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11 Improvements in Macroeconomic Stability: The Role of Wages and Prices

John B. Taylor

Macroeconomic fluctuations have been less severe in the past thirty years than in the period before World War II. Although the recessions in the 1970s and 1980s have been large and have been associated with big swings in inflation, the average amplitude of cyclical fluctuations is still smaller than in the prewar period.

This improvement in macroeconomic performance was already evident to most economists by the end of the 1950s. It served as the focal point of Arthur Burns's 1959 presidential address before the American Economic Association. Burns contrasted the milder postwar fluctuations with those he studied with Wesley Clair Mitchell at the National Bureau of Economic Research. He attributed the improvement to countercyclical fiscal and monetary policy as well as to structural changes in the economy: more stable corporate dividends, steadier employment practices, better inventory controls, and greater financial stability owing to deposit insurance.

The improvement in economic performance still deserves the attention of macroeconomists. An understanding of the reasons for the improvement is invaluable for recommending what changes in policy should, or should not, be adopted. Moreover, at a time when macroeconomic research is undergoing difficult and fundamental changes, the improvement serves as a useful reminder of the practical importance of continued progress in macrotheory and macroeconometrics. Regardless of one's approach to macroeconomic research, one can, as

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James Tobin (1980) has urged, "take some encouragement from the economic performance of the advanced democratic capitalist nations since the Second World War."

This paper examines the role of wage and price rigidities in this improvement in macroeconomic performance. Wage and price rigidities are at the center of most modern economic theories of the business cycle. According to these theories, if wages and prices were more flexible the economy would experience shorter and less severe business cycle fluctuations. Many economists have therefore suggested economic reforms—such as synchronized wage and price setting—to make wages and prices more flexible.

I examine changes in wage and price rigidities and in macroeconomic performance by concentrating on two episodes in United States history: the quarter-century before World War I, from 1891 through 1914, and the slightly longer period after World War II, from 1952 through 1983. Each period includes eight economic fluctuations. By ending the earlier period before World War I, we exclude the economic turbulence of both world wars as well as the Great Depression of the 1930s.[1] Even with these exclusions, economic fluctuations in the earlier period were larger than those in the postwar period. The data also indicate that wages and prices were more flexible in the earlier period. This latter finding, which has also been noted by other researchers,[2] presents a puzzle. Less flexibility of wages and prices should lead to a deterioration in economic performance. The comparison suggests that the opposite has occurred. Either other factors—such as those mentioned by Burns—were strong enough to offset the reduced wage/price flexibility, or macrotheory needs some revision if it is to provide a satisfactory explanation for economic fluctuations in both these periods of United States history.

The research reported here makes use of some recently developed econometric time series methodology. The differences in economic fluctuations in the two periods are documented using simple reduced-form vector autoregressions and their moving average representations.

1. The interwar period would also make a useful comparison. In the first draft of this paper I looked at the period 1910–40. To omit the observations from World War I—which would be analogous to the omission of World War II from the later sample—would mean that the period could not begin until 1919 at the earliest; and since some observers interpret the 1920 recession as a direct consequence of demobilization, the same logic would call for starting in 1921 or 1922. The sample size would then be fewer than twenty annual observations, which is already very small for statistical time series analysis. If one worried further that the Great Depression was unique and should not be lumped together with other cycles, then one would be left with the 1920s, a period far too short for statistical analysis. For these reasons I decided to focus on the period before World War I. This period has some other advantages as a contrast with the period 1952–83. These are discussed in the next section.

2. See Cagan 1979, Gordon 1983, and Mitchell 1983, for example.

These give the "facts without theory," much as the Burns/Mitchell NBER reference cycle methods did. This reduced-form evidence is then given an explicit structural interpretation in a simple mathematical form. One advantage of this statistical approach over the earlier NBER methods is that it provides a tight and formal connection between theory and the facts. The connection between theory and the facts revealed through reference cycle charts is necessarily looser and less formal, although these charts can be very useful in the early stages of model development. The methodology used here to compare time periods by looking at both reduced forms and simple structural models is similar to the method I used for an international comparison of different countries (Taylor 1980, 1982).

11.1 A Simple Scorecard for Macroeconomic Performance

It is useful to begin with some simple but objective statistical measures of macroeconomic performance in the different periods. These measures as well as all the statistical analysis in this paper are based on annual data. Output is measured by real GNP, prices are measured by the GNP deflator, and wages are based on average hourly earnings in manufacturing.

The means and standard deviations of the three detrended series are presented in table 11.1. To be specific, let Y be real GNP and let Y^* be potential GNP. Then detrended output given by $y = (Y - Y^*)/Y^*$, and is referred to as the *output gap* in the figures and tables of the paper. Potential GNP is assumed to be growing at a constant, but different, exponential rate in each of the periods. The level of potential is chosen so that the average of y is zero in each period. Experimentation with some alternative assumptions about the growth of Y^* did not affect the results by much. For example, when the trend in Y^* was permitted to change in 1973 to reflect the slowdown in productivity

Table 11.1 **Measures of Inflation and Output Stability**

	1891–1914	1952–83	1910–40
Standard deviation of			
Output gap	4.8	3.6	10.1
Wage inflation	1.9	2.2	8.9
Price inflation	2.8	2.6	8.1
Average of			
Wage inflation	1.5	5.4	4.1
Price inflation	0.9	4.2	1.5

Note: By definition the average output gap is zero. Prices are measured by the GNP deflator and wages by average hourly earnings in manufacturing.

growth in the United States, the results were similar. I chose to detrend output using a deterministic trend rather than first differences to capture the tendency for output to return to its potential growth path after a disturbance.

On the other hand, wages and prices were detrended by taking first differences of the logarithms; that is, by looking at the rate of price inflation (p) and the rate of wage inflation (w). In the postwar period there is no tendency for the price level to return to a trend path after a disturbance. At best, the *rate of inflation* tends to regress to some mean value; even this tendency was not present in the postwar data before 1982–83. Although the United States was on a gold standard during the period before World War I, the levels of prices and wages show no tendency to regress to a fixed trend or level in that period either, presumably because of changes in the world gold stock and in the relative price of gold.

The statistics reported in table 11.1 refer to the detrended series for output y, wage inflation w, and price inflation p. According to the standard deviation measure, output fluctuations have been about 25% smaller in the period after World War II than in the quarter-century before World War I. The improved output performance does not extend to inflation, however. The standard deviation of the year-over-year inflation rate is about the same in the two periods—up slightly for wage inflation (w) and down slightly for price inflation (p). The average inflation rate is much higher in the postwar period by both measures of inflation.

To provide some perspective, I have also included in column 3 of table 11.1 the same performance measures for the period 1910–40, which includes both World War I and the Great Depression. This period is far worse than the other two by any of the performance measures. Output fluctuations are almost three times as large as in the post–World War II period, and inflation fluctuations are about four times as large. Only the average inflation rate is less in this period than in the postwar period, but since the average is taken over very large positive values and very large negative values, this is not a very meaningful performance measure.

11.2 Output and Inflation Fluctuations

The statistics in table 11.1 are far from sufficient for characterizing the dynamic behavior of two such serially and contemporaneously correlated variables as output and inflation. Time series charts for inflation and output in the two periods are shown in the upper and lower panels of figures 11.1 and 11.2. For additional perspective, the corresponding charts for the 1910–40 time period are shown in the middle panels.

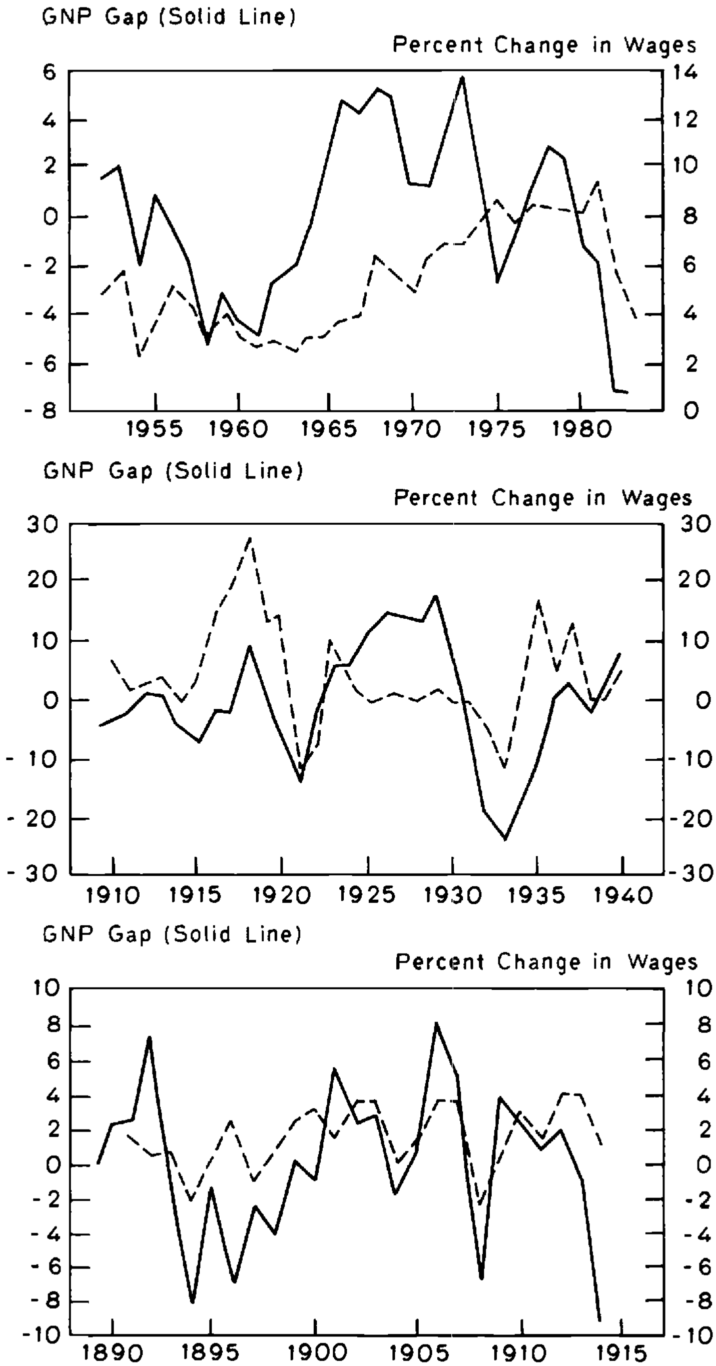

Fig. 11.1 Wage inflation and deviations of real output from trend during three periods.

