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INFLATION, UNCERTAINTY AND CAPACITY UTILIZATION

Inflation Expectations and Factor Demands in Manufacturing

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Since the business-cycle trough in the first quarter of 1975, economists have frequently noted the rapid growth in aggregate employment and the rather sluggish growth in real business fixed investment. From March 1975 to July 1978, total employment grew at a 3.5-percent annual rate, compared with a 2.4-percent average annual rate of growth for the previous four business cycles. In contrast, real fixed investment grew at a 5.5-percent annual rate over roughly the same time-span, compared with a 7.3-percent average growth rate in the previous four recoveries.

Against that background, this paper focuses on the role inflation plays in determining the demand for labor and capital in manufacturing. Will inflation tend to increase or reduce the demand for these factors of production, and under what conditions? To help answer the question, we shall consider two measures of inflation variability. The first is a measure of "unanticipated inflation," obtained from errors of forecasts of the wholesale-price index six months into the future. The second measure, referred to here as "relative price variability," is the variance of the rate of change in business capital-good prices, derived from the disaggregated components of the price deflator for business fixed investment. These inflation-variability measures are incorporated into a model of the demand for two "stock" variables, capital and workers, and two "flow" variables, capacity utilization and average weekly hours worked. The demands for these factors of production are considered "interrelated," with the adjustment in one factor affected by the state of the other factors. We statistically estimate the factor demands to determine the impact of inflation variability, and then ask whether the results are consistent with the observed growth in labor and capital in the recovery period beginning in early 1975.

This study suggests that, over the 1959-75 period, unanticipated inflation has tended to reduce the demand for investment goods in manufacturing, and to increase labor demand and the rate of capacity utilization. In addition, anticipated (trend) inflation has had no statistically significant impact on either labor or capital demand. The latter findings lend support to the "natural-rate hypothesis" that there is no permanent beneficial trade-off between anticipated inflation and unemployment.

I. Output Expansion With Known Relative Prices

To understand how inflation may affect the demand for, and utilization of, capital and labor, we must first distinguish between short-run and long-run firm behavior in an environment without any price uncertainty. The "short run" typically is defined as a period with fixed supplies of at least one factor of production, usually capital in the form of physical plant and equipment. The labor force is usually considered variable in the short-run; within certain limits, the labor force can be expanded or contracted to meet the requirement to produce a given amount of output.

The "long-run" is conceptually defined as a period with variable supplies of both factors of production, labor and capital; that is, both are decision variables capable of being expanded to meet desired levels of output.[1] A firm's long-run production problem consists of determining the desired physical plant size and the desired perm-

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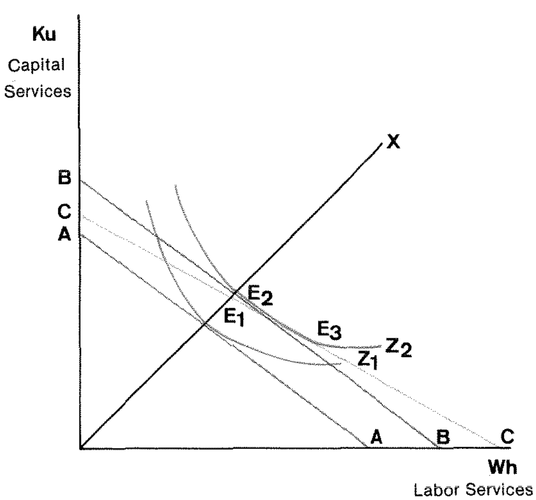
anent work force, while its short-run production problem consists of determining the optimal utilization of capital and labor, with some variation permissible in the size of the work force.

The firm's production process may have two dimensions, a stock and a flow dimension, with output being produced by the flow of services from capital and labor. The stock of capital, K (plant and equipment), times its utilization rate, u, determines capital services; the stock of labor, W (production workers), times its utilization, h (average hours worked) determines worker-hours, or the service flow from labor.

Chart 1 depicts the interaction of capital services Ku and worker services Wh. In the short-run we consider K fixed, while W, u and h are allowed to vary. In the long-run, with u and h set at their long-run "full utilization" levels, both the capital stock and the work force can vary to achieve a higher level of output.

The "constant output" curves Z_1 and Z_2 depict the combinations of capital and labor services that can produce the same output level. (Z_2 represents the higher output level of the two). The line AA is a "constant-cost" line, meaning that the same cost to the firm is incurred by varying expenditures on capital and labor anywhere along line AA. Equilibrium for the firm is achieved at point E, the most efficient combination of capital and labor given the prices of labor and capital. At point E, the ratio of the marginal

Chart 1
Capital and Labor Services



return to labor to the marginal return to capital is exactly equal to the ratio of their respective prices.

"Relative factor prices," that is, the ratio of the price of capital to the price of labor, is equal to the absolute value of the slope of the AA line. Hence, since equal-cost line BB is parallel to AA, line BB represents a greater expenditure on capital and labor but at the same relative prices as exist at constant-cost line AA.

The two equal-output curves Z_1 and Z_2 represent technical (or engineering) relationships between capital and labor. These equal-output curves are shown as "smooth", under the assumption that very small incremental substitutions between capital services and labor services can produce the same output level. The firm's most economical expansion path, with unchanged relative prices, would be along the ray OX, which technically is a straight line for a wide variety of production functions.[2] The ray, OX, depicts those points of minimum production costs, at constant relative factor prices, as the firm expands to higher output levels.

Relative factor prices play an important role, first, in determining the most economical combination of factor inputs for producing a given output level, and, secondly, in determining the ratio of capital to labor as output expands. Chart 1 shows that as output expands from level Z_1 to Z_2 at constant factor prices, with constant utilization rates of capital and labor, capital and labor stocks should expand in fixed proportion. This constant proportionality cannot, of course, be expected to hold over every point throughout a business cycle. However, we should expect long-run factor-expansion proportionality if relative factor prices do not change considerably. Given a significant—and permanent—increase in the cost of capital relative to labor, the firm and the industry will economize on the more costly factor by employing relatively more labor. For example, with the equal-cost line CC, the firm faced with higher capital costs will produce output level Z_2 by moving from E_2 to E_3.

