Carnegie-Rochester Conference Series on Public Policy 15(1981) 57-86
North-Holland Publishing Company

ON THE RELATION BETWEEN THE VARIABILITY OF INFLATION AND THE AVERAGE INFLATION RATE

John B. Taylor*
Princeton University
and
National Bureau of Economic Research

I. INTRODUCTION

In studying the inflationary experience of the United States during the last decade, many observers have emphasized the extremely high *variance* of inflation which accompanied the high average inflation rate. Some of this variance came from the general acceleration of inflation during the decade, but much came from cyclical fluctuations in inflation. The rate of change of the price deflator for consumer goods and services averaged 6.2 percent per year during the decade, but reached quarterly highs of 11.8 percent in 1974 and again in 1980 and lows of 2.5 and 4.0 percent in 1971 and 1976. This association between inflation and its variability is not unique to the United States economy nor to this time period. A number of historical studies and international comparisons have shown that periods of high inflation regularly coincide with periods of highly variable inflation.

Explanations for this empirical regularity have ranged across several branches of the social sciences and, not surprisingly, have produced a variety of policy implications. Political approaches, for example, have suggested that high average inflation is divisive and weakens government's ability to control aggregate demand. According to this view, maintaining a lower rate of inflation will improve monetary and fiscal control and thereby reduce the variability of inflation. Another view--more case-study oriented in its approach--emphasizes special one-time shocks that increase both the level and the variability of inflation. If this latter view is the whole story, then reducing the average rate of inflation will not affect the variability of inflation.

Recent studies of the welfare effects of inflation have argued that the variability of inflation has high economic costs, arising from the added risk and

*This research was supported by the National Science Foundation. I am grateful to Olivier Blanchard, Alan Blinder, and Robert Lucas for helpful comments.

0167-2231/81/0000-0000/$02.50

uncertainty about average and relative price changes.[1] This suggests that policymakers should aim for a lower variability of inflation than they would in the absence of such costs. Whether low variability is achievable by maintaining a lower average rate of inflation–as is frequently asserted–depends on which of the many explanations of the link between high and variable inflation is the correct one. As usual in policy analysis, it is important to establish as carefully as possible the "structural form" explanation underlying the "reduced form" correlation.

This paper has two main objectives: first, to review and update the empirical evidence showing a link between inflation and its variability; and second, to evaluate, within the context of a particular macroeconomic framework, some of the contending explanations for the link. That some formal framework is necessary in order to discuss the issues with any precision seems obvious, but the choice of a particular framework is less obvious because of the current lack of consensus among macroeconomists about fundamental behavioral theories. Some discussion of the choices made for the analysis of this paper is therefore in order.

The main choice is between contract-based and information-based macro-models.[2] It turns out that both types of models are capable of explaining certain broad-based features of inflation variability, such as the correlation between relative price variance and aggregate price variance. However, the contract-based models seem to do a better job of explaining the distribution of price change by commodity type and by stage of processing as well as the time pattern of relative price change in response to a monetary shock. Because of the advantages of the contract models in explaining these features of inflation variability, and also because of the prevalence of contracts in the economy, the macroeconomic framework chosen here is contract based. In particular, a model with staggered contracts described in Taylor (1980a) is used for the analysis.

Another choice is between what might be called the "comparative regime" versus the more traditional "comparative statics" approach to macroeconomic policy evaluation. Under the "comparative regime" approach, one compares the performance of the economy over a relatively long period of time

---

[1] Friedman (1977), for example, has argued that higher unemployment is a consequence of variable inflation because of added forecast uncertainty, and Evans (1980) and Mullineaux (1980) have provided evidence of such a relationship for the U.S. Fischer and Modigliani (1978) and Fischer (1981) discuss this and other costs of variable inflation. In his cost-benefit study, Phelps (1972) indicated how traditional analyses of the cost of inflation would need to be modified to handle uncertain or variable inflation.

[2] The terminology is used here to distinguish between models of the type considered by Taylor (1980a), for example, versus models of the type considered by Lucas (1973) or Barro (1976), for example. There have, of course, been numerous models of each type developed in the last few years.

under alternative policy *rules.* Using the more traditional approach one evaluates policy by comparing the impact of *single realizations* of alternative paths of the policy instruments. Lucas (1980) and Sargent (1980) have illustrated the distinction between these two approaches in particular historical contexts, and much of the applied econometric work on policy evaluation with rational expectations is based on regime analyses (see Taylor (1979), for example). The relationship between the variance of inflation and the average inflation rate seems to fall naturally into the regime approach to policy evaluation simply because obtaining meaningful comparisons of the average and the variance of inflation requires observing the behavior of an economy for a relatively long period of time. For this reason and also because of the importance of expectations in our analysis, the "comparative regime" approach is chosen here. In particular, the policy regime is defined in terms of a monetary policy rule in which the central parameter is the degree of monetary accommodation to inflation. Although monetary accommodation is an important element in inflation behavior (influencing both relative and aggregate inflation variance), previous studies of the link between inflation and its variability have generally ignored the issue. Our focus on policy regimes will tend to highlight it.

The paper begins by considering the empirical evidence and subsequently developing a simple macroeconomic framework which is generally consistent with the basic facts of inflation variability. The paper then goes on to show how several alternative explanations for the relation between inflation variability and the average rate of inflation can be compared and evaluated within this framework.

II. EMPIRICAL REGULARITIES

The most substantial body of evidence of a correlation between the level and the variance of inflation comes from comparisons of different countries and time periods. By computing the average inflation rate and some measure of *aggregate* inflation variability, such as the standard deviation of the inflation rate over a number of years, it is relatively straightforward to calculate the correlation across countries. This aggregate variability measure and the resulting correlations are the focuses of much of the theoretical analysis of this paper. Closely related to this aggregate inflation variability measure are other concepts of variability which are more directly related to the welfare cost of variable inflation and are useful for discriminating between different explanations and models. The more important of these are: (1) inflation *forecast* variance, which can be measured either from econometric inflation equations or from the actual

dispersion of forecasts of inflation across different individuals at a point in time and (2) *relative* inflation for different commodities at a point in time. As will be described below, the evidence suggests that these latter two notions of variability are strongly correlated with the variability of the aggregate inflation rate. Moreover, forecast variance, but not relative inflation variance, is also strongly correlated with the average inflation rate.

Aggregate Inflation Variability

Okun's (1971) study was one of the first attempts to examine systematically the relationship between inflation and its variability. Okun's aim "was to spell out some reservations" about cost-benefit analyses which had recently been offered as a rationale for moving to a higher average rate of inflation. In support of his view that a move to a higher average rate of inflation would be likely to bring forth a more variable inflation (not considered in cost-benefit analyses at that time), he cited an international comparison of 17 OECD countries during the period 1951-68. Using the standard deviation of the annual increase in the GNP deflator as a measure of variability, he found that countries in his sample with a high average inflation rate also had a high standard deviation of inflation. The United States had the lowest average inflation rate and the lowest standard deviation during this period. Canada, Germany, and the United Kingdom each had progressively higher inflation rates and higher variability.[3] Okun's findings were not left completely uncontested. Gordon (1971) in a companion piece showed that the correlation was weaker though still positive if the international comparison were confined to the 1960s. Gordon showed that the overall correlation of .78 for the entire 1951-68 period could be broken into .90 for the 1951-60 period and .40 for the 1960-68 period.