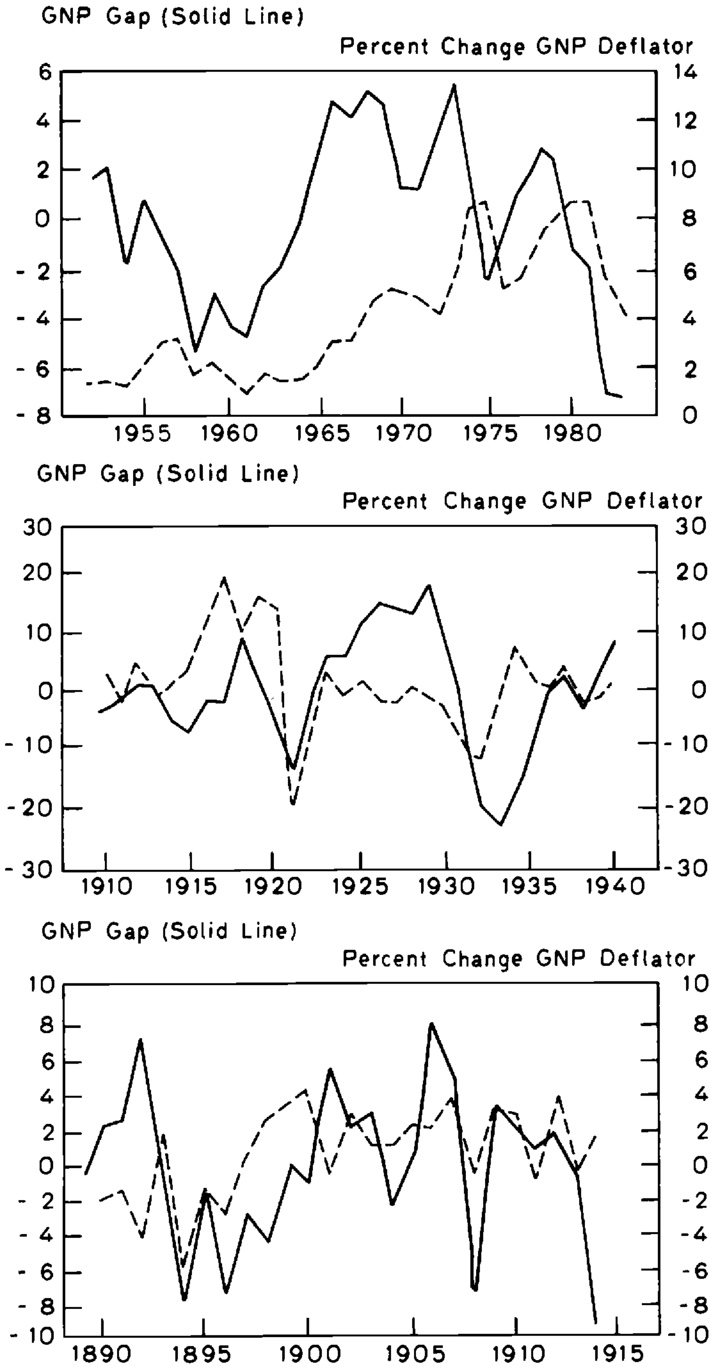

Fig 11.2 Price inflation and the deviation of real output from trend during three periods.

Note that the scales on the charts for the different time periods are different. (The output gap $y = (Y - Y^*)/Y^*$ is superimposed on both the wage inflation charts and the price inflation charts.) Some of the milder recessions in the earlier period are smoothed out by the use of annual data. The severe recession that began early in 1893 and ended in mid-1894 stands out as one of the worst of the period, as does the brief but sharp recession that began with the financial panic in 1907. The period ends with the 1914 recession before the beginning of World War I.

The charts clearly indicate that the tendency for inflation to fall in recessions and rise in booms is not new. Inflation fell during all the more severe downturns between 1891 and 1914. Inflation was negative on average from 1891 to 1907 and positive on average from 1907 until 1914. During this latter subperiod the world gold supply steadily increased.

A comparison of the charts for the earlier period with the charts for the later period reveals in a rough way many of the differences between the two periods that I will focus on. First, the amplitude of the fluctuations in output is smaller in the postwar period, as we have already observed. (Again note the difference in the scales on these figures.) Second, the duration of the fluctuations in inflation is longer in the postwar period; inflation has been much more "persistent." Stated another way, wages and prices have developed more rigidities, in the sense that past values of wages and prices influence their current values. Much of the higher inflation persistence is due to the prolonged period in the 1970s when the inflation rate was abnormally high before it fell sharply in 1982 and 1983. In comparison, during the period before World War I wage inflation fluctuated up and down much more rapidly. Even the persistent negative trend in prices and wages before 1897 is swamped by the fluctuations in the inflation rate; similarly, the positive trend after 1897 is hidden by the larger fluctuations around the trend. The third important difference between the two periods is in the duration of the fluctuations of real output. As with inflation, these are longer since World War II.

The fourth important difference between the two periods is more difficult to see in the charts but is somewhat more evident in figures 11.3 and 11.4. It relates to the timing of the fluctuations of inflation and output. In the postwar period, there is a marked tendency for increases in inflation to bring about a downturn in the economy, although with a lag. After the downturn inflation begins to fall. For example, an increase in inflation in the late 1960s preceded the downturn in the economy in 1969–70. After the downturn, inflation declined. Similarly, an increase in inflation in 1973–74 preceded the downturn in the economy in 1974–75. Inflation then subsided. Finally, an increase

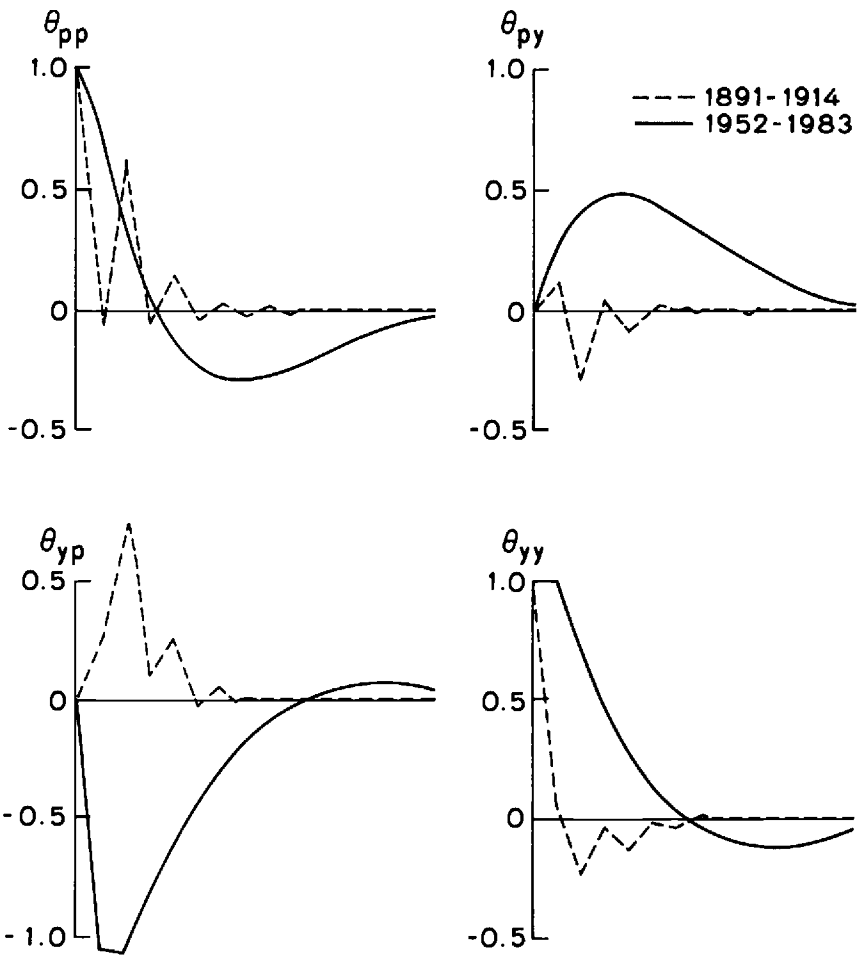

Fig. 11.3 Moving average representation for price inflation and output.

in inflation in 1979–80 preceded the back-to-back recessions in 1980–82. And as usual, inflation then fell. It is very difficult to detect similar patterns in the period 1891–1914. Increases in inflation do not seem to lead the economic downturns, and the declines in inflation seem to occur simultaneously with the declines in the real economy. Although this timing difference can be pried out of the charts, it emerges much more easily in the statistical time series analysis of the next two sections.