When the firm plans to expand plant size and work force, it does so presumably under the assumption that it knows what relative prices will be during the period when that expansion takes place. Thus, to the extent that inflation (i.e., the rise in the aggregate price *level*) affects long-run factor demands, the firm presumably knows how inflation affects *relative* factor prices over the planning horizon, when initial planning begins. As Chart 1 illustrates, relative factor prices will determine the most economical combination of factor inputs. Anticipated changes in the aggregate price *level* affect factor demands only to the extent that they alter relative factor prices. The relevant question is how inflation might affect relative factor prices, and what response firms are likely to make to both changing relative factor prices and variability in such prices.

Given current corporate accounting procedures, relative factor prices are sensitive to the aggregate rate of inflation even where the future inflation rate is known with certainty. This effect of *anticipated* inflation is analyzed in a recent article by Feldstein, Green and Sheshinski.[3] In their view, the real after-tax return to debt and equity reflects changes in the rate of inflation, because the U.S. tax system taxes the *nominal* income from investment (i.e., nominal interest and nominal capital gains) but permits borrowers to deduct *nominal* interest costs. The firm typically minimizes its total cost of capital by choosing an "optimal" debt-equity ratio, which ratio depends on the schedule of corporate tax rates and the rate of inflation. The shift in the debt-equity ratio due to inflation alters the firm's total cost of capital and, in turn, alters the firm's "implicit rental price of capital," defined as the incremental cost to the firm of a marginal increase in its real capital stock.[4]

The authors further argue that historical cost depreciation causes an implicit taxation of cash flow which increases with the rate of inflation. Quite simply, inflation reduces the real after-tax cash value of a dollar's worth of depreciation generated in the future.[5] This implicit taxation of cash flow is borne by both debt and equity holders. In addition, inflation aggravates a firm's tendency to extend debt in lieu of equity because of the deductability of nominal interest costs. Anticipated inflation, they argue, tends on balance to decrease the net rate of return to capital (which would *increase* the rental price of capital) and, in turn, to reduce the ratio of capital to labor.

These effects of fully anticipated inflation, by increasing the relative price of capital vis-a-vis the price of labor, should be captured in the relative price variable. If inflation causes the rental price of capital to rise more than the inflation-induced rise in wage rates, the firm will expand along a new expansion path, to the right of OX in Chart 1.

Fully anticipated inflation should have no effects independently of the relative price of capital, since it is relative prices which determine demands for factors of production. That is, fully anticipated inflation, and its consequent effects on the debt-equity ratio and the tax value of depreciation, presumably are captured in our measure of the firm's "rental price of capital."[6] Unanticipated inflation, on the other hand, must be incorporated in our model to capture the independent effect of this variable on factor demands in manufacturing.

II. Factor Demand and Unanticipated Inflation

Before considering how firms will respond to measures of inflation variability, we must first consider the aggregate relationship between inflation and employment, specifically, what has come to be called the "natural rate of unemployment" hypothesis. This hypothesis states that employment is a "real" phenomena and can therefore be determined only by other "real" phenomena—that is, it should be independent of any "nominal" phenomena. (Nominal factors, unlike real factors, depend on a monetary unit of account.) The natural-rate hypothesis basically states that there is no relationship (trade-off) between the rate of inflation and the unemployment rate in the long-run. This hypothesis is important because we are interested in the relationship of inflation to manufacturing employment, as well as to manufacturing capital demand and the utilization of capital and labor in that industry. Thus we should consider whether our results are consistent with the natural-rate hypothesis.

The natural-rate hypothesis does not necessarily preclude the existence of a relationship between employment and inflation in the short-run. One recent explanation of this short-run relationship concerns the way individuals form their expectations of inflation—the "rational expectations" argument. According to this argument, individuals have reasonably good knowledge in forming their inflation expectations. While those expectations may be wrong, they are not *consistently* wrong. Hence, there is no *systematic* error in the marketplace's expectations of inflation. (In other words, individuals' expectational errors average out to zero.) Given the basic premise that labor and capital demand is dependent on relative prices, and not on the level or rate of change of prices, the rational-expectations argument implies that any relationship between inflation and factor demand must result from individuals' short-term errors in forecasting inflation. These forecasting errors cause firms to temporarily misjudge current and future relative prices, thereby inducing a *temporary* relationship between inflation and employment. Yet because these errors are not systematic but rather fluctuate around zero, there is no systematic *long-run* relationship between employment and inflation.

Why do firms misperceive the rate of inflation, and thereby create a temporary misperception of relative prices? One possible explanation is simply incomplete information. Specifically, firms may have better present and future knowledge of their input prices, the prices of capital and labor, than of the future aggregate price level which will influence their output price. Thus if firms underestimate inflation, they may be led to believe that their output prices will rise in the future, so that they will then increase their demand for factors of production. This "paradigm of incomplete information"[7] implies that firms have better "local" price information, affecting their input prices, than "global" price information, affecting the aggregate price level. Yet under the rational-expectations model, only aggregate inflation-expectation errors trigger a factor-demand response. This argument thus suggests that factor demand can be affected by only one "inflation stock"—unanticipated inflation—and not by either the variability of input prices or by anticipated inflation acting by itself (independent of relative factor prices).

By including both the relative price variability in investment goods (local information) and unanticipated inflation (global information), we are able to test directly the natural-rate, rational-expectations argument. In the context of the manufacturing industry, this argument states that factor-demand adjustments are triggered by the effects of unanticipated inflation in the aggregate price level, rather than by the variability of inflation in input prices.