A more complete international comparison was completed by Logue and Willet (1976) for the period 1949-70. They examined a total of 41 countries including relatively non-industrialized countries and Latin American countries in addition to the OECD countries examined by Okun and Gordon. By breaking the sample into groups they found a strong positive relationship which was nonlinear: for countries with relatively low rates of inflation the correlation between the rate and variability was low; for countries with relatively high rates the correlation was stronger. In addition they found that the correlation was not as strong for the highly industrialized countries. One reason for this simply may be that the highly industrialized countries had relatively low

[3]Okun also looked at a possible relationship between the variance of GNP growth and the variance of inflation. Although the correlation was not strong, he noted that the U.S., Canada, and Germany had above-average variability in GNP growth and below-average variability for inflation. The results were reversed for France and Italy. The macro model described below indicates formally why this negative cross-country correlation might exist.

rates of inflation compared with the rest of the sample. Another reason is that industrialized countries might have more highly developed institutions for the control of aggregate demand policy. A more recent study by Foster (1978) confirmed many of the findings of Logue and Willet (1976), using average absolute changes rather than variances as measures of inflation. Using this same absolute change measure, Blejer (1979a) found that the positive relation between inflation and its variability also holds over time within a number of Latin-American countries.

Recent inflationary experiences in the United States and other large industrial countries provide additional evidence for a positive correlation as well as for nonlinearities in the relationship. Table 1 compares the average rate of consumer price inflation and its standard deviation for seven large industrial economies during the period 1954-79. For this longer period the positive association which Okun described for the years ending in 1968 is quite evident. For this group the United Kingdom and Italy have the two highest averages and the two highest standard deviations of inflation, while Germany has the lowest average and the lowest standard deviation.

In addition to this correlation across countries, there is also a strong correlation over time within each country. This correlation is most evident in a comparison of the 1960s with the 1970s. For every country in the group the average rate of inflation is higher in the 1970s than in the 1960s. With no exceptions, the standard deviation of inflation is also higher. The relationship is illustrated diagramatically in Figure 1. It is striking that there is considerable uniformity in the slope of the relationship over time. The United States, Germany, France, and Canada have about the same increase in the standard deviation of inflation associated with a given increase in the average rate of inflation. Japan, Italy and the United Kingdom have somewhat greater increases. The larger increases for these countries are consistent with a nonlinearity in the relationship. Note that the correlation between the average and standard deviation is quite weak for the 1960s alone. This corresponds with Gordon's finding mentioned earlier. In the context of a comparison of the 1960s with the 1970s, this finding suggests that the correlation is weak for average inflation rates under 4 or 5 percent but becomes much stronger for average inflation rates above this level.

Inflation Forecast Variance

The economic costs of a variable inflation rate–whether or not they are correlated with the average inflation rate–depend in part on the amount of forecast uncertainty which is a direct consequence of this variability. Forecast uncertainty would be expected to reduce welfare by interfering with resource

TABLE 1

International Comparison of The Average
Rate of Inflation and the Variability of Inflation[1]

Country	1954-1979		1960-1969		1970-1979	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
United States	3.96	3.22	2.33	1.49	7.11	2.70
Japan	5.98	4.75	5.48	1.43	9.03	5.91
Germany	3.16	1.78	2.39	0.74	4.84	1.47
France	5.94	3.92	3.85	1.28	8.87	2.75
United Kingdom	6.92	5.81	3.52	1.39	12.64	5.60
Italy	6.64	5.82	3.69	1.92	12.31	5.49
Canada	4.17	3.28	2.52	1.34	7.39	2.86

1. The average and standard deviation of year-over-year rates of change in the CPI for the sample period indicated.

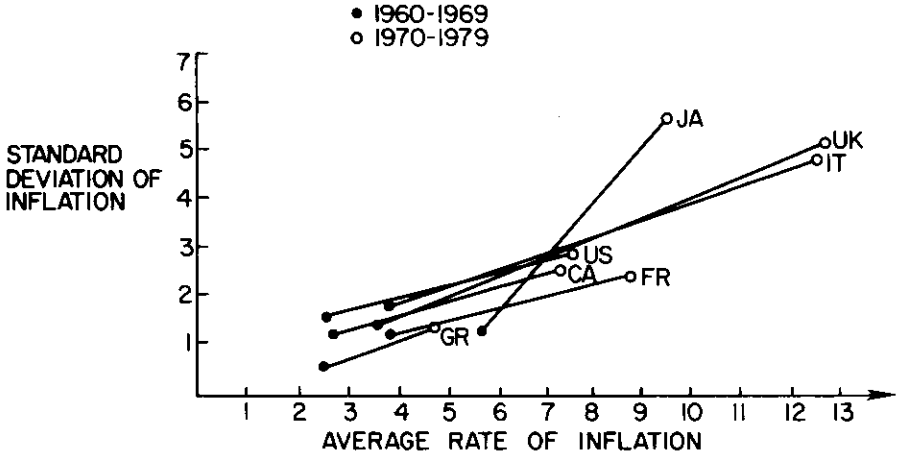

FIGURE 1

INTERNATIONAL COMPARISON OF THE AVERAGE RATE OF INFLATION AND THE VARIABILITY OF INFLATION. SEVEN COUNTRIES 1960-1969 AND 1970-1979

allocation across the economy and over time. Recent empirical work has provided some evidence that forecast uncertainty increases when the variance of inflation increases. As with the correlation between the overall inflation rate and its variability, the direction of causality--or whether other factors are influencing both variables--is not established by this evidence. Nevertheless, the evidence does give some information which can be useful for identifying an appropriate structural model of the inflationary process.

Cukierman and Wachtel (1979) recently examined the relationship between the variance of inflation in the United States and forecast uncertainty, as measured by the inflation expectations dispersion across respondents in the Michigan Survey Research Center (SRC) and Livingston surveys. They found a significant positive correlation for the 1948-1975 period using the Livingston data and for the 1966-1976 period using the SRC data. To the extent that the variance across survey respondents is a representation of the uncertainty in the forecast of an individual respondent (or in the case of the Livingston data, the uncertainty of users of these forecasts), the evidence of Cukierman and Wachtel suggests that higher variability of inflation is associated with greater forecast uncertainty.

Another important result of the Cukierman-Wachtel study is that the variance of real GNP seems to have an additional impact on inflation forecast uncertainty. As will be discussed below, this possibility is important if there is a tradeoff between the variability of inflation and the variability of real GNP. Reducing the variability of inflation may increase the variability of real GNP and thereby offset (though perhaps only partially) the reduction in forecast variance.