The middle panels in figures 11.1 and 11.2 clearly indicate that the amplitude of the fluctuations is much larger in 1910–40 than in either the period before or the period after. The effect of World War I is evident in the boom and the subsequent recession of 1920. But the

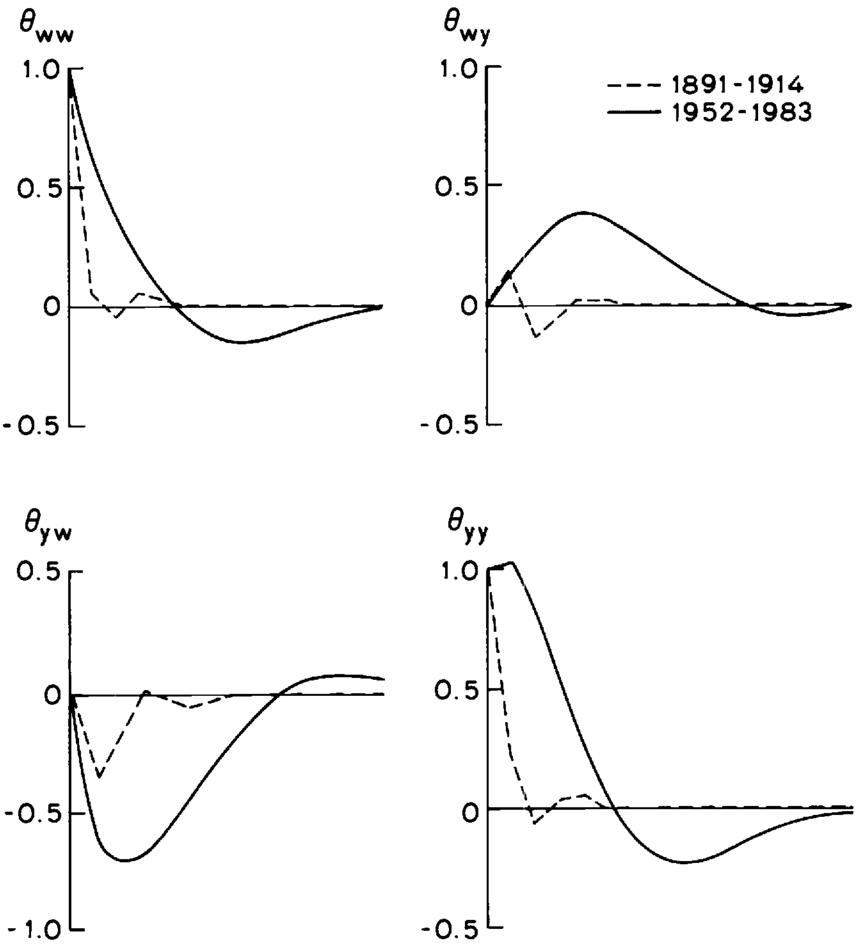

Fig. 11.4 Moving average representation for wage inflation and output.

extended boom in the 1920s and the Great Depression dominate the charts. The wide fluctuations in wages and prices indicate the same type of flexibility that is evident before World War I. The persistence of wage and price inflation—a sign of wage and price rigidities used in macrotheory—definitely seems relatively new.

11.3 Vector Autoregressions

The dynamic properties of output, wages, and prices can be examined more systematically by estimating unconstrained vector autoregressions. Estimates of bivariate autoregressions for wage inflation and output, and for price inflation and output, are reported in tables 11.2 and 11.3 for both 1893–1914 and 1954–83. The lag length is equal to two years for all the regressions. For annual data this choice of lag length seemed to eliminate most of the serial correlation of the residuals to the equations. Higher-order systems with both wage inflation and price inflation together with output were also estimated but are not reported here. At this level of aggregation the movements of wages and prices are very similar, so that including a third variable does not add much to the analysis.

These autoregressions are not necessarily structural equations. They are reduced-form equations that in principle can be derived from a variety of systems of structural equations. The lag coefficients in the autoregressions are in principle functions of parameters in all the structural equations. The shocks to each of the autoregression equations are in principle functions of the shocks to all the structural equations and depend on simultaneity parameters in the structural equations. In this section my aim is simply to describe the autoregressions rather than to give them a structural interpretation.

A quick glance at tables 11.2 and 11.3 reveals that the structure of the autoregressions differs by a large amount in the two periods. Both the structure of the shocks to the equations (the impulses) and the lag coefficients (the propagation mechanism) are much different.

Table 11.2 Autoregression Estimates for Price Inflation and Output, 1893–1914 and 1954–83

Dependent Variable	Lagged Dependent Variables: $p(-1)$	$p(-2)$	$y(-1)$	$y(-2)$	ρ	σ	R^2
	Sample Period 1893–1914						
p	−.051	.574	.108	−.281	−.02	1.91	.46
	(−0.3)	(3.3)	(1.0)	(−2.5)			
y	.279	.734	.053	−.260	−.18	4.00	.24
	(0.8)	(2.0)	(0.2)	(−1.1)			
Contemporaneous correlation between residuals = .30							
	Sample Period 1954–83						
p	.721	.084	.257	−.027	−.09	1.03	.82
	(3.5)	(0.4)	(2.7)	(−0.3)			
y	−1.05	.76	1.00	−.004	−0.5	2.07	.66
	(−2.6)	(2.0)	(5.2)	(−0.0)			
Contemporaneous correlation between residuals = .23							

Note: Each equation was estimated with a constant term. The variable p is the annual percentage rate of change in the GNP deflator. The variable y is the percentage deviation of output from linear trend estimated over the sample period. The numbers in parentheses are t-ratios; ρ is the first-order autocorrelation coefficient; σ is the standard error of the residuals.

Table 11.3 Autoregression Estimates for Wage Inflation and Output, 1893–1914 and 1954–83

Dependent Variable	Lagged Dependent Variables $w(-1)$	$w(-2)$	$y(-1)$	$y(-2)$	ρ	σ	R^2
		Sample Period 1893–1914					
w	0.52	.007	.147	−.213	.02	1.66	.30
	(0.2)	(0.1)	(1.3)	(−1.8)			
y	−.358	−0.30	.220	−.063	.05	4.49	.04
	(−0.6)	(−0.1)	(0.7)	(−0.2)			
Contemporaneous correlation between residuals = .66							
		Sample Period 1954–83					
w	.569	.175	.097	.103	−.03	1.20	.70
	(2.5)	(0.7)	(0.8)	(0.8)			
y	−.650	.336	1.026	−.181	.04	2.21	.62
	(−1.6)	(0.8)	(4.5)	(−0.8)			
Contemporaneous correlation between residuals = .52							

Note: The variable w is the annual percentage rate of change in average hourly earnings in manufacturing. For the definition of other variables see the note to table 11.2.

11.3.1 The Impulses

The variance of the shocks, or the impulses, to the output equation has decreased sharply from the prewar to the postwar period. To the extent that macroeconomic policy works by changing the dynamics of the economy—as it would with feedback policy, the finding that a reduction in the size of the shocks explains most of the reduced variability suggests that such feedback policy was not responsible for improvements in performance. However, part of the change in policy could affect the variance of the shocks by working "within the period" to offset exogenous disturbances. This would be more likely for the automatic stabilizers that react simultaneously, but with annual data even a feedback policy that reacts to economic disturbances within the year would affect the variance of the shocks rather than the dynamics of the system.

The variance of the shocks to the inflation equations is also much smaller in the postwar period. Since the overall variance of inflation is about the same in the two periods, changes in the propagation mechanism must have had a positive influence on the variance of inflation. The impulses have become weaker. It is perhaps surprising that the variance of the shocks to inflation has become smaller. According to these estimates, an increased importance of price shocks in postwar business cycles is not supported by a comparison with the period before World War I.

The contemporaneous correlation between the shocks to the equations is positive in both the prewar and the postwar periods. However, the correlation is stronger in the prewar period. More of the action seems to come within the annual time interval during the prewar period.

11.3.2 The Propagation Mechanism

The sum of the coefficients of the lagged inflation rates in the inflation equations is much smaller in the earlier period. This change is more marked for wage inflation than for price inflation. This change is consistent with the increased persistence of inflation in the postwar period that is evident in the time series charts. The sum of the coefficients on lagged output in the output equation is also higher in the postwar period, reflecting a corresponding increase in the persistence of output fluctuations.

The difference in the temporal ordering of inflation and output movements that seems to emerge from the time series plots is evident in the cross, or off-diagonal, autoregression coefficients. In the prewar period lagged inflation has either a positive or an insignificant effect on output. In the postwar period the effect of lagged inflation on output is significantly negative. Looking at the other side of the diagonal, in the prewar period lagged output has a negative effect on inflation; in the postwar period it has a positive effect.

11.4 Moving Average Representations

The moving average representations provide a more convenient way to look at the propagation mechanisms in the economy. They can be derived directly from the autoregression equations. The vector autoregressions reported in tables 11.2 and 11.3 can be written in matrix notation as follows:

$$z_t = A_1 z_{t-1} + A_2 z_{t-2} + e_t, \quad (1)$$

where $z_t = (w_t, y_t)$, in the systems with wage inflation and output, and where $z_t = (p_t, y_t)$, in the systems with price inflation and output. A_1 and A_2 are two-by-two matrixes of lag coefficients. The two-by-one vector e_t is supposed to be serially uncorrelated. The moving average representation is then given by

$$z_t = \Sigma_{i=0}\Theta_i e_{t-i}, \quad (2)$$

where the Θ_1 matrixes are found by successive substitution of lagged zs in equation (1). Alternatively, and perhaps more intuitively, the Θ matrixes can be computed by dynamically simulating the effects of unit shocks to each of the equations in (1). The two elements of the first column of Θ_1 are given by the effects of a unit inflation shock on inflation and output, respectively, in this simulation. The two elements of the second column of Θ_1 are given by the effects of a unit output shock on inflation and output, respectively, in the simulation.

Denote the elements of the first column of Θ by θ_{pp} and θ_{yp}, and the elements of the second column of Θ by θ_{py} and θ_{yy}. These four elements of the Θ_i matrixes are tabulated in tables 11.4 through 11.7 for i equals 0 to a value where the coefficients are negligible in size. The coefficients are also plotted in figures 11.3 and 11.4 for easy comparison of the two time periods.

Table 11.4 Moving Average Representation for Price Inflation and Output, 1893–1914

θ_{pp}	θ_{py}	θ_{yp}	θ_{yy}
1.00	.00	.00	1.00
−.05	.11	.28	.05
.61	−.28	.73	−.23
−.06	.04	.10	−.03
.15	−.10	.24	−.14
−.04	.02	−.01	−.00
.02	−.02	.04	−.03
−.02	.01	−.02	.01
.00	−.00	−.00	.00
−.00	.00	−.01	.00
−.00	.00	−.00	.00

Note: Derived from the autoregression coefficients reported in table 11.2.

Table 11.5 Moving Average Representation for Price Inflation and Output, 1954–83

θ_{pp}	θ_{py}	θ_{yp}	θ_{yy}
1.00	.00	.00	1.00
.72	.26	−1.05	1.00
.33	.41	−1.06	.72
.06	.48	−.85	.47
−.12	.48	−.65	.27
−.23	.44	−.47	.12
−.28	.38	−.32	.02
−.29	.31	−.20	−.05
−.27	.24	−.10	−.09
−.24	.18	−.03	−.11
−.20	.12	.02	−.12
−.16	.08	.05	−.11
−.12	.04	.07	−.10
−.08	.01	.07	−.08
−.05	−.00	.07	−.06
−.03	−.02	.06	−.05

Note: Derived from the autoregression coefficients reported in table 11.2.