Other analysts have considered the aggregate economy impact of unanticipated inflation, but we are interested in an additional question which deserves more empirical investigation[8]—namely, whether unanticipated inflation affects labor demand differently from capital demand. We argue that since unanticipated inflation creates additional uncertainty regarding a firm's future output prices, the firm when expanding output will attempt to minimize the future cost of its forecasting errors by using more of its variable factor, labor, and less of its fixed factor, capital. A similar argument can be found in Albert Gailord Hart's 1940 book *Anticipations, Uncertainty, and Dynamic Planning*.

> "The fact that uncertainty—specifically, a high dispersion of anticipations around the expectation—favors processes under which durable equipment will be held to a minimum lends color to the widely held view that an increase in uncertainty will act upon the firm like an increase in interest rates."[9]

Hart's argument would suggest that, because of greater uncertainty in aggregate inflation, firms will not expand output along the expansion path shown in Chart 1. This variability, as measured by unanticipated inflation, causes greater uncertainty over the real value of future streams of income, so that the risk-averse firm will choose to minimize those investments that are least reversible, such as long-term investment in plant and equipment. This argument complements the Feldstein-Green-Sheshenski argument, which states that a reduction of fixed investment minimizes the implicit taxation of the firm's cash flow due to the use of historical-cost depreciation in an environment of uncertain inflation. Our hypothesis thus states that unanticipated inflation causes changes in factor-demand response by inducing the substitution of labor for capital.

III. Price Variability Data

Two measures of price variability are used in this study. The first measure consists of the variance of the rates of change of prices for individual components of business fixed investment from the average rate of change for the group as a whole.[10] For example, if P_{it} is the price of investment good i in period t, and P_t is the aggregate investment-goods price index, our relative price variance, RPV, measures the nonproportionality of price changes across the entire class of business-investment expenditures. It should be noted that RPV is a measure of *relative* price variability for investment goods.

The second measure of price variability consists of the forecast errors of projections of the wholesale-price index six months in the future. The forecasts have been compiled by Joseph Livingston, the Philadelphia Inquirer's business editor, and have been analyzed and cleansed for computational errors by John A. Carlson.[11] We used simple linear interpolation in order to obtain quarterly data from the semi-annual Livingston-Carlson series. These forecast errors provide a measure of "unanticipated inflation," since they are obtained from actual survey forecasts of wholesale-price inflation. The Livingston-Carlson forecasts can be said to be "rational," in that they utilize past inflation data to produce efficient and consistent inflation forecasts.[12] Thus the unanticipated rates of wholesale-price change utilized in our study appear to provide adequate representations of actual price-forecast errors that would take place in factor markets.

Our data clearly show that relative prices of investment goods displayed a good deal of stability for the 1958-69 period, but considerable variability thereafter (Chart 2). The wholesale-price forecast errors apparently fluctuated around zero during the 1958-72 period, with no prolonged cycle or trend, but they provided substantial underforecasting thereafter (Chart 3). The forecast errors were calculated as the actual price level less the forecast level, divided by the actual level.

Chart 2

Relative Price Variance of Investment

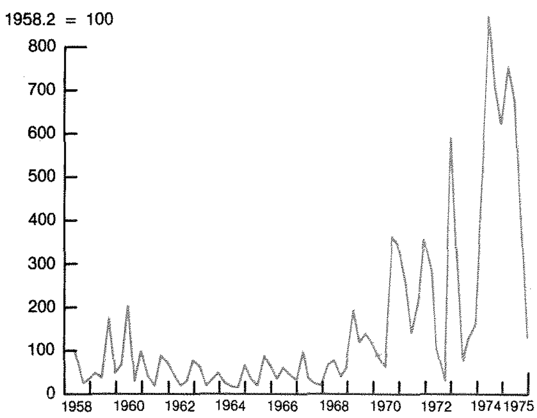
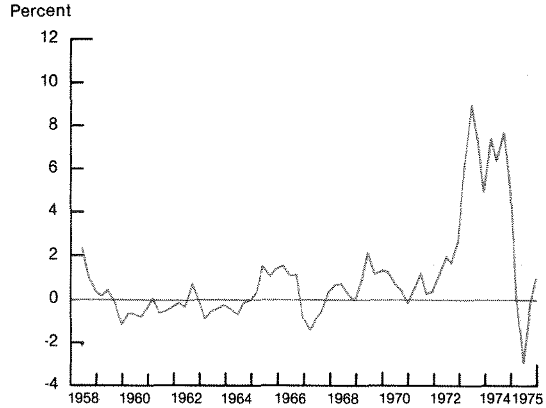


Chart 3

Unanticipated Price Change in Wholesale Price Index*



*6-month Horizon Forecast Error: Actual Less Forecast/Actual

IV. Model of Factor Adjustment Behavior

The factor-adjustment model estimated in this paper assumes that the demand for a factor is dependent on the difference between the desired and actual stock (or utilization) of the particular factor *and* the difference between desired and actual stocks of related factors of production. For example, the demand for labor will depend not only on the difference between the desired and actual stock of labor, but also on a similar differential for the stock of capital. Utilization rates may also affect the demand for stocks. For example, the demand for capital— and also the demand for labor—may rise because a firm is fully utilizing its current capital stock.