Another approach to measuring forecast uncertainty is to estimate econometric inflation equations and use these as approximations to the forecasting procedures used by individual households or firms. The variance of the forecast error in projecting inflation using these equations would then be a measure of forecast uncertainty. Evans (1980) has used this approach to measure forecast uncertainty.[4]

An advantage of this approach is that it can be easily applied to the international comparisons described above. By estimating an inflation forecasting equation for each country, it is possible to obtain an estimate of the forecast uncertainty for each country and thereby see whether forecast uncertainty is correlated with the average rate of inflation as well as with the

[4] As Fair (1979) has pointed out, a proper estimate of forecast uncertainty from econometric models should include measures of uncertainty about exogenous variables and specification errors as well as the usual variance of the estimated coefficients and standard errors. In what follows we consider only the variance of the standard errors.

variability of inflation. Identifying the separate effects of the level and the variability of the overall inflation rate on forecast uncertainty is difficult in a single country setting.

To apply this approach to the seven countries considered earlier we estimated annual inflation equations in which lagged inflation and output were the only explanatory variables. Limiting the explanatory variables by excluding explicit measures of shocks such as productivity shifts and oil price changes seemed appropriate since these cannot generally be forecast with much accuracy. Aside from this omission, this functional form is a close approximation to inflation equations in many econometric models.[5] The results are shown in Table 2 and Figure 2. The standard deviation of the error to the equation (the uncertain inflation shock) is clearly related to the average level of inflation according to these estimates. This suggests that forecast uncertainty increases with the average rate of inflation. It would be useful to check the stability of this result with more general methods of measuring forecast uncertainty in economic models (as described by Fair (1979)), with alternative econometric models, and with different sets of countries. As they stand, the results tend to confirm the findings of the survey-based studies that forecast uncertainty is positively correlated with inflation variability as well as with the average rate of inflation.

Relative Inflation Variability

Information about the behavior of relative prices and their association with the overall inflation rate is useful not only for making judgments about the economic costs of variable inflation but also for determining an appropriate model of the inflationary process. Relative price variability would be expected to have direct economic costs, if it were largely the result of signal-distorting noise. The true signals in relative price movements are benefits, not costs. Attempting to net out the signal from the noise in relative price change, however, is difficult. Consequently, most empirical studies have used measures of actual relative price variability which implicitly include both signal and noise. The use of first differences–that is, computing relative *inflation* variability rather than relative *price-level* variability–can be viewed as an attempt to filter out the noise. But unless all true price signals are long-run trend movements in relative prices, this filter is not sufficiently discriminating. Hence, although they can provide useful information about the inflationary process, such studies do not have immediate welfare implications.

[5]We have also excluded lagged money growth from the equation, though this cannot be justified if money affects prices directly through expectations effects and not solely through its effect on demand. Adding money to these equations would be a high agenda item in a robustness check of this procedure.

TABLE 2

International Comparison of The Average Rate
of Inflation and The Variability of Unanticipated Inflation
1956-1979

Country	(1) Average Inflation Rate	(2) Standard Deviation of Inflation Shocks[1]	(3) Standard Deviation of Inflation	(4) Column (3) less Column (2)
United States	4.29	1.39	3.13	1.74
Japan	6.31	3.71	4.69	.98
Germany	3.35	.89	1.71	.82
France	6.40	3.38	3.71	.33
United Kingdom	7.23	3.28	5.94	2.66
Italy	6.96	3.03	5.96	2.93
Canada	4.48	.94	3.22	2.28

1. Shocks are measured by the residual of a fitted annual inflation equation for each country. These shocks represent unanticipated inflation or the forecast error in a one-period ahead projection. The inflation equation includes two lagged values of the inflation rate and the output gap as explanatory variables. Inflation is measured by annual percentage changes in the CPI and the output gap is measured by the percentage deviation of industrial production from a linear trend.

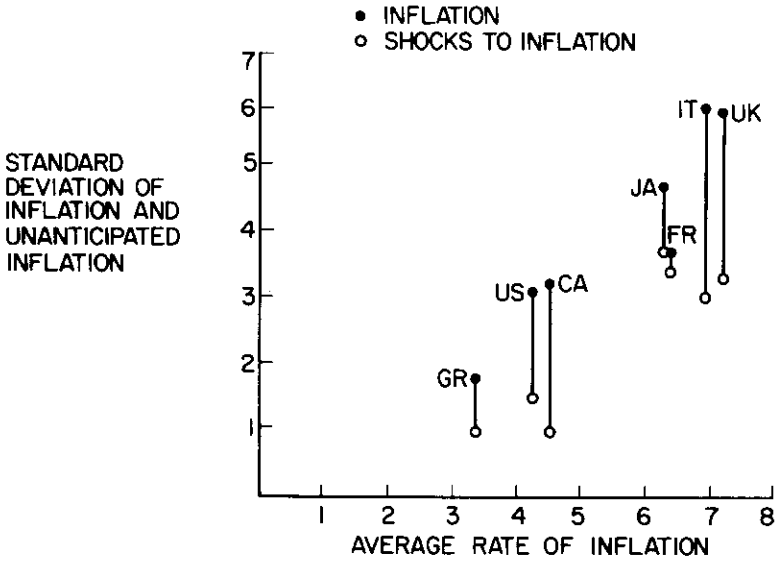

FIGURE 2

INTERNATIONAL COMPARISON OF THE AVERAGE INFLATION RATE, THE VARIABILITY OF INFLATION, AND THE VARIABILITY OF UNANTICIPATED INFLATION (1960-1979)

Two studies which have formed the basis for much of the recent empirical research on relative price variability are those by Vining and Elwertowski (1976) and Parks (1978). Both these studies concentrated on the United States and measured relative price dispersion by the variance of individual commodity inflation rates at a point in time. Using different measures of variability in the overall inflation rate, both studies showed a strong positive correlation between relative and overall price variability. Parks' measure of overall price variability was the first difference in the overall inflation rate, which can be interpreted as a two-period moving variance.[6] Parks also examined the effect of the level of the inflation rate and found that the variability was a much more significant factor in expalining relative price dispersion. In this sense, relative price variability is strongly associated with overall inflation variance but not with the trend inflation rate. Blejer (1979b) found similar results for Argentina during a limited time span in the late 1970s, as did Blejer and Leiderman (1981) for Mexico during the 1951-76 period.[7] The fact that the trend (expected) rate of inflation is generally very weakly associated with relative price dispersion in widely different economic circumstances raises some doubts about the quantitative significance of the type of price adjustment costs developed by Sheshinski and Weiss (1977), for example. This type of model predicts that relative price dispersion should increase with the average rate of inflation, even in the absence of variability in inflation. The results available thus far on relative inflation variability suggest that the link exists only for the variability in the overall inflation rate.