Table 11.6 Moving Average Representation for Wage Inflation and Output, 1893–1914

θ_{ww}	θ_{wy}	θ_{yw}	θ_{yy}
1.00	.00	.00	1.00
.05	.15	−.35	.22
−.04	−.17	−.12	−.07
.06	−.06	.01	.03
.03	.01	−.01	.04
−.00	.00	−.02	.00
−.00	−.01	−.00	−.00
.00	−.00	.00	.00
.00	.00	−.00	.00

Note: Derived from the autoregression coefficients reported in table 11.3.

Table 11.7 Moving Average Representation for Wage Inflation and Output, 1954–83

θ_{ww}	θ_{wy}	θ_{yw}	θ_{yy}
1.00	.00	.00	1.00
.57	.10	−.65	1.03
.44	.26	−.70	.81
.21	.35	−.69	.52
.06	.37	−.58	.25
−.06	.35	−.43	.02
−.12	.29	−.28	−.12
−.15	.22	−.15	−.20
−.15	.14	−.05	−.23
−.13	.08	.03	−.22
−.10	.02	.07	−.18
−.07	−.01	.09	−.13
−.04	−.03	.09	−.09
−.02	−.05	.08	−.05
−.00	−.05	.07	−.01

Note: Derived from the autoregression coefficients reported in table 11.3.

The use of moving average representations in macroeconomics originates with the influential paper by Sims (1980) in which he refers to it as innovation accounting; the approach has since been adopted by many other researchers. There are many moving average representations of a given multivariate process depending on what one assumes about the contemporaneous correlation between the shocks. Sims suggests that a form be chosen so that the covariance matrix of the shocks is diagonal—an orthogonalization of the shocks. This requires a transformation of the Θ_i matrixes. The transformation is a function of the correlation of the shocks and depends on how one wishes to order the way the shocks enter the system. The methodology used here is different from that of Sims in that the Θ_i matrixes have not been transformed to yield orthogonal shocks. I have found that such a transformation makes it difficult to give a direct structural economic interpretation of the Θ_i matrixes. The method used here was also used for very similar purposes in an international comparison of economic performance (Taylor 1980).

Figures 11.3 and 11.4 indicate the enormousness of the change that has taken place in the dynamics of inflation and output since the period before World War I. The charts on the diagonal of figures 11.3 and 11.4 show the persistence of inflation θ_{pp} and output θ_{yy}. Both have increased.

The cross effect of the shocks has changed even more. The θ_{py} coefficients have changed sign; an output shock has a long-delayed effect on inflation in the more recent period. Before World War I this dynamic effect was very small. Recall, however, that a positive *contemporaneous* relation between output and inflation existed before World War I. The θ_{yp} coefficients have changed in the reverse direction. Whereas inflation shocks generated a reduction in output in the more recent period, they generated an increase in output before World War I. This change, which emerges so clearly from the moving average representations, is the same change that was barely visible in the time series charts: when inflation rises in the recent period, output falls; inflation then subsequently subsides.

11.5 Summary of the Facts

The preceding examination of the facts of inflation and output fluctuations in 1891–1914 (the first period) and 1952–83 (the second period) can be summarized as follows:

1. Output fluctuations are smaller in amplitude and more persistent in the second period.

2. Inflation fluctuations are about the same in amplitude in both periods but are more persistent in the second.

3. Inflation shocks have a negative, but lagged, effect on output in the second period; output shocks have a positive, but lagged effect on inflation in the second period. No such timing relation exists in the first period. If there is any intertemporal effect in the first period, it is in the reverse direction.

4. There is a positive contemporaneous correlation between the inflation shocks and the output shocks in both periods. This correlation is larger in the first period.

5. The variances of the shocks to inflation and to output are smaller in the later period.

11.6 Structural Interpretations

The vector autoregression can be viewed as a reduced form of a structural model. Unfortunately the mapping from the reduced form to the structural form is not one-to-one. The traditional identification literature shows formally that there will in principle be many structural models that are consistent with a given reduced form. In practice, however, the situation is not so dismal. There are a relatively small number of theoretically sound or "reasonable" structural models. Moreover, the properties of an estimated reduced form can frequently narrow the range of possible structural models.

11.6.1 The Postwar Period

The third property of the estimated autoregressions listed at the end of the previous section is very useful for nailing down a reasonable structural model. The dynamic interaction between inflation and output in the postwar period is very strong. Inflation "Granger causes" output in a negative direction; and output "Granger causes" inflation in a positive direction. This pattern naturally leads to the following interpretation for the postwar period.

The Federal Reserve, or the "aggregate demand authorities" in general, is concerned with stabilizing inflation as well as unemployment. For aggregate demand shocks this joint aim causes no conflict; the best policy for both price and output stabilization is to offset the shocks. When an inflation shock comes, however, there is a conflict. The Fed must decide how "accommodative" to be. On average during the postwar period the Fed seems to have made a compromise. Policy is described by a policy rule. When an inflation shock occurs, the Fed neither fully "accommodates" the shock by increasing the rate of growth of the money supply point for point with inflation nor tries to eliminate it immediately by sharply reducing money growth. Instead, it lets money growth increase, but by less than the inflation shock. The result is the dynamic pattern observed in the vector autoregressions. When inflation increases the Fed lets real money balances—appropriately defined—fall, and the economy slips into a recession. Hence, inflation "Granger causes" output. The slack demand conditions then gradually work to reduce inflation. Hence, output "Granger causes" inflation.

This structural interpretation is by no means new, and it is gradually being incorporated in standard textbooks. For the data used here the following simple algebraic structural model seems to match the reduced form very well:

$$P_t = \delta p_{t-1} + \alpha E y_t + u_t, \tag{3}$$

$$y_t = -\beta_1 p_{t-1} + \beta_2 p_{t-2} + y_{t-1} + v_t. \tag{4}$$

The notation for output y_t and inflation p_t is the same as earlier. The operator E is the conditional expectation based on information through period $t - 1$. The shocks u_t and v_t are assumed to be serially uncorrelated.

The first equation is a simple price adjustment equation. This equation has no simulaneous effects between output and inflation. The second equation is the policy rule described above. It states that the rate of growth of output relative to trend is reduced if inflation has risen. If this system is to match up with the reduced-form evidence, the parameters should all be positive.

The estimated equations (written with the constants explicit and the t-ratios in parentheses) are:

$$(5) \quad p_t = \underset{(10.1)}{.89p_{t-1}} + \underset{(3.6)}{.25Ey_t} + \underset{(1.3)}{.55}, \qquad \sigma = 1.0,\ R^2 = .83$$

$$(6) \quad y_t = \underset{(-3.5)}{-1.01p_{t-1}} + \underset{(2.5)}{.69p_{t-2}} + y_{t-1} + \underset{(1.6)}{1.17}, \qquad \sigma = 2.0,\ \mathrm{R}^2 = .67$$

These equations were estimated using the full information maximum likelihood method. This method takes account of the cross-equation restrictions that occur when the second equation is used to forecast output in the first equation. The output equation is already in reduced form and is clearly not much different from the estimated equation in table 11.2. The reduced form for inflation can easily be derived by substituting the expectation of equation (6) into equation (5). It also matches up well with the reduced-form equation in table 11.2.

Equation (6) indicates that there is much less accommodation of inflation in the short run than in the long run. The short-run reaction coefficient is about -1, whereas the long-run reaction is about -0.3. Equation (5) indicates that inflation responds to slack demand with a lag.[3] The coefficient on lagged inflation depends on the structure of contracts in the economy as well as on expectations of inflation; the parameter would change with a change in the policy rule that changed expectations, and in this sense it is incorrect to refer to the equation as structural.

The policy rule can be written in the following interesting form:

$$(7) \quad y_t - y_{t-1} = -.32p_{t-1} - .69(p_{t-1} - p_{t-2}) + 1.17.$$

In other words, the rate of growth of real GNP (relative to potential) is reduced by 32% of the inflation rate in the last period plus 69% of the change of the inflation rate. The response of the Fed to high inflation is stronger when inflation is increasing than when it is decreasing. A

3. The data cannot discriminate between the assumptions that y_t or E_t appears in equation (5). The contemporaneous correlation is positive and could equally well be due to the correlation between the structural shocks as to a direct simultaneous effect of y_t on p_t.

nominal GNP rule could be interpreted[4] as having an implied coefficient -1 on the lagged inflation rate, with no adjustment for increasing or decreasing inflation. The estimated rule is less accommodative than a nominal GNP rule in the short run and more accommodative than a nominal GNP rule in the long run.

11.6.2 The Prewar Period

This model of price adjustment and policy is explicitly oriented to the postwar period in the United States. The wide differences between the autoregressions in the prewar and the postwar periods indicate that the same model is unlikely to fit in the prewar period. In fact, the model does very poorly in the prewar period. The coefficient on lagged inflation in the inflation equation (3) is negative though small and insignificant, whereas the coefficients on lagged prices in the output equation (4) are all positive. As the reduced-form results suggested, the dynamic relation between inflation and output in the prewar period is weak and opposite in sign from that for the postwar period.

The price adjustment equation without the insignificant lagged inflation rate is

$$p_t = \underset{(2.5)}{.28y_t} + \underset{(2.0)}{1.33}. \tag{8}$$

Hence, although the lagged inflation rate disappears, the adjustment coefficient is about the same size as before.

There are two possible implications of this failure of the postwar model.[5] First, prices and wages appear to be more flexible in the prewar period in that their correlation with output fluctuations is almost entirely contemporaneous. Adjustments occur within the annual time interval, unlike the postwar period, where the adjustments are drawn out for several years. Second, macroeconomic policy appears to be very accommodative; inflation shocks seemed to have no prior negative effect on output. Are these implications plausible?

11.6.3 More Flexible Wages and Prices?

The reduced importance of the lagged inflation term could be due to simple expectations effects as well as to changes in the structure of

4. Taken literally, a nominal GNP rule would respond to inflation shocks in the current period. In practice, however, a lag would probably occur.

5. It should be noted that there are fairly strong dynamic feedback effects from output and prices two years earlier in the price inflation system (see table 11.2). This is puzzling since the impact from prices and output one year earlier is weak. This two-year leap is the reason for the sawtooth moving average representation for this system (see fig. 11.3).

wage and price setting. The inertia effect in the postwar period is a combination of expectations effects and structure. Since inflationary expectations were probably much lower in the prewar period, the effect of lagged inflation would be smaller. Unfortunately, it is difficult to distinguish these two effects with aggregate data.