Factor demands are divided into four separate categories. Two of them are stocks—physical capital, K, and total manufacturing production workers, W. The other two are flows—the utilization rate of capital, U, and the average workweek in manufacturing, H.[13] At the conceptual level, output, Q, is described as a function of all factor stocks and utilizations, or

$$Q = F(K,U,W,H)e^{\gamma t} \qquad (1)$$

The γ term measures the exponential rate of technical progress in the production function for the firm and, via aggregation over firms, for the industry. If in the short-run the firm considers output as given, and then minimizes costs associated with the production of this output level, it will obtain a "desired factor-demand" equation which is dependent on output, relative input prices and a time trend.

$$Y^*_{it} = f_i(Q,\frac{C}{W},t) \quad i = 1,2,3,4 \qquad (2)$$

where Q is output, C/W the relative user price of capital (i.e., the rental price of capital, C, divided by the wage rate, W), and t a time trend. By substituting (1) into (2) and assuming lagged adjustment, we obtain

$$Y_{it} - Y_{it-1} = \sum_{j=1}^{4} \beta_{ij} \left[Y^*_{jt} - Y_{jt-1} + \lambda_1 w_{1_t} + \lambda_2 w_{2_t} \right] + \gamma\pi_t + \epsilon_t \quad i=1,2,3,4 \qquad (3)$$

where Y_{it} is the ith factor (e.g., workers), Y^*_{jt} is the "desired" level of the jth factor. Equation (3) is the interrelated adjustment model, previously estimated for the manufacturing industry by Nadiri and Rosen.[14] Appended to the adjustment process are the random price-shock terms w_i, which are the price-forecast error and the variance of the relative prices of investment goods. The anticipated rate of wholesale-price inflation, π_t, is included to test the hypothesis that there are no independent effects of *anticipated* inflation aside from the relative rental price of capital. Hence the null hypothesis is that π should have no statistically significant effect on factor demands.

There has been little empirical work measuring the effect of price uncertainty, first, on the firm's optimal long-run capital stock, and secondly, on the adjustment path of capital-stock accumulation. Some theoretical work suggests that output price uncertainty should reduce the optimal capital stock of the firm. But these results, unfortunately, are very sensitive to the a priori specification of the firm's underlying production function.[15]

One important question relates to the differential impact of the two measures of inflation variability on manufacturing factor demands. Does the rise in unanticipated inflation have a significantly different impact on the demand for labor than on the demand for capital? If so, we could obtain a better understanding of the behavior of capital and labor demand in the recent economic recovery.

V. The Estimated Model

To repeat, the desired factor levels, denoted by Y^*_{jt} in equation (3), are assumed to be determined by output, the relative rental price of capital, and a time trend.[16] The relative price variance of investment goods and the unanticipated inflation variable are appended to this factor-adjustment equation. In addition, anticipated inflation (the Livingston series) is included as a independent variable to test the hypothesis that "surprise" or unanticipated inflation provides the major inflation impact on factor demands (aside from the relative user price of capital). All variables except the time trend and the anticipated and unanticipated inflation variables are entered as natural logarithms. The equations for capital, production workers, the average workweek and the capacity-utilization rates were estimated over the period 1959.III to 1975.IV.

As shown in Table 1, the "own rate of adjustment," that is, the portion of the discrepancy between desired and actual stocks or utilization of factors, is measured by one minus the estimated own-adjustment coefficient (e.g., the coefficient on K(t−1) in the K(t) equation). This computation shows that capital adjusts the slowest, as expected, and the average workweek adjusts the most rapidly. These results need to be qualified somewhat, because adjustment in any one factor is constrained or augmented by the gap between desired and actual stocks and utilization rates in other equations. For example, the average workweek and the capacity-utilization rate affect the capital-stock adjustment very little, that is, the coefficients for H(t−1) and U(t−1) are statistically insignificant. However, an increase in the discrepancy between desired and actual production workers will slow this capital adjustment. (In equation (3), lagged factor variables enter with a negative sign, indicating a negative cross-adjustment coefficient on lagged workers in the capital equation.) Similarly, the adjustment in workers, equation (2) in Table 1, is similarly constrained by the gap between the desired and actual capital stock. Interestingly, the estimated capital utilization equation implies that the greater the gap between desired and actual production workers, the greater the utilization of the existing capital stock.

Because of the dynamic specification of our factor-adjustment model, the estimated coefficients on the exogenous variables can only be considered short-run (first period) coefficients. The short-run output elasticities are all statistically significant and reasonable in size except in the capital equation. The relative rental price of capital should, a priori, yield a negative coefficient in the capital equation and positive coefficients in the remaining equations. However, this variable is statistically significant only in the capital equations with the expected negative sign.

As for our three inflation variables, we hypothesized that unanticipated inflation effects ought to predominate over relative price-variance effects if firms respond to "global" price shocks—that is, price shocks over which the firm

Table 1
Estimated Factor Adjustment Equations in Manufacturing (1959III-1975IV)

Explanatory Variables	Dependent Variables* (1) Capital (K)	(2) Workers (W)	(3) Hours (H)	(4) Utilization (U)
Constant	-.005	-.734	2.635	1.974
	(0.0)	(1.0)	(6.3)	(1.6)
K(t-1)	.871	.204	.040	-.098
	(20.6)	(3.1)	(1.1)	(.9)
W(t-1)	.165	.271	-.264	-.464
	(2.3)	(2.5)	(4.5)	(2.6)
H(t-1)	.034	.005	.091	-.071
	(.2)	(.02)	(.6)	(.2)
U(t-1)	.032	.048	.154	.377
	(.4)	(.5)	(2.8)	(2.3)
$\left(\frac{C}{W}\right)_t$ Relative rental price of capital	-.009	.001	-.003	-.008
	(2.9)	(.3)	(1.1)	(.9)
Output (t)	-.042	.448	.158	.767
	(1.3)	(11.0)	(7.1)	(11.3)
Time trend	.0016	-.0050	-.0012	-.0052
	(4.1)	(7.6)	(3.3)	(4.9)
Anticipated inflation (t)	-.0007	.0027	-.0006	.0038
	(.8)	(1.9)	(.8)	(1.7)
Unanticipated inflation (t)	-.0015	.0031	.0010	.0043
	(3.1)	(3.8)	(2.2)	(3.3)
Relative capital price variance (t)	.0002	-.0008	-.0020	-.0018
	(.2)	(.6)	(2.8)	(.9)
$\bar{R}^2$	.9992	.990	.928	.963
D.W.	1.78	1.88	1.99	1.65
RHO	-.30	.41	.39	.36
SER	.0064	.0069	.0038	.0115

* t-statistics in parentheses

has incomplete information. (This hypothesis fits in with that of some rational-expectations theorists.) This result, indeed, is implied by the estimated coefficients. The unanticipated-inflation variable is statistically significant in all of the four factor-demand equations, while the relative price-variability variable is only significant in the average-workweek equation. An increase in unanticipated inflation is found in the short-run to decrease the demand for capital but to increase the demand for workers, the capacity-utilization rate and the average workweek. Also, as hypothesized, anticipated inflation has no independent effect on any of the four factor demands, as this variable is statistically insignificant (at the 95-percent confidence level) in all the equations.