A difficulty with studies which focus on single summary measures of relative price variation (such as the variance) is the loss of information about the behavior of individual price movements. This information could be useful in extracting the signal from the noise (in the case of a specific supply disturbance, for example) or for making judgments about causal or structural relationships. To illustrate these points an alternative nonparametric summary of the data on relative price variability in the United States is presented in Figure 3. The consumer price data corresponds with that used in Parks' parametric analysis. For the 1960s and the 1970s, the unweighted rates of change in the major elements of the deflator for consumer expenditures are plotted along with a defined letter code. (Numerical codes represent points where two or more

---

[6] That is, $(\pi_t - \pi_{t-1})^2 = 2[(\pi_t - \bar{\pi})^2 + (\pi_{t-1} - \bar{\pi})^2]$, where $\bar{\pi} = .5(\pi_t + \pi_{t-1})$. Parks' interpretation was that this first difference represented unanticipated inflation, and his tests attempted to distinguish between what he called anticipated and unanticipated inflation. In a single country analysis, it is difficult to distinguish between squares of unanticipated variables and measures of variability.

[7] Their measure of unanticipated inflation is similar to Parks' but subtracts about two-thirds of the lagged inflation rate from the current inflation rate.

letter codes occupy the same position on the chart. In situations of large relative inflation movements, these multiple points are easy to sort out.) In each quarter the index which is increasing fastest occupies the top position and the slowest rising index the bottom position. These maximum and minimum points have been connected by solid lines to graphically represent the range of variation in relative price movements. The width of the resulting band is then a measure of relative price dispersion which corresponds with the variance measure used by Parks and others.[8] The level of inflation during the period is represented by the height of the band, and the variability of the overall inflation rate is represented by fluctuations in the band.

A number of facts about average and relative inflation in the United States during this period are readily evident in Figure 3: (1) both aggregate variability and relative variability are greater in the 1970s compared with the 1960s; (2) relative price variability is small during the aggregate demand induced acceleration of inflation during the *late* 1960s; (3) the swings in energy prices in 1973 and 1979 dominate the variability measures in the 1970s; (4) the inflation rates for all consumer items rose during these two supply shock periods, not just energy prices; either there were other forces driving up inflation during these periods, or in the process of passing through the system, these energy price shocks raised the inflation rate of other items; (5) there is considerable serial correlation in relative price movements; this implies either that the forces causing these movements are serially correlated or that there is a gradual relative price adjustment in response to a given change in demand or supply.

Figure 3 suggests a causal pattern in which supply shocks rather than demand shocks are responsible for much of the aggregate and relative inflation variability during this period in the United States. In this sense there is a causal ordering in which relative price variability (due to exogenous supply shocks) is the main reason for variability in the overall inflation rate. Moreover, by most interpretations these large relative price shifts represent useful price signals, communicating a shift in energy supply rather than signal-distorting noise.

A recent empirical study of the United States by Hercowitz (1980) reports results which correspond with this causal interpretation, and, in particular, with findings mentioned in points (2) and (3) above. Hercowitz (1980) found that aggregate demand effects (as represented by unanticipated money) had an insignificant effect on relative price variability in the post-war United States and that a much more important role could be attributed to supply effects.[9]

[8]Parks weighted the components by their share in total consumption when computing the variance. In the diagram the rates of change are unweighted.

[9]This finding does not generalize to situations of hyperinflation: Hercowtiz found unanticipated money was a significant factor in relative price dispersion during the Germman hyperinflation.

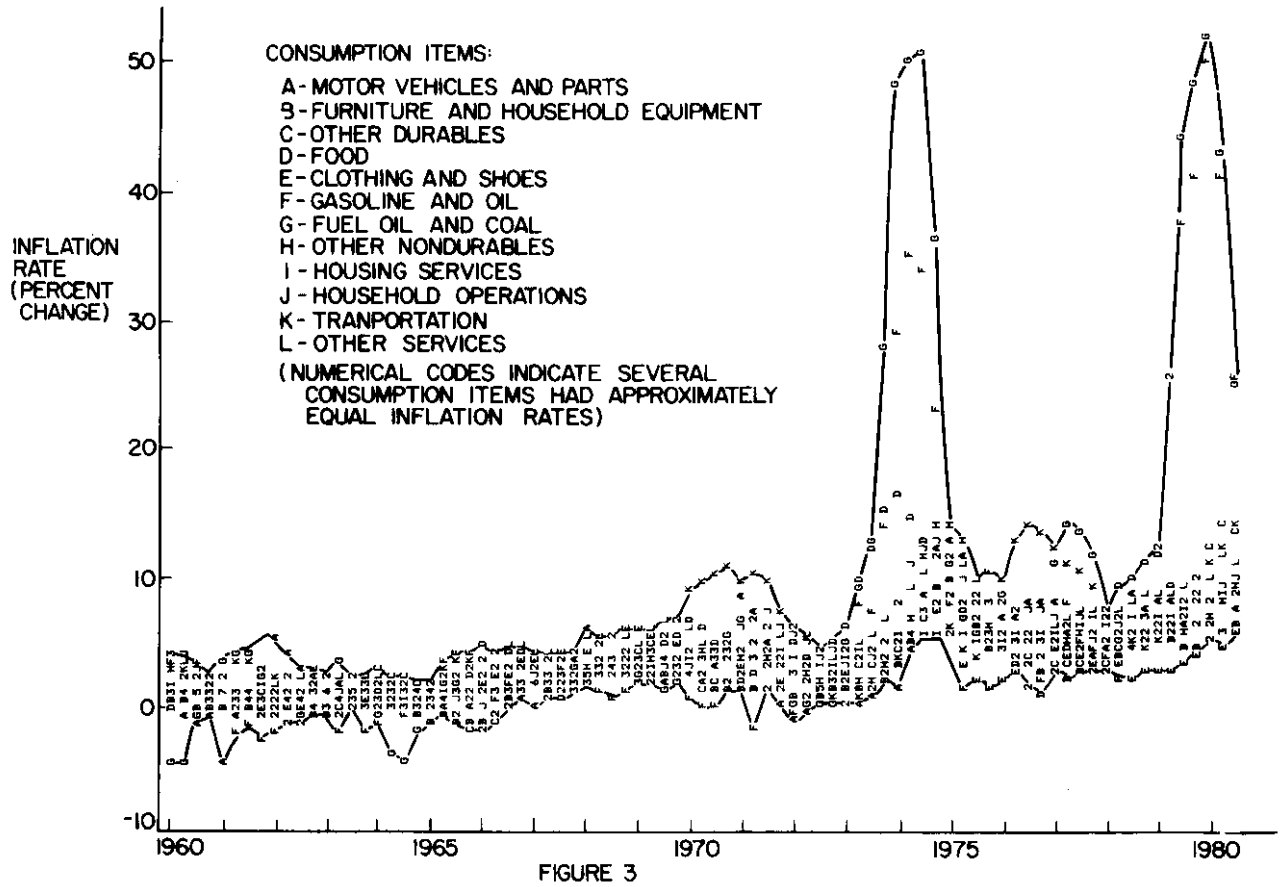

FIGURE 3

RELATIVE INFLATION RATES FOR U.S. CONSUMPTION ITEMS (UNWEIGHTED PERCENT CHANGE OVER FOUR QUARTERS)

It should be emphasized that the results in Figure 3 do not suggest that monetary policy, or aggregate demand policy in general, had a negligible impact on the relative or aggregate price variability during the 1970s. The data show only that the *timing* of large movements in relative prices and aggregate inflation correspond with periods of known supply disturbances. The effect of this initial impact on both relative price adjustments and the total inflation rate will depend on how accommodative monetary policy is to these movements. The policy issue is whether a less accommodative monetary policy could have made the aggregate price adjustments less variable and prevented the accelerations in the rate of inflation. The model presented below indicates that it could have, and in this sense monetary policy cannot be ignored when studying relative price variability, even if monetary *shocks* themselves are not a big factor.

