.1) and (G.4.2) is from a re-estimation of the Gordon forecast equation.)

ENDNOTES

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1. A large literature is surveyed by Drazen (1980).

2. The contracting approach is vulnerable to the complaint that institutional arrangements would be unlikely to survive which prevented wages and prices from reaching perceived, desired levels for several years. The (micro-economic) conjectural analysis and signalling theory has not yet developed a convincing explanation of endogenously-sticky prices and unemployment, at least not for several-year periods. On the latter, see Drazen (1980, p.299).

3. This refers to the classic papers (among others by the same authors) : Lucas (1973) and Sargent and Wallace (1975).

4. If y_n^* grows at a constant rate, g, the steady-state solution for $y_t^* - y_{n,t}^*$ is $\frac{1-\lambda}{\lambda}$ $(\hat{y}_t - \hat{y}_{t-1} - g)$. That is, the "gap" will increase by $\frac{1-\lambda}{\lambda}$ percentage points for each percentage point increase in $\hat{y}_t - \hat{y}_{t-1}$.

5. Gordon has charged (1981, p.510) that it is unreasonable in the context of rational expectations for agents to incur the risk of long-term, productive-stock mistakes when they could avoid making them simply by waiting the short time necessary for ambiguities of demand signals to be resolved. This argument appears to imply that agents will view with regret any deviations in productive stocks from their natural levels. But rational agents by definition should know enough about the underlying model to know that demand shocks result in output effects and that the demand in real terms for their specific products is likely to be affected. Agents will presumably acquire productive-stock levels that are consistent with their (rational) forecasts of the "business cycle."

6. A procedure which has a cleaner appearance would be to test the neutrality conditions ($\lambda = 1$, or $a_0 = 1$ and $a_i = 0$ for $i > 1$) in what is assumed to be "the" Lucas-Sargent-Wallace model. (See this type of test in Barro (1978), Barro and Rush (1980), Grossman (1979), Leiderman (1980), Mishkin (1982a,b), and Wogin (1980)). The estimates I describe in this section are identical

to those I would make in conducting this test and they turn out to be consistent with the price-flexibility requirement of structural neutrality. I shall not however, use the estimates as tests of neutrality in this paper. The central issue and topic is the output-price lag in context of a general class of models and not just the Lucas-Sargent-Wallace one. Further, the specification of this "general" model is uncertain, a feature of this study that increases my obligation to consider whether misspecification might have affected the estimates. An estimating issue in point is the best way to employ cross-equation constraints, constraints this model requires. As I shall show in Section V, the results are sensitive to the choice of statistical procedure.

7. When, for example, three NRH-GAP-lag coefficients (a_i's) are permitted the resulting coefficients of the explanatory variables are related to each other in the following way :

coefficient	explanatory variable.
a_0	$\hat{y}_t - y^*_n$
a_1	$\hat{y}_{t-1} - y^*_{n,t-1}$
a_2	$\hat{y}_{t-2} - y^*_{n,t-2}$
$a_1 \frac{1}{1+\alpha}$	$y_t - \hat{y}_t$
$a_1(\frac{1}{1+\alpha})$	$y_{t-1} - \hat{y}_{t-1}$
$a_2(\frac{1}{1+\alpha})$	$y_{t-2} - \hat{y}_{t-2}$
$-a_0\theta_{t-1}$	$y^*_{t-1} - y^*_{n,t-1}$
$-a_1\theta_{t-1} - a_0\theta_{t-1}$	$y^*_{t-2} - y^*_{n,t-2}$
$-a_1\theta_{t-2} - a_2\theta_{t-1}$	$y^*_{t-3} - y^*_{n,t-3}$
$- a_2\theta_{t-2}$	$y^*_{t-4} - y^*_{n,t-4}$

8. In several empirical, reduced-form studies of rational expectations wherein output or employment is employed as the dependent variable against distributed lags of "forecasts" and "forecast-errors" of money or nominal GNP, a second-order serial correlation has appeared in the residuals (c.f. Barro and Rush (1980), Grossman (1979), and Mishkin (1982a,b)). The pattern of

estimated ρ-coefficients in these studies falls in of the same general order of magnitude (including sign) as my estimated θ_{t-1} and θ_{t-2}. A plausible implication of the serial correlation pattern they find is a failure to include a role in their models for supply-side persistance. If true, supply-side error terms like $e_{s,t}$ (first appearing in equation (1) of this paper) will have a built-in serial correlation component which has the pattern of the (missing) θ's. I might add that the proper remedial step is to include the left-out variables rather than the Cochrane-Orcutt technique used by these authors.

8a. Gordon (1982), equation 5 of Table 3, p.1103.

9. Estimates made in such circumstances are consistent provided serial correlation is not present. It serial correlation is present the coefficience will be biased even in large samples.

10. In making these calculations I changed the y-forecast equation so that it conformed to Gordon's.

This required changing the variables to first (lag) difference form and altering the list of lagged explanatory variables.

11. (G.4.2) is not an exact reduced-form translation of (G.4.1). I did not allow a distributed lag on the supply-"shock" variable NIXCON (see footnote, Table 2) on the presumption Gordon did not intend NIXCON's effects to be distributed over time. Second, I included only the first $(y_t - \hat{y}_t)$ term separately and lumped the lagged $(y_{t-i} - \hat{y}_{t-i})$'s with the demand-forecast variables. This reduced the standard error of the sum of current and lagged demand variables (a not-surprising outcome, since the forecasts are correlated with previous forecast errors) but had negligible effect on the point estimate of the sum.

12. There is no firm ground on which to justify the serial correlation correction. It is interesting, however, that the correction turns out to involve an approximate first-differencing and that the data used for Gordon's equations (and the revised equation (G.4.2)) is first-differenced. When the serial correlation correction is not made, the two-step OLS procedure produces much faster (through imperfect) price adjustment speeds.

13. The greater doubt about specification is over the forecast equation. Under rational expectations assumptions, we face the problem of finding the "best" forecast equation. The necessarily casual way the forecast is treated under NRH-GAP makes misspecification almost inevitable.

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