The estimated coefficients represent only the initial-period responses to a change in the exogenous variables. But we are also concerned with "long-run elasticities" (Table 2), which represent the total response of the factors to changes in output, unanticipated inflation and the relative rental price of capital. The long-run coefficients should be used with the estimated coefficients to determine the "reasonableness' of the estimated model.

For the long-run effect of the relative rental price of capital, all signs are as expected except in the workers equation. As expected, a rise in this variable is seen to decrease the demand for capital. The long-run output effects are also of correct (positive) sign in all the equations. And as expected, the largest long-run output elasticities are on capital and labor stocks.

The long-run effects of unanticipated inflation are seen to be negative on capital demand, but positive on worker demand and capacity utilization. There is no long-run effect on average hours worked. These results imply that the overall

Table 2
Long-Run Elasticities

	Exogenous Variable		
Factor	**Relative Rental Price of Capital**	**Output**	**Unanticipated Inflation**
Capital	-.0956	.942	-.0062
Workers	-0.235	.905	.0028
Hours	.0024	.021	.0000
Utilization	.0198	.407	.0057

effect of unanticipated inflation has been to reduce the long-run demand for capital, but to increase the long-run demand for labor and the utilization rate of the capital stock. This would thus imply a decline in the capital-labor ratio in manufacturing. These empirical results are consistent with the theoretical argument of Feldstein, Green and Sheshinski—that inflation reduces the demand for capital—although their argument stems primarily from a rise in steady-state or permanent inflation.

The results displayed in Tables 1 and 2 appear to confirm the hypothesis that inflation affects factor demand in manufacturing through unanticipated inflation, and not through the increased variability in the relative price of investment goods or independently through anticipated inflation. Our results also imply that there may indeed be a persistent long-run increase in labor demand because of unanticipated inflation, but that this positive response in labor demand is compensating for the reduced demand for capital from the same cause. These results would suggest that, in order to reach a better understanding of inflation's long-run impact on the economy, we should consider its effect on capital-investment demand as well as its short-run effect on the demand for labor.

VI. Dynamic Response to Inflation

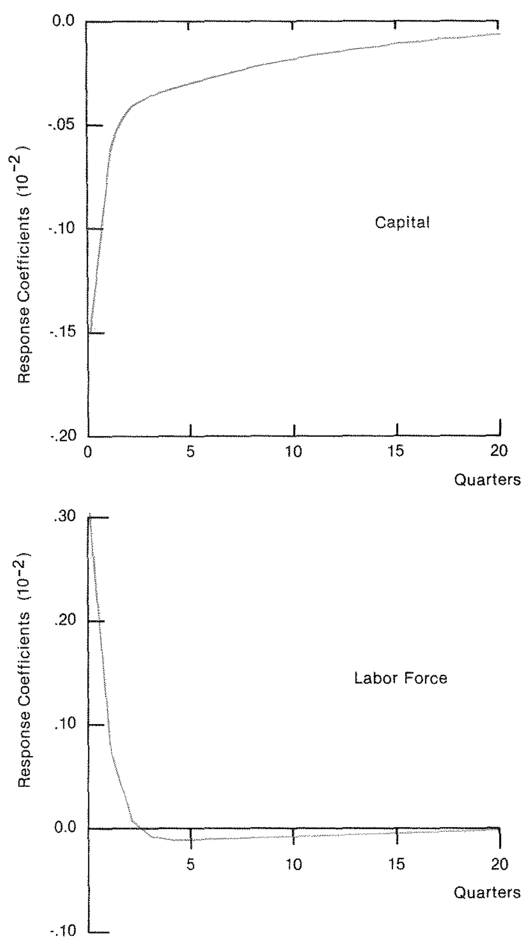
To understand the dynamic behavior of factor demands in manufacturing, we need to ask two questions. First, is the interrelated lagged-adjustment model stable? Technicalities aside, the answer is yes.[17] That is, a unit change in any exogenous variable will cause the factor demand to respond over time, and as time goes on, the level of the factor stock or utilization will return to its long-run equilibrium value.

Secondly, how do factor demands respond over time to a unit change in unanticipated inflation? Because of the interrelated nature of the adjustment process (where, say, the labor adjustment is affected by the current level of capacity utilization) we must use the entire adjustment matrix to see how any one factor demand changes over time.[18] As Chart 4 indicates, the capital stock in manufacturing adjusts suprisingly quickly to unanticipated inflation. Although the response is distributed over twenty quarters, 75 percent of the impact occurs after ten quarters. Again, the demand for workers responds very rapidly to unanticipated inflation, with almost all of the adjustment complete after five quarters.

Most importantly, a rise in unanticipated inflation leads to significant offsetting behavior, with a reduced demand for capital being offset by an increased demand for production workers. Unanticipated inflation, in effect, acts like a rise in the relative price of capital vis-a-vis the price of labor.