Another feature of relative price variability which is sometimes hidden in summary measures, is variation in adjustment speeds of different commodity prices in response to shocks. Because of contractual arrangements some prices do not adjust as fast as others, and this causes additional variation in relative prices. A recent study by Bordo (1979) has shown that adjustment speeds in response to monetary shocks differ widely by commodity type and stage of processing. Raw materials and agricultural products which are frequently sold on auction markets adjust much more rapidly than manufactured products in which contracting is more prevalent. Cagan (1980) reports similar variations in adjustment speeds across commodity classes in response to aggregate demand changes. These differences in adjustment speed appear to depend on the extent of contractual arrangements in the production and distribution of the commodity. For example, the prices of products in which value added is a large share of the value of shipments tend to be slower to adjust than products with small value added, presumably because of the greater importance of wage payments which are frequently contractual. In sum, disaggregated data on relative commodity prices indicate that contracts are likely to be an important factor in explaining relative price variation and adjustment speeds.

III. A MODEL OF INFLATION VARIABILITY

The empirical regularities of inflation variability described in detail in the previous section can be summarized as follows: (1) There is a systematic tendency for periods of high average inflation to be characterized by high variability of the aggregate inflation rate and high uncertainty about future rates of inflation; (2) there is a strong correlation between relative price dis-

persion and the variability of the aggregate inflation rate.[10] In the United States during the last 20 years the *impulse* behind the movements in relative price dispersion appears to have come from supply shocks rather than aggregate demand shocks. In this section we develop a simple contracting model which explains the correlation between aggregate variability and relative variability, and between aggregate variability and forecast uncertainty. The demonstration that these correlations can be explained by a contracting model may be of some general interest, since almost all previous work on relative price dispersion, forecast uncertainty, and aggregate variability measures have been in the context of information-based models (e.g., Cukierman and Wachtel, and Hercowitz). In the next section we summarize a number of theories which can explain the correlation between the average inflation rate and these variability measures. The explanations are interpreted in terms of parameters of the structural model for the purpose of testing the various hypotheses.

The model is based on research reported in Taylor (1980a, 1980b) and is only briefly summarized here. We consider a version of the model in which all contracts are the same length. A modification to consider alternative patterns of relative price dispersion due to a mixture of contracts of different lengths would be straightforward. All variables in the model are measured as log deviations from trend. The basic equation is the contract determination equation

$$x_t = .5(x_{t-1} + \hat{x}_{t+1}) + \frac{\gamma}{2}(\hat{y}_t + \hat{y}_{t+1}) + \epsilon_t, \tag{1}$$

where x_t is the contract signed at time t and y_t is a measure of market tightness, which will be proxied by the deviation of real GNP from a secular trend. The "hat" over a variable represents its conditional expectation based on period t-1. While the most natural interpretation of x_t is a wage contract of two periods' duration, the model is general enough to permit the interpretation of x_t as a commodity price contract.[11] As with labor contracts, price contracts are generally staggered across firms in the economy. The aggregate price level p_t is defined by

$$p_t = .5(x_t + x_{t-1}). \tag{2}$$

Our interpretation of the model is that $E(x_t - x_{t-1})^2$ represents relative price

[10] But not between price dispersion and the average level of inflation.

[11] In Taylor (1980a) the variable x_t represents the contract *wage*. Hence, the relative dispersion measure (the variance of r_t) would represent wage dispersion across workers disaggregated by contract signing date. The interpretation here is that the variance of r_t represents dispersion across commodities.

variability and the variance of p_t represents aggregate price variability.[12] Both these variances will depend on the shock ϵ_t which we assume is uncorrelated with variance σ_ϵ^2.

The model can be closed with a simple quantity equation for aggregate demand

$$y_t = m_t - p_t + v_t \ , \tag{3}$$

where m_t is the money supply and v_t is a velocity shock, both measured as log deviations from trend. We assume that v_t is uncorrelated with variance σ_v^2. The monetary policy rule is assumed to have the form

$$m_t = \theta p_t + u_t \ , \tag{4}$$

where θ is the accommodation parameter, assumed to be less than 1, and u_t is a serially uncorrelated monetary shock with variance σ_u^2. A larger θ represents more accommodation.

The solution of the model, assuming that expectations are formed rationally, is given in terms of the contract wage by

$$x_t = \alpha x_{t-1} + \epsilon_t \ , \tag{5}$$

where α is a positive function of the policy parameter θ and a negative function of the structural parameter γ. Equations for the aggregate price level and the real output then follow directly and are given by

$$p_t = \alpha p_{t-1} + .5(\epsilon_t + \epsilon_{t-1}) \ , \tag{6}$$

and

$$y_t = -(1-\theta)p_t + u_t + v_t \ . \tag{7}$$

The variances of p_t and y_t are given by

$$\sigma_p^2 = \frac{\sigma_\epsilon^2}{2(1-\alpha)} \ . \tag{8}$$

[12] An alternative measure of relative price variability might be the variance of ϵ_t, since this represents the amount by which the current contract is shocked relative to the past and future contracts. The measure used here seems to correspond more closely with the empirical measures of relative price variability.

$$\sigma_y^2 = (1-\theta)^2\sigma_p^2 + \sigma_u^2 + \sigma_v^2 \quad , \tag{9}$$

if the velocity shocks and monetary policy shocks are uncorrelated. The variance of relative price variability (as defined by $r_t = x_t - x_{t-1}$) is given by

$$\sigma_r^2 = \frac{2\sigma_\epsilon^2}{1+a} \quad . \tag{10}$$

The k period ahead forecast error for forecasting p_t is given by

$$\sigma_k^2 = .25\sigma_\epsilon^2 \left[1 + (1+a)^2 \sum_{i=0}^{k-1} a^{2i} \right] . \tag{11}$$