The problem has been addressed by Cagan (1979) and Mitchell (1983) using microeconomic data. Although neither author looks at data before World War I, their findings are probably relevant for the comparison of this paper. Cagan compares price movements in the business cycles of the 1920s with price movements in the business cycles after World War II. Mitchell compares wage adjustments in the 1930s with wage adjustments in the postwar period. Both find that price and wage adjustments were larger and more frequent in the earlier period. From a microeconomic perspective wages and prices were more flexible.

Two possible reasons for this change have been noted. First, the increased importance of large business enterprises and large unions could have centralized price and wage decisions and made them less subject to short-run market pressures. In the major labor unions, for example, the costs of negotiating a large settlement made it economical to have long three-year contracts in many industries. The overlapping nature of these contracts added to the persistence of wage trends. Second, economic policy changed so as to reduce the severity of recessions and thereby lessen the need to reduce wages and prices quickly in the face of slack demand conditions. This policy effect is different from the expectation of inflation effect mentioned above.

11.6.4 More Accommodative Policy?

Although the United States Treasury took on some central bank functions in the early 1900s, during most of the period 1891–1914 monetary policy was determined solely by the United States commitment to the gold standard. A gold standard is normally thought to generate aggregate demand "discipline." Policy would automatically be non-accommodative. For example, if there was an inflation shock, then a contractionary policy would be necessary in order to bring the price level back to its relative position with gold. Then why do the data suggest the opposite, that policy was accommodative?

One explanation comes from the fact that the United States was a small open economy during this period. Most price shocks probably came from abroad, much as the price shocks in the 1970s came from abroad. An increase in external prices with a fixed exchange rate will make domestically produced goods cheaper. This will lead to a balance of payments surplus until internal prices rise. A balance of payments surplus increases the money supply for a country on a gold standard.

The increase in the money supply will therefore tend to occur just as the domestic price level rises in response to the rise in world prices. Policy will look very accommodative.

A fixed exchange rate gold standard will be less accommodative to price shocks that originate at home. A price shock will raise domestic prices relative to external prices. The resulting balance of payments deficit will reduce the domestic money supply, and the economy will tend to fall into a recession. Internal prices will then fall. Either this type of scenario did not occur in 1891–1914, or it occurred so quickly that the timing cannot be detected with aggregate annual data. It is interesting that accommodation under a gold standard seems to be different for external shocks and internal shocks. According to modern expectations theories this discrimination is appropriate. Internal endogenous price and wage shocks are discouraged, whereas external exogenous price shocks are accommodated. Because the external price and wage behavior is unlikely to be influenced by the monetary policy in a small open economy, accommodation will not do any long-run harm. But internal price and wage behavior is likely to be adversely affected by an accommodative policy.

Another way to describe the prewar policy rule is to say that it was accommodative in the short run, permitting much slippage to accommodate external price shocks, but nonaccommodative in the long run. Prices in the United States could not differ from world prices in the long run. This is in contrast to the characterization in the previous section of policy in the postwar period: in the short run policy is much less accommodative than in the long run.

To summarize, the interpretation that prices and wages adjust quickly and that policy is very accommodative in the short run is plausible from a microeconomic perspective. Unlike the postwar period, where lags in the relation between output and inflation permitted one to narrow down the field of potential models, for the prewar period data are more ambiguous. If all the action occurs within the annual timing interval, it is difficult to distinguish one structural model from another. The lags are not long enough to identify the structure. In fact, the contemporaneous relation between prices and output in equation (8) could have been generated from a mechanism like the Lucas (1972) supply curve. If prices were as flexible as they appear to be during this earlier period, then the Lucas model itself is more plausible.

11.7 Concluding Remarks

Macroeconomic performance in the United States from 1891 through 1914 was much different from the performance after World War II. This difference is apparent in reduced-form autoregressions, in their moving average representations, in simple structural models, and even in simple time series charts of the data. The shocks, or *impulses*, to the economic system were smaller in the second period, mainly because of the policy and structural changes that Arthur Burns mentioned in his 1959 presidential address. Deposit insurance, for example, reduced the shocks to aggregate demand that came from financial panics.

But the dynamics, or *propagation mechanisms*, of the economic system are much slower and more drawn out in the postwar period. This tends to translate the smaller shocks into larger and more prolonged movements in output and inflation than would occur if the prewar dynamics were applicable in the later period. In other words, the change in the dynamics of the system offset some of the gains from the smaller impulses. These postwar dynamics can be given a structural interpretation in terms of the accommodative stance of monetary policy and the speed of wage and price adjustments. These dynamics were not evident in the prewar period.

One interpretation of these developments is that the change in the dynamics was a direct result of the reduction in the importance of the shocks. For example, prices and wages may have became more rigid because of the reduced risks of serious recessions or because movements in the money supply began to do some of the macroeconomic stabilization work that was previously done by wage and price adjustments. The analysis of this paper is not conclusive on this or on the other interpretation that the change in the dynamics was unrelated to the change in policy. But the possibility that a combination of the smaller postwar shocks with the shorter prewar dynamics might improve macroeconomic performance should be sufficient motivation for further study of these historical developments and their alternative interpretations.

Comment Phillip Cagan

It has long been noted that prices fluctuate less in post–World War II business cycles than they used to, though with the higher rates of inflation in the 1970s the amplitude of fluctuations became larger. One reason was that business cycles were generally less severe in the postwar period; none matched the severity of 1929–33, 1937–38, 1920–21, or 1907. Yet even for cycles of comparable severity in terms of real variables the postwar period appeared to exhibit less price fluctuation. It was generally agreed that prices and wages had become less flexible.

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In Taylor's annual data, these differences between periods are less clear. Compared with the interwar cycles 1910–40, the post–World War II period shows a standard deviation only one-quarter of the earlier value for price inflation and one-third of the earlier value for wage inflation. But compared with the pre-World War I cycles 1891–1914, the post–World War II cycles had about the same standard deviations—only 8% smaller for price inflation and actually 16% larger for wage inflation, even though the standard deviation of real GNP from its trend was 25% smaller in the post–World War II period. Inflation rates in this later period had a greater upward trend until the past few years, however, so that their standard deviations, if measured from trend, would be smaller.

The smaller variation in inflation in the later period becomes clear in the vector autoregression analysis of price and wage inflation and the real GNP gap. The residuals from these regressions represent unexplained movements, which Taylor interprets as "shocks" to the system. These shocks are much smaller in the postwar period. Compared with the pre–World War I period, in the postwar period shocks are reduced by 50% for prices and for the output gap and by 25% for wages.

Taylor uses this comparison of shocks to explain why, if prices and wages are less flexible in the postwar period, the output gap at the same time shows less rather than more variability. The answer is that shocks in the postwar period were sufficiently smaller to overcome the tendency of cyclical fluctuations to show up more in output than in prices and wages.

What are these shocks? Some are supply shocks, best illustrated by the OPEC oil price increases of 1973 and 1979 or by major labor strikes, as in steel in 1953 and automobiles in 1971, but for the most part these are fairly rare events. Shocks can also appear on the demand side, as in the financial panics of 1893 and 1907, which produced sudden contractions in the available money supply. In addition, we should recognize the possibility of mundane but ubiquitous measurement errors, particularly in the earlier period when the data are clearly less accurate. When Simon Kuznets put together his annual GNP data for the pre-1929 period, he was so concerned with the imprecision of the estimates that he was unwilling to publish the annual figures and planned to release only five-year averages. He was subsequently persuaded, I understand, to allow Friedman and Schwartz to use the data in annual form, since the five-year averages would have been useless for cyclical analysis. Kuznets obviously knew something about these data that the rest of us should not ignore. The GNP series from *Historical Statistics* that Taylor used are not much better.

Finally, Taylor's shocks may reflect variations over time in cyclical relationships that cannot be captured by a small number of autoregression lag terms. Cycles vary in duration and amplitude, and such variations may reflect the internal dynamics of the cyclical process as well as different dynamics depending on the type of shock, particularly whether it is viewed as temporary or permanent. I cannot refrain here from expressing my uneasiness with the spreading popularity of vector autoregression analysis. My concern is not with its atheoretical approach, which bothers some critics—that can often be an advantage—but with the fact that relatively simple autoregression and moving average representations do not fit many time series adequately, even though the residuals may pass tests as white noise. In work that I have done, an ARIMA fit to M1 growth produces residuals that have a much smaller variance in the 1960s than in the 1950s and 1970s. There is no simple way to model this pronounced change in variance. I also found that GNP growth in the 1970s cannot be represented by ARIMA functions that fit earlier periods. (Of course, structural econometric models may face the same problem of inadequate fit over different periods.) The NBER used to have a tradition of presenting charts of basic data. I would be less uneasy if the users of vector autoregressions pondered charts of their fits and showed them to the reader.

Having raised these red warning flags, I do not wish to dismiss all such statistical analyses. In many cases, and in Taylor's analysis of prices and wages, I find the vector autoregressions a useful and enlightening supplement to other modes of analysis.

His autoregressions contain three other pieces of information in addition to the variance of the residuals. The first is the contemporaneous correlation of residuals in the paired regressions. These are about the same for the pre–World War I and post–World War II periods but twice as large in the wage as in the price regressions. Although Taylor does not comment on this information, I interpret it as some evidence against greater measurement error in the earlier period. The shocks should be correlated, since most demand and supply shocks will affect prices and wages as well as output in the span of one year. Measurement error would normally be uncorrelated and thus would produce no correlation of residuals.

Another more important piece of information provided by the vector autoregressions is the coefficients on lagged values of the dependent variables. These are a measure of persistence—the degree to which the series is a continuation of its previous values. Based on the size and statistical significance of these coefficients, the postwar period shows much more persistence, as we knew it would from previous studies of the flexibility of prices and wages. Taylor's measure of persistence nicely summarizes this development. The pattern of increasing persistence is broken, however, by a large significant coefficient in the earlier period on the lag of prices two years previous. This coefficient, which is positive and characteristic of "sawtooth" movements, has no obvious interpretation. A feedback mechanism such as existed under the gold standard would produce a negative coefficient. It appears to be a fluke and lends support to the importance of measurement error.