"Surprise inflation" thus can have a statistically significant short-run impact on the process of adjustment of factor demands, especially capital and labor. But because of the substitutability of the factors considered here, aggregate inflation shocks can affect their interaction as well. As we have seen, the capital stock tends to be reduced while capital utilization tends to be increased over the long run. Our results contradict the "complete inflation neutrality" proposition that inflation has no long-run impact on real variables. Our results, in contrast, indicate that if significant unanticipated inflation continues over a lengthy period, the capital stock in manufacturing will grow more slowly. Persistent unanticipated inflation thus could lead over time to a fall in the capital-labor ratio in manufacturing.

Chart 4
Response Pattern to a Unit Increase in Unanticipated Inflation



VII. Forecasting the 1976-77 Recovery

To evaluate the forecasting value of our interrelated factor-adjustment model, we performed two types of forecasts for the period 1976.I-1977.IV. The first (static) forecast utilized actual values for all of the explanatory variables. The second (dynamic) forecast utilized known values for all exogenous variables except the lagged values of the endogenous variable for capital stock, workers, hours and utilization. These latter values were set at their previous forecasted values, where the lagged values for 1975.IV were the fitted values obtained in the estimation.

The dynamic forecasts consistently overforecast the capital stock in manufacturing but underforecast workers and the utilization rate. The dynamic forecast was significantly worse than the static forecast only for the capital equation (Table 3). However, the root-mean-square percentage errors indicate that the worst forecasts surprisingly did not occur in the capital equation, but rather in the capacity-utilization equation. The capital and workers equations had almost equal root-mean-square percentage errors, but this statistic was almost double in size for the utilization forecasts.

Since our dynamic forecasts were consistently *less* than the actual rates of capacity utilization, we should not be asking why the aggregate capacity-utilization rate was so *low*, but rather why it was so *high*. Given the interrelated nature of the demand for stocks and utilization of capital and labor, our forecasts indicate that the capacity utilization rate was *higher* during the 1976-1977 recovery period than expected. In isolation, the rate may appear relatively low when compared with previous recovery periods. But this observation ignores the way the utilization of capital interacts with the utilization of labor and the growth in the capital stock and manufactuing labor force.

We used Theil's "U-Coefficient" to further judge the overall forecasting accuracy of the period 1976 I-1977 IV. A U-coefficient which exceeds unity indicates that the ex ante forecast of factor demands does not provide more useful information than a simple "no change" forecast.[19] As Table 3 indicates, the U-coefficient is less than unity for capital and workers, but greater than unity for the average hours and utilization equations. This suggests that the estimated interrelated factor-adjustment model was quite useful in forecasting the demand for capital and workers, but not of much use in forecasting average hours and capacity utilization for the 1976-77 period. Indeed, the U-coefficient is lowest for the capital-stock forecasts. These results support the use of the estimated model in explaining the demand for capital and labor, but they cast doubt on the forecasting properties for the capacity-utilization rate.

We also decomposed Theil's U-coefficient into three components, to analyze further the source of error in the utilization forecasts. The first two terms capture systematic errors that should be avoided in the forecasts, while the last (imperfect covariation) involves nonsystematic random error.[20] As Table 3 indicates, the largest source of forecast error in capacity utilization occurs because of nonsystematic random movements in the capacity-utilization rate. The utilization forecasts have the largest ratio of imperfect covariation to bias. These forecast errors indicate that, during the 1976-77 recovery, relatively greater nonsystematic random behavior occurred in capacity utilization than in capital demand, labor demand or the average workweek. The forecast performance also indicates that the recovery surprisingly was characterized by a greater-than-anticipated rate of capacity utilization.

Table 3
Forecast Performance 1976 I-1977 IV*

	Capital	Workers	Hours	Utilization
RMSE—Dynamic	$1.60 bil.	210 thous.	.263 hrs.	2.144 % points
RMSE—Static	$0.80 bil.	196 thous.	.286 hrs.	1.962 % points
RMS%E—Dynamic	1.3%	1.5%	0.65%	2.63%
RMS%E—Static	0.66%	1.4%	0.71%	2.41%
Theil Inequality Coefficients (Dynamic Forecasts)				
U-coefficient	.422	.904	1.955	1.248
Unequal Central Tendency	.06517	.00176	.00163	.00002
Unequal Variation	.00048	.00137	.00300	.33163
Imperfect Covariation	.16330	.87318	1.1379	1.4493

* RMSE = root mean square error; RMS%E = root mean square percentage error.The RMSE statistics were obained by first taking the antilogs of the forecasted variables.

VIII. Conclusion

Economists only recently have come to consider the effects of price uncertainty on the behavior of the firm, either in output markets or in factor markets. Yet this question must be answered if economists are to be able to explain how inflation affects the real economy. Our tentative evidence suggests that unanticipated inflation can affect the demand for factors of production as well as the utilization of these factors. This type of inflation thus may slow the process of capital growth. Moreover, unanticipated inflation shocks, and their persistent effects over a prolonged period, help explain why investment demand has been sluggish since the early-1975 cyclical trough. While our evidence is obviously tentative, it provides an avenue to a more complete understanding of the inflation-induced factor-demand adjustments in U. S. manufacturing.