The expressions in equations (8), (10), and (11) permit us to consider some of the empirical regularities among variability measures in terms of this particular structural model. The variance σ_p^2 corresponds to aggregate variability, the variance σ_r^2 corresponds to relative price variability, and the variance σ_k^2 corresponds to the error in forecasting. The latter may be assumed to be a close proxy to the variability of forecasts across survey respondents, but as the model does not explicitly consider heterogeneous beliefs, the proxy is not precise.[13]

The variance of the shock term ϵ_t appears in each of these expressions, and its impact on the variability measure is positive in each case. Hence, one interpretation of the positive association among the three variability measures is that they each react to changes in the variability of exogenous shocks as represented by ϵ_t. Note that the variance of monetary shocks and velocity shocks does not appear in these expressions. Technically, this is due to our omission of *current* aggregate demand from the contract determination equation. A modification of the model to include y_t rather than $\hat{y}_t$ in the contract determination equation has the effect of adding monetary and velocity shocks as determinants (along with supply shocks) of the price variability measures. However, in light of the recent United States experience as described in the previous section, the extreme emphasis on price (contract) shocks rather than

[13]Cukierman and Wachtel (1981) consider a model with nonuniform inflation expectations. In their model the heterogeneity arises because of differential information across markets. It would be an interesting extension to modify the contract model considered here to allow for such heterogeneity.

aggregate demand shocks implicit in the above variability expressions is not unreasonable.[14]

The effect of monetary policy on aggregate price stability is represented by the parameter a, which is positively related to the accommodation parameter θ. The more accommodative is monetary policy in response to aggregate price movements, the larger will be the variability of aggregate prices. The expression for σ_k^2 indicates that more accommodative policy will also increase forecasting uncertainty for all forecast horizons longer than one period. This contrasts with the effect of σ_ϵ^2, which increased forecast uncertainty for all time horizons. The reason for this difference is that the one-period-ahead forecast error does not involve the parameter a. It is interesting that the relative variability measure is negatively related to a and hence to the amount of monetary accommodation. Drawing policy implications from this result requires a careful decomposition of signal from noise in the relative price measures. This is difficult and beyond the scope of this paper. In the absence of any shocks, relative price variability would be zero by assumption in this model. This reflects our detrending assumptions where all contracts are measured relative to a given trend. If these trends represent the true relative price signals, then the remaining relative price variability can be interpreted as noise. According to these results, the best way to eliminate such noise from the relative price structure (once it is incorporated into existing contracts) is to let new contracts adjust by the full amount of the noise (i.e., choose aggregate demand policy so that $a = 1$). This choice minimizes the variance of r_t but has obvious disadvantages in that it maximizes the variance of prices and the forecast errors. Clearly, there is a tradeoff. In any case, this simple decomposition of signal from noise based on trend is unlikely to be very accurate, as discussed earlier. In reality the shocks ϵ_t are mixtures of signal and noise.

The expression for the variance of y_t indicates how the size of business cycle fluctuations will change according to policy, given the variances of the shocks. There is a tradeoff between output stability and price stability which arises naturally from this analysis. We argue below that this tradeoff is likely to be one of the reasons for the correlation between average inflation and its variability observed across countries.

---

[14] The aggregate variability measure should be interpreted empirically as the variance of deviations of the log of the aggregate price level from a given trend. This is not the same as the variance of the first difference of the logarithm of the price level. It can be shown that the above results on correlation among the variability measures also hold for the variance of the inflation rate. However, some of the results on accommodation which are described in what follows will depend on whether the inflation rate is considered rather than the deviation of the log of the price level from trend. These differences arise because we have specified the money supply to be measured relative to a deterministic trend path. Stochastic detrending of the money supply would enable one to interpret accommodation results in terms of the variance of inflation.

IV. THEORIES OF AGGREGATE INFLATION VARIABILITY

The model described above gives a structural interpretation of the observed relation between the variability measures we have discussed. In this section we consider a number of theories put forth to explain the relationship between these measures and the average rate of inflation. We then go on to interpret these theories within the specific structure of the model. Most of the theories have concentrated on the relationship between the average rate of inflation and the variance of *aggregate* inflation, and our discussion will follow along those lines. However, each of the theories, when interpreted in terms of the model, has implications for the other variability measures. This provides additional information which can be used to check the various theories.

Nonlinearities (γ)

One of the explanations offered by Okun (1971) for the relationship between average inflation and its variability is based on nonlinearities in the response of prices to demand conditions. According to this view, at high levels of inflation the tradeoff is very steep: fluctuations in unemployment, or other measures of excess supply, will be associated with large fluctuations in inflation. In the low inflation area the tradeoff is much flatter: the same fluctuations in unemployment will be associated with small fluctuations in inflation. Hence, for a given amplitude of business cycle fluctuation, the cyclical swings in inflation will be higher if the average rate of inflation is higher.

In terms of the model presented above, the response of inflation to aggregate demand is represented by the parameter γ. According to Okun's nonlinearity, γ should increase with the average rate of inflation. Note, however, that the relationship between aggregate price variability and γ is a *negative* one: a smaller persistence parameter α reduces the variability of aggregate prices, and α is inversely related to γ. The intuition behind this result is that a given contract shock ϵ_t will have a smaller propagation effect on future contracts if γ is high. The more responsive are contracts to a change in aggregate demand pressures, the more quickly contracts will adjust to a shock, given a monetary policy rule which is less than fully accommodative and which, therefore, will be *expected* to result in a decline in aggregate demand. The result depends on our omission of *current* aggregate demand shocks from the contract equation but, as was discussed earlier, recent United States experience suggests that this is not an unrealistic approximation. If this approximation is accurate, Okun's explanation of the relationship between average inflation and its variability is not consistent with recent experience. Moreover, there is some evidence that the sensitivity of

prices to aggregate demand has declined rather than risen as average inflation rates have increased.[15] If so, then a nonlinearity in a direction opposite to the one Okun mentioned might be a factor in the recent rise of both inflation and its variability.

Policy Inefficiencies (σ_u^2, σ_v^2)

Friedman (1977) offered two explanations for the relationship between the variability of inflation and high inflation rates. These explanations play an integral role in the rationale for his "backward bending" Phillips Curve. First, the swings in aggregate demand policy are greater when the average inflation rate is high. According to this view, when high inflation comes (perhaps as a result of high employment policies) there are strong pressures to reduce it; subsequently there is an overreaction.[16] "Policy goes from one direction to the other, encouraging wide variation in the actual and anticipated rate of inflation." Compared with a more efficient aggregate demand policy, this view suggests that high average inflation rates cause larger than optimal swings in the aggregate demand instruments. A second explanation offered by Friedman focuses on the possible social and political divisiveness that can come with a high inflation. If high inflation makes the achievement of a political consensus difficult, then aggregate demand management–which in most Western countries requires political support–can become inefficient. Erratic swings in aggregate demand policy, unrelated to stabilization goals, would be evident in such circumstances and would lead to larger and more erratic swings in inflation.