The cross-coefficients in these regressions, those showing the effect of price and wage inflation on output, can be interpreted as the response of the monetary system to inflationary pressures. Positive coefficients indicate accommodation, zero coefficients no accommodation, and negative coefficients a counter response. Here I am surprised by the results, and apparently Taylor was also. In the postwar period these coefficients of prices and wages in the output regressions are negative for the first lag and positive for the second. This has the interesting interpretation that policy since World War II has initially opposed inflationary pressures but then accommodated them, possibly as a reaction to the consequences of the initial anti-inflationary actions or in any event as an inability or unwillingness to carry through with them. Although I am surprised to find this in the autoregressions, it is not implausible. The time series pattern of inflation since World War II can be viewed as supporting this interpretation: inflationary movements have fluctuated but overall have tended to rise from cycle to cycle, except (let us hope!) for the most recent episode, 1979–83.

The indicated degree of such accommodation in the pre–World War I period is quite different. The response to wage inflation is weakly negative in the first lag and then zero in the second, indicating either a partial accommodation over the two years or perhaps an immediate strong opposition to inflation that is completed within one year and so is absent from the first lagged year. For price inflation, however, the response in the pre–World War I period is surprisingly positive, and it is significantly positive in the second lagged year. This implies that price movements were more fully accommodated under the gold standard than later under the Federal Reserve System. This may at first seem counterintuitive, but I believe it correctly depicts the dynamics of the gold standard. The vaunted monetary discipline of the gold standard occurred only in the long run. The gold standard took two to three cycles or more to reverse monetary and price developments if they were moderate and not severely out of line with world trends, and it was quite loose in the short run. I and others have pointed out that United States gold specie flows were much smaller than cyclical movements in the foreign trade balance. Most of the cyclical trade imbalances were financed by capital flows, probably because of a general expectation that gold would remain convertible at a fixed exchange rate. The distribution of growing world gold stocks to maintain fixed exchange rates worked slowly over long periods, except when convertibility was threatened, such as by financial panics or by the United

States silver purchase legislation of the early 1890s. The managed monetary regime under the Federal Reserve System, on the other hand, could and usually did act more quickly at first to counter inflationary pressures, but since World War II, unfortunately, inadequately.

The vector autoregression technique allows a description of the path of the variables when a shock to one of the variables occurs. Taylor shows the paths of the variables for the two periods in his figures 11.3 and 11.4 where the contemporaneous correlation between the error terms has been ignored. He suggests that the two periods are best represented by two quite different model interpretations. For the later period he postulates that changes in output depend on the one-year lagged inflation rate and the change in the inflation rate between the two previous years. This is consistent with the results reported for the autoregression equation. It is intended to represent a one-year lagged effect of monetary policy on output. When fit to the data, this equation suggests that policy actions reduce output by 30% of the previous year's inflation rate and by 70% of the change in the inflation rate in the previous year. This differs from a straightforward rule of keeping nominal GNP constant, by which the coefficient for the inflation rate in this equation on a one-year lag would be -1. The fitted equation for the later period thus differs from the GNP rule in that the response is well under unity, and stronger if inflation is increasing than if decreasing.

In the other equation for the later period, price inflation is made dependent on the one-year lagged inflation rate and the expected output gap. This expectation is based on the output equation. The assumption that expected rather than actual output belongs in this equation follows the literature on rational expectations and staggered contracts. Price inflation is persistent because of contracts but partially responds in any year to expected demand, here represented by expected output.

This model for the later period is an interesting and ingenious interpretation of the empirical results. It is useful for comparison with the earlier period. My main difficulty is with its extreme abstraction from the details of the business cycle. Monetary policy is assumed to respond only to inflation and not to output or other variables, and all the contributions to the business cycle other than policy and price responses are subsumed in the error terms. It is anyone's guess whether the cyclical process that is approximated by this high degree of abstraction is valid or misleading.

In comparing the later with the earlier period, what in summary can be said? First of all, prices in the later period lost much of the flexibility they displayed earlier. Unions and longer wage contracts are a major reason. But I believe the later inflexibility reflects more than this: adjustments have become less flexible on a broader scale than can be attributed to union contracts or their influence on costs. Taylor mentions the growth of large business enterprises centralizing price decisions, but inflexibility is just as true of fabricated products supplied by many small firms. The only broad effect that Taylor or anyone else, including me, has been able to identify that stands up is the lessened severity of cyclical fluctuations since World War II and presumably a general expectation that government policies will oppose severe price movements, thus reducing the likelihood that major price or wage changes will have to be made. This shows up in the time series as autocorrelation and greater persistence.

The second conclusion is that in the short run the monetary system did not accommodate price movements in the later period but did so in the earlier period. Taylor suggests that the earlier period reflected the difference between external and internal price shocks. Under the gold standard external price increases from abroad produced trade surpluses and gold inflows along with direct price increases and thus appeared to accommodate the price shock. On the other hand, domestic price increases not matched abroad led to gold outflows and a subsequent contraction. The effect of internal price shocks in the earlier period either occurred very quickly and so was invisible in the annual data or was dominated by the external shocks. The latter is conceivable, but there is no particular reason to believe that external shocks dominated. Although the United States was somewhat like a small open economy in this period and so was subject to influences from abroad, it also generated major internal shocks such as harvest surpluses, banking panics, and the silver agitation.

In any event, I favor Taylor's other explanation, which in my interpretation is to view the gold standard as accommodative in the short run through variations in the gold reserve and as disciplined to be nonaccommodative only in the long run to maintain convertibility.

Finally, although shocks were smaller in the later period, the dynamics of the system translated the shocks into larger and more prolonged movements in output and inflation. The change in dynamics from the earlier to the later period would have produced *larger* cycles in the later period had the shocks not become smaller.

The lack of conclusiveness of the results here is due to the undefined character of the shocks. Taylor alludes to stabilizing developments listed by Arthur Burns in his 1959 presidential address, which included deposit insurance to prevent panics, less fluctuation in dividend payments, automatic fiscal stabilizers, and so on. Most of these are "shocks" only in the sense that they are not directly specified in Taylor's vector autoregression. Moreover, they may not have been independent of the dynamics. As Taylor suggests, price adjustments may have become slower in response to these other developments that reduced the amplitude of the shocks.

The interpretation of these developments I like is that policy became more responsive to output gaps in the later period and that this allowed prices and wages to become less responsive. The effect was both to reduce cyclical fluctuations and to accommodate a gradually rising inflation rate. At first sight the autoregressions appear to contradict this explanation, which implies that the output gap in the later period should have a negative coefficient on its lagged value when in fact it has a positive value. However, the negative coefficient may occur only for contractions in output, not expansions, if policy has been asymmetrical. The vector autoregressions miss such a distinction.

Taylor's analysis forces us to grapple with an apparent change in the degree of accommodation between the earlier and later periods and a reduction in the amplitude of shocks. I find these results generally plausible. My main reservation is that the shocks may be misleading if their large size in the earlier period reflects an inadequacy of the price and output lags for explaining the dependent variables. It might be that a structural representation of both periods would yield exogenous shocks of equal amplitude. A comparison of these periods will remain incomplete until we can empirically demonstrate whether structural changes or a decline in shocks account for the reduction in amplitude of cycles. But my best guess is that mild cycles in both periods were similar in dynamics and shocks and that the periods differ overall because of selected "severe" cycles owing to monetary disturbances, which were a special breed prevalent before World War II.

Comment Stephen R. King

John Taylor has written an elegant paper on interpreting the differences in the cyclical behavior of output and inflation between the eight business cycles that preceded World War I and the eight that followed the World War II. The central difference he identifies between the periods is that the postwar fluctuations in inflation and detrended output display lower variance, but higher persistence, than those before World War I. In fact, the mean peak-to-peak period of the postwar output cycles is 4.2 years, ten months longer than in the prewar period.[1] To distinguish the impulses that initiate cycles from the propagation mechanism that extends them, he examines innovations, or shocks to the system, which

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1. These calculations are computed from a second-order autoregression for the output gap, using the formula for the mean cyclical period given in Taylor (1980): period $= 2\pi/\cos^{-1}(-0.5(1 - a_1 + a_2))$, where a_i are the coefficients of the ith lags in the autoregression for output.

he finds display much lower variance in the second period, and the degree of serial correlation in the responses of the system to shocks, which he finds increases.

A particular strength of the paper is that Taylor interprets the reduced-form evidence gleaned from vector autoregressions (VARs) of de-trended output and inflation in the light of a simple structural model to account for the stylized facts that emerge. The transformation of a mass of data into a few key parameters is very welcome. The model combines "sticky" price setting (with prices unresponsive to contemporaneous demand movements) with a reaction function for aggregate demand policy that implies that the monetary and fiscal authorities respond with some degree of accommodation to output and inflation shocks.

The postwar results, as one might suspect, are quite consistent with the interpretation offered by Taylor's model. The well-known stickiness of wages and prices, combined with partial demand accommodation, leads to a cyclical response of inflation, recession, and eventual return to equilibrium in response to a price shock.

The pre–World War I results do not fit easily with such a model. The shortness of output cycles in the data is consistent with the very low degree of serial correlation of prices (lack of stickiness) in this time period. But the fact that price shocks do not lead to output fluctuations, except contemporaneously, suggests full accommodation by the monetary authority. This is the puzzle Taylor faces us with, since we usually think of policy as being unaccommodative under a gold standard. The resolution of the puzzle is obtained by noting that under a gold standard, imported (but not domestic) price shocks would be accommodated by gold inflows and hence would not necessarily be followed by adverse fluctuations in real output.

Credence is given to this interpretation by adding the growth rate of money to the VAR that Taylor estimates. When this is done, price innovations not only are found to be positively correlated with money shocks, but are also followed by subsequent accommodating monetary movements.[2] For the explanation to be convincing, however, it must

2. Exactly the opposite results hold for the postwar period when it appears that positive output shocks leave money unchanged (and are followed by velocity increases), but price shocks are followed by expansionary monetary growth. These observations, too, are in accord with Taylor's conjectures. The actual equations (estimated for 1893–1914 and 1954–83, with m representing the growth rate of M2 prewar and M1 postwar and t ratios in parentheses) are:

$$\text{Prewar: } m_t = \underset{(2.1)}{.64p_{t-1}} + \underset{(2.4)}{.70p_{t-2}} - \underset{(2.8)}{.52y_{t-1}} - \underset{(1.8)}{.33y_{t-2}} \qquad R^2 = 0.51$$

$$\text{Postwar: } m_t = \underset{(2.1)}{-.59p_{t-1}} + \underset{(4.6)}{1.25p_{t-2}} + \underset{(1.9)}{.25y_{t-1}} + \underset{(0.1)}{.02y_{t-2}} \qquad R^2 = 0.66$$

also be argued that the price shocks really did originate overseas. In view of the desynchronization of the United States cycle from European fluctuations that Moore and Zarnowitz document for the prewar period, this is by no means self-evident. More doubt arises because Taylor is using a deflator for domestic prices to measure inflation, not one that includes the prices of imports directly. It is true, of course, that the rapid expansion of world gold production after 1896 is consistent with the importation of price rises from abroad. Taylor's other conjecture from looking at the output/inflation results is that output shocks were followed by extinguishing monetary fluctuations. The VAR mentioned above also confirms this supposition.