Appendix
Deviation of a Risk-Adjusted Rental Price of Capital

Jayant Kalawar and Joseph Bisignano

The procedure used to derive the rental price of capital used in the text is similar in spirit to most other definitions of this variable seen in the investment literature. Basically, the rental price of capital is defined as

$$C = \frac{(1-k)\,(1-wz)}{(1-w)} P_k(r + \delta) \qquad \text{(A1)}$$

where:

- C = rental price of capital
- k = investment tax credit[1]
- w = tax rate for manufacturing corporations, computed as (provision for federal income taxes ÷ income before taxes)[2]
- z = present value of depreciation allowance, computed as

  $$[(1-e^{-dt})/dt]$$

  where:

- d = (Aaa corporate-bond rate) $(1-w)$[3]
- t = tax lifetime of investment goods = $1/\delta$
- δ = depreciation rate = .054511 (constructed by F. Brechling);
- P_k = implicit capital-stock price deflator (constructed by F. Brechling)
- r = total cost of capital in manufacturing, defined as

  $$r = (1-\phi)r_e + \phi(1-w)r_{Aaa}$$

where $\phi = \dfrac{\text{long-term debt}}{\text{long-term debt + stockholders' equity}}$[4]

- r_{Aaa} = Aaa corporate-bond rate
- r_e = cost of equity

It is quite common in investment studies to use some readily available measure of r_e, the cost of equity, such as the dividend-price ratio. This measure for r_e was used here, but the implied rental price of capital was not found to be significant in the capital equation. In fact, utilizing alternative derivations of the rental price of capital, we found the most significant measure of c to be simply $P_k\,(r_{Aaa} + \delta)$. However, this variable was not used because it ignores important tax and equity cost considerations.

One of the authors (Kalawar) suggested constructing a risk-adjusted cost of equity for use in our final derivation of the rental price of capital. This was done by inferring the return demanded on equity from the returns on bonds, the returns on a "risk-free" asset, and measures of the "riskiness" of bonds and equity. To do so we utilized the Sharp-Lintner capital-asset pricing model, assuming that portfolios exist (consisting of all Aaa corporate bonds outstanding and a portfolio of Standard and Poor's 500 common stocks) which are efficient; that is, the risk-return characteristics can be simulated by holding the "market portfolio" in the appropriate proportions. Under this assumption the following relationship holds, (Sd indicates standard deviation):

$$r_e = r_f + \frac{(r_{Aaa} - r_f)}{Sd(r_{Aaa})} * Sd(r_e) \qquad (A2)$$

The above equation describes the "capital market line," with an intercept of r_f (the risk-free rate), and, since both the bond and equity portfolio lie on this straight line, the slope is given by $(r_{Aaa} - r_f) / Sd(r_{Aaa})$. Using this relationship, we can construct a series of expected rates of return on common stock which, in equilibrium, give us the cost of equity. Specifically:

r_e = expected return on equity for S&P 500 stocks;

r_f = yield to maturity, annualized, on 3-month Treasury bills outstanding, quarterly averages;

r_{Aaa} = yield to maturity, annualized, of Aaa corporate bonds outstanding, quarterly averages;

$Sd(r_{Aaa})$ = standard deviation of one-month holding-period returns on all corporate bonds outstanding (industrial and utility) with Moody's Aaa and Aa rating;

$Sd(r_e)$ = standard deviation of one-month holding-period returns on S&P 500 common stocks.

Twelve monthly observations were used to construct the standard deviations defined above, and were computed from the data developed by R. A. Ibbotson and R. A. Sinquefield.[5] The construction of our measure of the cost of equity requires one strong assumption, namely, that the covariance between equity and bond returns is zero. This assumption was made to ease the empirical derivation of the cost of equity.

The derived cost of equity and the ultimate rental price of capital are shown in Charts A1 and A2, respectively.

Chart A1

Derived Cost of Equity Capital

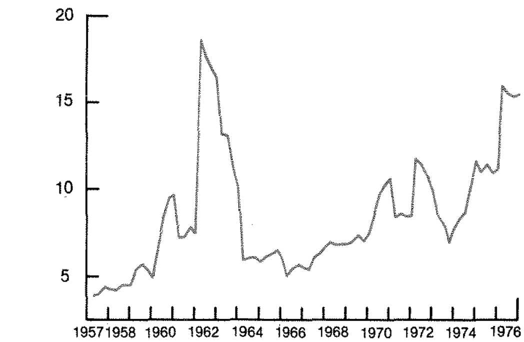
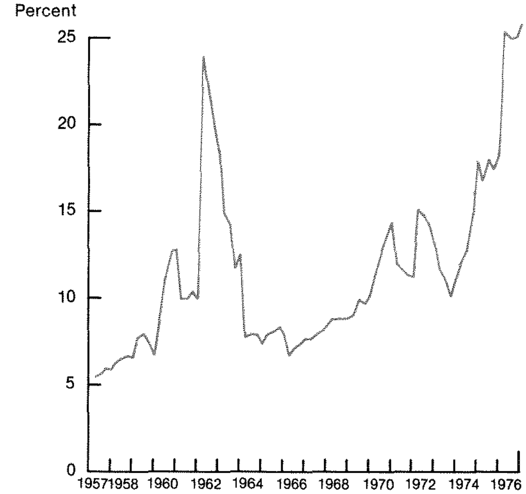


Chart A2

Derived Rental Price of Capital



FOOTNOTES

1. For a concise summary of the important properties of firms' long-run behavior, see Eugene Silberberg, "The Theory of the Firm in 'Long-Run' Equilibrium," **American Economic Review** (September 1974).
2. The expansion path will be linear for any homogenous production function. The intertemporal maximization of the net wealth of the firm usually assumes known fixed prices. See, for example, Dale W. Jorgenson, "Technology and Decision Rules in the Theory of Investment Behavior," **Quarterly Journal of Economics** (November 1973).
3. Martin Feldstein, Jerry Green and Eytan Sheshinski, "Inflation and Taxes in a Growing Economy with Debt and Equity Finance," **Journal of Political Economy,** Part 2 (April 1978).
4. For a derivation of the "rental price of capital" see Dale W. Jorgenson and James A. Stephenson, "Investment Behavior in U.S. Manufacturing, 1947-1960," **Econometrica** (April 1967).
5. See T. Nicolaus Tidemand and Donald P. Tucker, "The Tax Treatment of Business Profits Under Inflationary Conditions," in **Inflation and the Income Tax,** Henry J. Aaron, ed., Brookings Institution, Washington, D.C. (1976). An analysis of the erosion of capital-recovery allowances by inflation is considered for different inflation rates and for different tax-depreciation methods in Eric Schiff, "Inflation and the Earning Power of Depreciable Assets," Domestic Affairs Study 25, **American Enterprise Institute** (November 1974).
6. See the appendix to this paper for the derivation of our "rental price of capital."
7. For a review of the "paradigm of incomplete information" see Herschel I. Grossman, "Why Does Aggregate

Demand Fluctuate?" paper delivered at the August, 1978, meeting of the American Economic Association, Chicago, Illinois.