Within the context of the model used in this paper, these policy inefficiencies could show up in two alternative ways. Over-reaction to inflation might naturally be interpreted in terms of the reaction coefficient for monetary policy, θ. If one thought that a fixed rate of growth for money was optimal, then a value for θ less than zero would represent over-reaction to inflation. According to our formula for σ_p^2, however, lower values of θ will tend to reduce the variance of aggregate prices, given the other parameters of the model and the variances of the shocks. Either over-reaction should not be characterized in terms of the reaction coefficient θ, or over-reaction is not the source of the observed correlation pattern. Under-reaction is a more plausible explanation, as described later.

Another way to characterize these policy inefficiencies is through the

[15] See Cagan (1979) for time series evidence on the sensitivity of prices for the U.S. and Taylor (1980b) for international comparisons.

[16] Okun (1971) offered a similar explanation comparing the economy to a vehicle driving along a highway with intermittent stretches of uncomfortable bumps. "...the brakes have been applied whenever inflation seemed a more serious problem..than idle resources. Such fiscal-monetary 'stops' have produced the characteristic stop-go pattern of the economic time series in Western nations."

monetary shock variance σ_u^2 or the velocity variance σ_v^2. The latter could be high because of erratic fiscal policy. In general, an increase in the variance of such shocks would be expected to increase the variability of prices. As discussed, however, recent evidence on inflation variability suggests that such aggregate demand shocks (as distinct from monetary accommodation) do not appear to be the major explanation behind the fluctuations in relative price variability which has accompanied the fluctuations in inflation.

Policy Preferences (θ)

While policy over-reaction defined in terms of the reaction coefficient θ, does not appear to generate a result consistent with the observed correlations, there are reasons to suggest the opposite: namely, that policy under-reaction–very accommodative policy–is likely to be correlated with high inflation rates across countries. According to this view, the observed correlation is not due primarily to inefficiencies but to a rather efficient government policy apparatus which leads to high inflation was well as variable inflation *by choice.* The notion that a higher average rate of inflation (within a certain range) will result in higher average output levels (with the average taken over the long run) has until relatively recently been widely believed. Such a belief should certainly be taken into account when analyzing policy choice during the postwar period. Moreover, despite the shifting Phillips Curve there are some reasons to expect that a higher inflation rate (again within limits) will permit wider fluctuations in the real rate of interest (the nominal rate being bounded below), thereby allowing better countercyclical policy and a higher rate of average unemployment. In any case, if the policymaking apparatus in the industrialized countries has generated policies taking such a tradeoff into account, then countries which place relatively high weights on employment goals in their social welfare function would tend to have relatively high average inflation rates.

The connection between these high average inflation rates and high variability of inflation comes from another type of tradeoff: that between fluctuations in inflation and fluctuations in output or employment. This tradeoff was discussed above in the context of the contract model. Because of the slow adjustment of these contracts, smaller swings in inflation can be achieved only by permitting larger swings in output. Hence, countries which place relatively high weights on output and employment *stability* in their social welfare function will also tend to choose relatively high variability in inflation. It seems reasonable to suppose that an emphasis on low unemployment would be closely correlated (across countries) with an emphasis on low variability unemployment.

If so, then a correlation between high inflation and variable inflation would be evident in an international comparison.

A test of this theory would require examining the relationship between θ and the average rate of inflation across countries. Although estimating reaction functions is very difficult, some results of an international comparison reported by Taylor (1980b) indicate that countries with high variability of aggregate prices have used more accommodative aggregate demand policy than those with low variability. Hence, this explanation is not inconsistent with the observed correlation patterns.

Cost Push or Supply Shocks (σ_ϵ^2)

One of the most common explanations for the correlation between the variance and the average inflation rate is an appeal to exogenous factors which derive up prices. Recent examples of this approach are found in Blinder (1980) and Frye and Gordon (1980) with special reference to the United States. In terms of the model used here, this explanation could be characterized in terms of the variance of the contract shocks σ_ϵ^2. As we have indicated in previous sections, such an explanation is appealing for the United States in recent years. Known supply shocks coincide with the major periods of large commodity price dispersion and with the fluctuations in aggregate inflation. However, while this is likely to be a good explanation for the impulse effect, the response of monetary policy is crucial for the propagation effect and, therefore, for the variability of the aggregate inflation rate. As our expression for σ_p^2 indicates, aggregate price variability depends on the degree of accommodation as well as on σ_ϵ^2.

A Preliminary Assessment

The preceding discussion has reviewed some of the major theories of the relationship between inflation and its variability, in light of empirical evidence on several variability measures as interpreted from the perspective of a particular macroeconomic model. Although the model is rudimentary and abstract, a number of preliminary conclusions concerning the relative importance of these theories have emerged from this analysis.

First, there is little evidence in favor of the hypothesis that the response of inflation to aggregate demand increases with the average rate of inflation, thereby causing larger swings in inflation. If supply shocks are important relative to demand shocks, then such nonlinearities in the response of inflation would have the opposite effect on inflation variability. Moreover, there appears to be no strong empirical evidence that this type of nonlinearity exists.

Second, there appears to be no strong evidence, especially if we focus on United States inflation behavior over the past 20 years, in favor of the hypothesis that increasingly *erratic* aggregate demand policies have been the source of the increased variability of inflation. Empirical results suggest that monetary shocks are not primarily responsible for the increased dispersion of relative prices which regularly is associated with increased inflation variability in the United States. Further, *over-reaction* of aggregate demand policy to inflation, if interpreted in terms of a monetary reaction coefficient, would tend to reduce the variability of inflation rather than increase it. These types of "policy inefficiency" theories seem to run into difficulties as explanations of the relationship between inflation and its variability in recent years.

Third, there is some evidence that the degree of monetary accommodation–which will affect inflation variability–is correlated with aggregate inflation variability across countries. Countries which choose more accommodative policies tend to have higher variability of inflation. The choice of monetary accommodation and, in particular, the tendency of countries which are more accommodative to be willing to accept higher average inflation rates, is broadly consistent with the facts.

Finally, there appears to be strong evidence that supply shocks have been major contributing factors to the variability of aggregate inflation and relative price dispersion during recent years, when much of the empirical work on inflation variability has been conducted. However, the evidence only suggests that the initial impact on inflation has been due to such shocks. As the model described in this paper indicates, the propagation of these shocks, which could multiply significantly the initial impact on the variability of inflation, depends on the accommodation of monetary policy to these shocks. Some preliminary attempts to isolate the accommodation effect, in an international comparison, using a model similar to the one described here, suggests that a significant amount of inflation variability is due to accommodation effects (See Taylor (1981)). For example, if each of the six countries–United States, United Kingdom, Sweden, Germany, Canada, and Italy–had chosen a monetary policy to give the same ratio of output variability to aggregate price variability, the standard deviation of aggregate price variability across these countries would be reduced by a factor of 2. These calculations have been made using a formula for the variability measures σ_p^2 and σ_y^2 similar to that described above, with the structural parameters obtained using maximum likelihood estimation in the different countries.