For whatever reasons, then, prewar policy does appear to have been more accommodating of price shocks and less accommodating of output shocks than it was in the postwar period. What does all this have to do with the role of prices and wages in improving macroeconomic stability? Despite the usefulness of Taylor's interpretive model and reduced-form findings, we learn little about the really fundamental difference between the two time periods. Given that wages and prices do appear stickier in the postwar period, is this increase in stickiness a result of more accommodative demand policy followed since the 1946 Employment Act, or was the accommodative policy itself a reaction to an increase in wage and price stickiness? The answer to this question is absolutely crucial in learning from these two periods.

Many reasons have been advanced for "exogenous" reductions in wage and price flexibility: increased concentration in industry, reduction in the role of primary industries and their replacement by service industry, and increased unionization of the labor force. The growing importance of explicit and implicit contracts is also cited by some. But the increased willingness of the government to accommodate fluctuations, either by automatic stabilizers, by institutions such as deposit insurance, or through discretionary policy, will also increase the incentive of private agents to save on costly negotiations by writing long-term contracts.

Since a problem in interpreting the appearance of high coefficients on the lagged dependent variable in an inflation equation as due to inertia is that they may be in part expectational, it might make sense to estimate inflation equations for the two periods with lagged inflation and anticipated nominal GNP growth (in excess of trend real GNP growth) as explanatory variables. If the lagged dependent variable in Taylor's inflation equation was capturing expectations of inflation ac-

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The prewar and postwar contemporaneous correlation coefficients of output and money are .61 and .63 respectively, and the corresponding inflation and money correlations are .29 and .36.

commodation, then such an approach might remove the significance of the lags of the dependent variable in the equation. Doing this for the prewar and postwar samples yields an insignificant sum of coefficients on two lags of inflation of .42 ($F(2,19) = 2.81$) for the prewar period, and a highly significant .67 ($F(2,26) = 47.1$) for the postwar.[3] It seems, therefore, that this simple technique has not found evidence that the increased importance of lags represents purely expectational effects. Inertia still characterizes the postwar, more than the prewar, data. Just as in Taylor's paper, however, there is some limited evidence of stickiness in the prewar period at a two-year lag.

One must applaud Taylor's use of the pre–World War I sample. This interesting period deserves study and provides an instructive comparison with the postwar period. At the same time, one runs the risk of treating the prewar period as though it were the "normal" state of affairs and contrasting it with the postwar era with its "exceptional" price stickiness. A slightly broader comparison might be made with some evidence from an earlier period. David Hume, in his justly famous essay on money, reports that in the last year of Louis XIV (1715) in France, prices rose by only one-third the amount by which money grew. That performance is comparable to postwar behavior in the United States. Perhaps, then, the period that requires special explanation is not the recent quarter-century but the twenty-four years that preceded World War I.

Taylor provides results for both price and wage inflation. To measure wages, he uses hourly earnings in manufacturing, which may not reflect economywide wages, especially in view of the hypothesized changes in relative prices of tradable goods. In his empirical results, he consistently finds lower coefficients on wages than on prices, especially in the prewar sample. Because of this, the moving average results give the appearance of a procyclical real wage before the war. Although this may be true, the lower coefficients on nominal wages, and the consequent cyclical pattern of real wages, may simply be due to measurement error in the wage series and hence may be spurious.

A methodological problem with the empirical analysis is the weight put on interpretation of moving average coefficients, whose statistical significance is not given in the paper. The very weak "fit" of the prewar inflation and output equations (for example, none of the coefficients in

3. The actual equations estimated for 1893–1914 and 1954–83 are:

$$\text{Prewar: } p_t = \underset{(0.6)}{.12p_{t-1}} + \underset{(1.5)}{.30p_{t-2}} + \underset{(1.6)}{.20E(py)_t} \qquad R^2 = .41$$

$$\text{Postwar: } p_t = \underset{(7.0)}{1.06p_{t-1}} - \underset{(-2.4)}{.39p_{t-2}} + \underset{(2.5)}{.27E(py)_t}, \qquad R^2 = .85$$

where a constant and two lagged values of inflation and growth of nominal output and the money supply are used as instruments for contemporaneous nominal output growth.

the prewar wage/output system is individually significant at the .05 level) must be hiding some "true" stickiness from the observer. It would certainly be surprising if any of the moving average terms from that system were significantly different from zero.

Another obstacle to interpreting the moving average coefficients is Taylor's decision to ignore the contemporaneous correlation of the innovations to the two equations, which in the systems he estimates are always significantly different from zero (and positive). Although there are, as he says, an infinite number of possible decompositions of this correlation, his model specifically implies one. Since prices are modeled as being unresponsive to contemporaneous demand shocks, it seems natural to allow price shocks (assuming they represent something more than pure measurement error) to enter the output gap equation contemporaneously. This might upset the interpretation of the output equation as a policy reaction function. In fact, it would lead to a model with three equations—one for price adjustment, one for real GNP, and a monetary policy rule. In any event, given the size of the contemporaneous correlations involved, such an orthogonalization may well make quite a difference to the results.

In conclusion, John Taylor's paper has made a very useful and provocative contribution to the analysis of price/wage interaction in two disparate periods of United States history. If there are still questions to be answered about the roles of wages and prices in the behavior of the economy between the two periods, then this simply underscores Taylor's concluding statement in the paper: that the policy implications of understanding why the Phillips curve has become flatter with the passage of time are sufficient motivation for further study of the issues.

Comment J. Bradford DeLong and Lawrence H. Summers

In his contributions to this volume John Taylor reaches exactly the opposite conclusion from that in our paper (chap. 12); he finds that improved macroeconomic performance has taken place in spite of rather than because of the increased rigidity of wages and prices in the postwar period. Our explanation has the virtue of parsimony. We attribute the major change in economic performance to the major change in economic structure rather than telling a complex story involving offsetting effects. Moreover, Taylor provides no explanation of the forces that have accounted for the huge decline in the variance of aggregate demand shocks he claims took place. As we shall argue below, Taylor's

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theory that monetary policy has become less accommodative over time also seems implausible. He rests his conclusions on bivariate time series analysis of prices and output. We begin by showing that his conclusions can be reproduced in a model where increased price flexibility increases macroeconomic instability and then turn to other aspects of his argument.

Begin with an aggregate demand curve similar to that in section 12.3 of our paper:

$$q_{t+1} = \beta_1(m_t - p_t) + \beta_2(E_t p_{t+1} - p_t) + \epsilon_t \tag{1}$$

and assume perfect foresight for investors:

$$E_t p_{t+1} = p_{t+1}. \tag{2}$$

Equation (1) contains q_{t+1} in order to make the timing come out right: think of firms placing orders for investment goods this period, orders that do not show up in output until next period.

For simplicity, specify a simpler aggregate supply equation than in section 12.2;

$$p_{t+1} - p_t = p_t - p_{t-1} + \alpha q_{t+1}. \tag{3}$$

The inflation rate accelerates or decelerates depending on the output gap. This aggregate supply equation is the simplest that both is "superneutral" and exhibits "persistence."

To close the model, a money supply rule is needed. The simple assumption of section 12.2, the assumption of no movement at all in the money stock will not be a satisfactory underpinning for empirical analysis. We assume:

$$m_t = (1 - \lambda)p_t + \lambda p_{t-1}. \tag{4}$$

The money stock accommodates to the price level partially within the period and fully after two periods. A value of one for λ would imply no accommodation within the period; a value of zero would imply complete accommodation within the period.

Denoting $p_t - p_{t-1}$ by $\dot{p}_t$, solving the model, produces:

$$\dot{p}_t = \frac{1 - \lambda\beta_1}{1 - \alpha\beta_2}\dot{p}_{t-1} + \frac{\alpha}{1 - \alpha\beta_2}\epsilon_t \tag{5}$$

$$q_t = \frac{\beta_2 - \lambda\beta_1}{1 - \alpha\beta_2}\dot{p}_{t-1} + \frac{1}{1 - \alpha\beta_2}\epsilon_{t-1}. \tag{6}$$

Stability requires that:

$$\lambda > \beta_2/\beta_1 \tag{7}$$

$$\alpha < \frac{2}{\beta_2 + \lambda\beta_1}. \tag{8}$$

If ϵ_t follows a white-noise process with unit variance, then solving for the inverse of the variance of output leads to the equation:

$$\frac{1}{\sigma_q^2} = 1 - \left(\frac{3}{2}\beta_2 + \frac{1}{2}\beta_1\lambda\right)\alpha + \left(\frac{\beta_2^2}{2} + \frac{\beta_1\beta_2\lambda}{2}\right)\alpha^2. \tag{9}$$

Therefore further increases in the price flexibility parameter α are destabilizing and *increase* the variance of output, so long as

$$\alpha < \frac{1}{2\beta_2} + \frac{1}{\beta_2 + \beta_1\lambda}. \tag{10}$$

But (7) and (8) imply that α must satisfy (10). In this model, the variance of output is least when α equals zero, when there is no flexibility at all in the aggregate price level.

And yet empirical analysis of a system generated by (1) through (4) would produce results that might mimic quite closely those Taylor obtained for the postwar period. An economist who knew the timing of the aggregate supply equation might be able to recover it exactly:

$$\dot{p}_t = \dot{p}_{t-1} + \alpha q_t. \tag{11}$$

And an attempt to estimate a combined aggregate demand/monetary reaction function equation would yield:

$$q_t - q_{t-1} = \left(-\frac{\lambda\beta_1 - \beta_2}{1 - \alpha\beta_2} - \frac{1}{\alpha}\right)\dot{p}_{t-1} + \left(\frac{\lambda\beta_1 - \beta_2}{1 - \alpha\beta_2} + \frac{1 - \alpha\lambda\beta_1}{\alpha(1 - \alpha\beta_2)}\right)\dot{p}_{t-2}, \tag{12}$$

where $\lambda\beta_1 - \beta_2$, $1 - \alpha\beta_2$, and $1 - \alpha\lambda\beta_1$, are all positive.