V. CONCLUSION

The widely-noted coincidence of the increase in the variability of inflation and the increase in the average rate of inflation in the United States in the 1970s is not atypical when viewed from an international or an historical perspective. A correlation between the average and the variability of inflation has been observed earlier in historical or international comparisons of the inflationary experiences of different countries. This paper has reviewed some of these earlier comparisons and presented more recent evidence which confirms such a correlation. This empirical regularity is potentially important for macroeconomic policy analysis, because the welfare costs of a variable inflation are likely to be significantly greater than for a steady inflation.

The policy relevance of the correlation depends heavily on the economic theory underlying the correlation. Policy actions which exploit this correlation in the absence of such a theory–say, by aiming for a lower average rate of inflation in the hope of achieving a less variable rate of inflation–may fail by altering the structure of the relationship in a way which could not be predicted from the correlation. In econometric terminology, such policy actions should be based on structural relationships rather than simple reduced-form relationships.

A number of economic theories have been proposed to explain the coincidence of high average and high variance inflation. These have been reviewed, and another–based on a tradeoff between the variability of inflation and the variability of real output–has been suggested in this paper. To date, few attempts have been made to distinguish empirically between these alternative theories. The results of this paper suggest that supply shifts have played an important role in the variability of relative and aggregate inflation rates in recent years, apparently more important than erratic aggregate demand policies. Nevertheless, a significant part of the variability in inflation has been due to macroeconomic policy. By determining the degree of accommodation of aggregate demand to inflation, macroeconomic policy influences the *propagation* of these supply shocks into swings in inflation, and hence into the measured variability of inflation. This paper has presented the view that part of the observed correlation between inflation and its variability has been the result of a natural coincidence of high average inflation policies and highly *accommodative* monetary policies. These highly accommodative policies bring forth large fluctuations in inflation in an attempt to minimize the fluctuations in real output and employment.

References

Barro, R.J.

(1976) Rational Expectations and the Role of Monetary Policy, *Journal of Monetary Economics:* 2, 1-32.

Bordo, M.D.

(1979) The Effects of Monetary Change on Relative Commodity Prices and the Role of Long-Term Contracts. Unpublished paper, Economics Department, Carleton University.

Blejer, M.I.

(1979a) Inflation Variability in Latin America: A Note on the Time Series Evidence, *Economic Letters:* 2, 337-341.

(1979b) The Dispersion of Relative Commodity Prices and the Demand for Money under Very Rapid Inflation, unpublished paper, Hebrew University.

Blejer, M.I. and Leiderman, L.

(1981) Inflation and Relative Price Stability in the Open Economy, Working Paper No. 1-81, The Foerder Institute for Economic Research, Tel-Aviv University.

Blinder, A.S.

(1981) The Anatomy of Double Digit Inflation in the 1970s, Conference Paper No. 95, National Bureau of Economic Research, Cambridge, Massachusetts.

Cagan, P.

(1979) *Persistent Inflation: Historical and Policy Essays,* Columbia University Press, New York.

Cukierman, A. and Wachtel, P.

(1979) Differential Inflationary Expectations and the Variability of the Rate of Inflation: Theory and Evidence, *American Economic Review,* **69**: 4, 595-609.

Cukierman, A. and Wachtel, P.
(1981 forthcoming) Relative Price Variability and Non-Uniform Inflationary Expectations, *Journal of Political Economy.*

Evans, P.
(1980) Monetary Uncertainty and the Unemployment Rate. Unpublished paper, Economics Department, Stanford University.

Fair, R.
(1979) An Analysis of the Accuracy of Four Macroeconomic Models, *Journal of Political Economy,* **87**: 4, 701-718.

Fischer, S.
(1981) Towards an Understanding of the Costs of Inflation: II, Carnegie-Rochester Conference Series on Public Policy, 15 eds. K. Brunner and A.H. Meltzer. Amsterdam: North-Holland.

Fischer, S. and Modigliani, F.
(1978) Towards an Understanding of the Real Effects and Costs of Inflation, *Weltwirtschaftliches Archiv,* 114: 810-833.

Foster, E.
(1978) The Variability of Inflation, *Review of Economics and Statistics,* **60**: 3, 346-350.

Friedman, M.
(1977) Inflation and Unemployment, *Journal of Political Economy,* **85**: 3, 451-472.

Frye, J. and Gordon, R.J.
(1980) The Variance and Acceleration of Inflation in the 1970s: Alternative Explanatory Models and Methods, Working Paper No. 551, National Bureau of Economic Research.

Gordon, R.J.
(1971) Steady Anticipated Inflation: Mirage or Oasis? *Brookings Papers on Economic Activity,* 2: 499-510. Brookings Institute, Washington, D.C.

Hercowitz, Z.

(1980) Money and Relative Price Dispersion in the United States, Working Paper No. 433, National Bureau of Economic Research.

Logue, D.E. and Willett, T.D.

(1976) A Note on the Relation Between the Rate and Variability of Inflation, *Economica*, **43**: 151-158.

Lucas, R.E., Jr.

(1973) Some International Evidence on Output-Inflation Tradeoffs, *American Economic Review*, **63**: 326-334.

(1980) Rules, Discretion, and the Role of the Economic Advisor, S. Fischer (ed.), *Rational Expectation and Economic Policy*, University of Chicago Press for National Bureau of Economic Research.

Mullineaux, D.

(1980) Unemployment, Industrial Production, and Inflation Uncertainty in the United States, *Review of Economics and Statistics*, **62**: 163-169.

Okun, A.

(1971) The Mirage of Steady Inflation, *Brookings Papers on Economic Activity*, 2, 435-498.

Parks, R.W.

(1978) Inflation and Relative Price Variability, *Journal of Political Economy*, **86**: 1, 79-96.

Phelps, E.S.

(1972) *Inflation Policy and Unemployment Theory*, New York, Norton.

Sargent, T.J.

(1980) The Ends of Four Big Inflations, Working Paper No. 158, Federal Reserve Bank of Minneapolis.

Sheshinski, E. and Weiss, Y.

(1977) Inflation and Costs of Price Adjustment, *The Review of Economic Studies,* 287-303.

Taylor, J.B.

(1979) Estimation and Control of a Macroeconomic Model with Rational Expectations, *Econometrica,* **47**, 5: 1267-1286.

_____

(1980a) Aggregate Dynamics and Staggered Contracts, *Journal of Political Economy,* **88**, 1: 1-23.

_____

(1980b) Output and Price Stability: An International Comparison, *Journal of Economic Dynamics and Control,* 2: 109-132.

_____

(1981) Cyclical Swings in Inflation and Output: Policy Choice versus Economic Structure, Occasional Paper, Group of Thirty, New York.

Vining, D.R. and Elwertowski, T.C.

(1976) The Relationship Between Relative Prices and the General Price Level, *American Economic Review,* **66**: 699-708.