These coefficients are too large to be taken seriously. However, their size (but not their sign) is clearly an artifact of the model. The coefficients on $\dot{p}_{t-1}$ and $\dot{p}_{t-2}$ are highly correlated, and the introduction of a supply shock or of serial correlation in the demand shock would quickly bring them down to more reasonable values—their large size in (12) is due to the fact that the difference between $\dot{p}_{t-1}$ and $\dot{p}_{t-2}$ carries lots of information about ϵ_{t-1}. It is interesting that (11) and (12) might be rewritten as:

$$\dot{p}_t = \dot{p}_{t-1} + \alpha q_t \tag{13}$$

$$q_t = q_{t-1} = -\pi_1\dot{p}_{t-1} + \pi_2\dot{p}_{t-2} + u_t, \tag{14}$$

which bear a close resemblance to Taylor's (5) and (7):

$$\dot{p}_t = .88\dot{p}_{t-1} + .25q_t \tag{15}$$

$$q_t - q_{t-1} = -1.03\dot{p}_{t-1} + .73\dot{p}_{t-2}. \tag{16}$$

Therefore we conclude that Taylor's empirical findings are neither evidence for nor evidence against the hypothesis that an increase in persistence has led to an increase in stability. By assuming that the size of the shocks is independent of the structure of the model, he can reach one conclusion. By specifying a different underlying model—one that stresses the role of variations in the real interest rate in producing variations in output—the opposite conclusions emerge.[1]

It is a striking feature of Taylor's structural analysis that in explaining the changes in cyclical patterns between the pre–World War I period and the present one, he finds that all the structural parameters in his model change. Particularly surprising are his conclusions about monetary policy. He finds that it has become less accommodative under the current fiat money regime than it was under the earlier gold standard. He attributes the looseness of short-run monetary policy under the gold standard to the effects of foreign price shocks, which should have led to specie inflows. There are at least two important flaws in this argument. First, it is implausible that, at a time when imports represented only about 6% of GNP, foreign price shocks were the principal source of inflation shocks, especially using the GNP deflator to measure prices. Second, analyses of the gold standard surveyed in Bordo and Schwartz (1984) have made it clear that short-run specie flows in response to price shocks were negligible during the gold standard period. There thus seems to be little evidence for the monetary policy assumptions necessary to drive Taylor's conclusions.

Reply John B. Taylor

In their comments on my paper DeLong and Summers introduce a simple three-equation macromodel to argue their main point. Using this model, they show that a *decrease* in price flexibility—that is, a reduction of the coefficient of demand in the price adjustment equation—leads to a *decrease* in the variance of real output. They assert that this model is roughly consistent with the empirical findings in my paper. Therefore, they argue, my empirical findings support the view that a decrease in price flexibility unambiguously decreases output variance, contrary to my own stated views.

1. Taylor's finding that output is a decreasing function of past inflation is not evidence that the positive effect—through the real interest rate—of inflation on output is small. Taylor's negative coefficient is for an equation that is itself not structural, that is a combination of the aggregate demand equation and the monetary policy reaction function.

Upon closer inspection, however, the model produced by DeLong and Summers is grossly inconsistent with the empirical findings reported in my paper. This inconsistency turns out to be crucial for the question of price flexibility and output variability. The discrepancy between the DeLong/Summers model and the data occurs in their treatment of the stochastic disturbance terms in their equations. These disturbance terms generate the movements in the model that underlie their calculation of the output variance. Although they include a disturbance term in the aggregate demand equation, they put no disturbance terms in the price adjustment equation.

The empirical findings in my paper indicate that disturbances to the price adjustment equation constitute a significant part of the explanation of output fluctuations. Ignoring these shocks could obviously be misleading. Moreover, as I showed in a 1979 *Econometrica* paper, the shocks to the price adjustment equation are what cause the trade-off between output and inflation variance: attempts to stabilize inflation sometimes require increased fluctuations in output, a factor that is ignored throughout the Delong/Summers analysis but that I think is a major factor in the business cycle.

What happens if we add a price shock to the DeLong/Summers price adjustment equation? Suppose that the shock has a variance of 1, and that the shock to the aggregate demand equation has a variance of 4 (these numerical values correspond with the empirical findings in my paper). Suppose also that the coefficient β_1 equals 1, and the coefficient β_2 equals .1. Then for two choices of the policy parameter λ the resulting output variance depends of the coefficient α in the price adjustment equation in the following way:

	Variance of output (q_t)	
α	when λ = .8	when λ = .9
.0	∞	∞
.1	7.87	9.00
.2	6.26	6.91
.3	5.82	6.34
.4	5.69	6.16
.5	5.69	6.16
.6	5.76	6.26
.7	5.89	6.43
.8	6.06	6.68
.9	6.27	7.00

Adding a shock to the price adjustment equation changes the DeLong/Summers results dramatically. Rather than obtaining the minimum value of the output variance when the price adjustment coefficient is zero, we see that the maximum value of the variance (∞) is obtained. The rationale is clear. When demand has no effect on inflation, there is nothing available to stabilize inflation, and the inflation rate takes a random walk with infinite variance. Since inflation appears in the aggregate demand equation, output also has infinite variance. As we increase the price adjustment parameter the variance of output declines, contrary to the DeLong/Summers findings. Only for very large values of the price adjustment term does the variance of output begin to increase again. But such large values are not empirically realistic.

The DeLong/Summers model—appropriately augmented to realistically take account of price shocks—therefore does support the view stated in my paper that an increase in price flexibility would tend to improve macroeconomic performance. In fact their model (with price shocks) is much like the structural model reported and estimated in my 1979 *Econometrica* paper, in which I computed trade-offs between output and inflation fluctuations. In that paper the expected rate of inflation appears in the aggregate demand equation (though with an insignificant negative sign), so that the same possibilities for destabilizing price flexibility, which DeLong and Summers have emphasized, exist in that model. As in this example, such a possibility does not appear to be borne out empirically in the estimated version of that model.

Some of the other criticisms of my analysis that DeLong and Summers raise are irrelevant, in my view. For example, they argue that my explanation of the change in economic performance is too complicated, involving offsetting effects. What is so complex? More stable aggregate demand reduced economic fluctuations more than changes in wage- and price-setting behavior increased them. Many people have investigated the reasons for the increased stability of aggregate demand. That was not the subject of my paper, though I found the revisionist analysis of these issues in the DeLong/Summers paper in this volume fascinating reading. In general, however, how can one defend rejecting a two-step argument that is correct in favor of a one-step argument that is wrong?

DeLong and Summers also question the explanations of my empirical finding that aggregate demand policy appears to be less accommodative under the current fiat money regime than under the gold standard. As the numerical example above shows, the degree of accommodation (as measured by λ) does not change the conclusion that decreased price flexibility increases output variance over the relevant range of parameters. The result also holds for a wide range of values of λ not reported above. In no way is this observed change in the response of aggregate demand policy to inflation "necessary to drive Taylor's conclusions," as DeLong and Summers argue. I found my empirical results on aggregate demand policy surprising and offered some possible explanations, but these results are unrelated to my view of the relation between price flexibility and output variability.

Discussion Summary

Much of the initial discussion focused on the problems involved with Taylor's structural interpretations of his VAR results. Martin N. Baily commented that it seemed impossible to distinguish between aggregate demand and aggregate supply shifts when the reduced- form equations are used. Consequently it was unclear how Taylor's "structure" could be differentiated from a Lucas-type supply function in which price flexibility leads to output fluctuations. Taylor's response was that the dynamics embodied in his VAR results provide evidence for the aggregate demand/supply structure rather than a Lucas supply function. These dynamics show that positive price surprises are associated with negative output movements and hence are identified with aggregate supply shocks. Also, positive output surprises are found, over a longer horizon, to be associated with positive price movements, which is consistent with aggregate demand shocks. Robert Hall remarked that in the classic demand/supply curve estimation problem, Taylor's strategy was equivalent to identifying every price rise with a shift in the demand curve and every price decline with a shift in supply.

Blanchard questioned Taylor's use of a two-variable vector autoregression involving price and output. Since so much of the paper was concerned with the accommodative policies of the government, would not a three-variable VAR including a policy variable like money have been preferable? Taylor replied that he had decided against using a government policy variable for two reasons; first, the problems in finding a satisfactory measure of policy—M1, M2 unborrowed reserves, or such—seemed difficult, and second, the goal of the paper was to place structure on VAR results. This task is difficult enough in a two-variable system. McCallum then noted that the structure Taylor employed essentially involved collapsing the monetary authority's price rule into the aggregate demand curve to arrive at equation (7). McCallum thought that an undesirable feature of the resulting equation was that it implied that the monetary authority could influence the growth rate of real output through its choice of the inflation rate. Taylor agreed with McCallum's interpretation but said he felt equation (7) was justified by the data. In a world of sticky prices, in which the Fed targets nominal GNP growth, its policies can affect real output growth directly.

The final point raised in the discussion was methodological and involved Taylor's procedure for generating the moving average representations shown in tables 11.4–11.7 and figures 11.3 and 11.4. John Geweke declared that VAR techniques can be used for two legitimate purposes: to generate the response of the system to a shock in a particular variable, and to identify how the shocks in each variable feed back from one another over some time period (the "historical decomposition of the series"). Both of these procedures require the researcher to specify how the covariance matrix of the shocks in the system is to be orthogonalized. In constructing his moving average representations Taylor has deliberately avoided specifying such an orthogonalization. He thus ignores the effect of the correlations between the shocks of the two equations on the moving average coefficients. The moving average representations Taylor presents are therefore "partial" in that they ignore the channels for feedback from the other variable. Taylor agreed with Geweke's statements but argued that for the purposes of this paper the "partial" moving average representations facilitated a behavioral interpretation of the results. Transforming the VAR estimates by a sample covariance matrix would only muddle the structural interpretations that could be placed on the resulting moving average representations.

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