8. For aggregate studies of the unemployment rate and unanticipated inflation, see R. E. Lucas, Jr., "Some International Evidence on Output-Inflation Trade-offs," **American Economic Review** (June 1973), and Thomas J. Sargent, "Rational Expectations, the Real Rate of Interest and the Natural Rate of Unemployment," **Brookings Papers on Economic Activity** (1973). Regarding the effect of inflation on the employment of fixed and variable factors, Sheshinski and Weiss have shown, in a model of costs of adjustment associated with varying nominal output prices, that a firm will reduce the employment of fixed factors if there is an increase in inflation expectations. See Eytan Sheshinski and Yoram Weiss, "Demand for Fixed Factors, Inflation and Adjustment Costs," Discussion Paper No. 3, Stanford Workshop on the Microeconomics of Inflation (March 1976).

9. Albert Gailord Hart, **Anticipations, Uncertainty, and Dynamic Planning,** University of Chicago Press (1940).

10. The relative price variance, or RPV, is defined as the measurement of the nonproportionality of price movements across a group of expenditure classes. Here the group is business fixed investment. Specifically,

$$RPV_t = \sum_{i=1}^{n} W^*_{it}(DP_{it} - DP_t)^2 \qquad (a)$$

where: $DP_{it} = \log P_{it} - \log P_{i,t-1}$

P_{it} = price index of good i in period t

$W^*_{it} = \dfrac{W_{it} - W_{it-1}}{2}$

W_{it} = expenditure share of good i in period t

$$DP_t = \sum_{i=1}^{n} W^*_{it} DP_{it} \qquad (b)$$

The expression $(DP_{it} - DP_t)$ is seen as the rate of change in the ith relative price, i.e., the logarithmic difference in the relative price P_{it}/P_t, where P_t is the aggregate price level for the group of n goods. Thus the rate of change of the index is defined as the weighted average of the rates of change of the individual goods. Similarly, the relative price variance is defined as the weighted sum of squared deviations of the individual rates of price change around the average rate of change. The rate-of-change price index is recognized as a Divisia price index. The use of such an index was suggested by Richard W. Parks in "Inflation and Relative Price Variability," **Journal of Political Economy** (February 1978). On the use and construction of Divisia indices, see Henri Theil, **Economics and Information Theory,** Rand McNally (1967).

The aggregate investment class used in construction of the RPV series was business fixed investment, composed of structures and producers' durable equipment. Producers' durables equipment was broken down into 27 durable-equipment investment classes. The producers' durable-equipment category is composed of household furniture, other furniture, fabricated metals, steam engines, internal-combustion engines, construction tractors, agricultural machinery, farm tractors, construction machinery, mining and oil-field machinery, metalworking machinery, special industrial machinery, general industrial machinery, office and stores machinery, service industrial machinery, communications equipment, electrical transmission and distribution, household appliances, miscellaneous electrical, trucks, passenger cars, aircraft, ships and boats, railroad equipment, instruments, photographic equipment, and miscellaneous.

11. The data and comments on their construction and interpretation may be found in John A. Carlson, "A Study of Price Forecasts," **Annals of Economic and Social Measurement** (1977).

12. See Donald J. Mullineaux, "On Testing for Rationality: Another Look at the Livingston Price Expectations Data," **Journal of Political Economy,** Vol. 86, No. 2 (1978), and Carlson, cited above. Carlson could not reject the hypothesis at the 5-percent significance level that the consensus WPI forecasts are rational. Mullineaux conducted tests on the Carlson-Livingston consumer price-index forecasts and found that these forecasts were also "rational."

13. One of the early papers incorporating the interrelationship between factor-demand adjustments was M. I. Nadiri and S. Rosen, "Interrelated Factor Demand Functions," **American Economic Review** (September 1969). For an excellent review and extension of the cost-of-adjustment approach to dynamic firm behavior, see Frank Brechling, **Investment and Employment Decisions,** Manchester (England) University Press (1975).

14. See M. Ishag Nadiri and Sherwin Rosen, "Interrelated Factor Demand Functions," **American Economic Review** (September 1969). Their model, based on cost minimization, is more fully described and disaggregated in **A Disequilibrium Model of Demand for Factors of Production,** National Bureau of Economic Research (1973). Two general points should be noted about the estimated interrelated model. In matrix form the model may be written as

$$Y_t = \beta A x_t + (I-\beta) Y_{t-1}$$

where Y_t is the vector of factor levels, β the matrix of adjustment coefficients, A the matrix of behavioral coefficients on exogenous variables (e.g., output, relative prices, etc.) where $Y^*_t = Ax_t$, and x_t the vector of exogenous variables. I is the identity matrix. The matrices of estimated coefficients are βA and $(I-\beta)$. Long-run desired demand coefficients are obtained from

$$[I - (\widehat{I-\beta})]^{-1} \widehat{\beta A}.$$

The dynamic stability of the system of factor demands depends on the characteristic roots of $(I-\beta)$. Stability is obtained if the modulus of the largest root, in absolute value, does not exceed unity. The sequence of distributed-lag coefficients in response to a unit increase in any of the exogenous variables is given by $(I-\beta)^k \beta A$ for $k = 1,2, \ldots$. Note that Nadiri and Rosen assume that firms are at each moment in time on their production functions. This can only be insured by imposing production-function coefficient constraints, usually nonlinear, across the estimated factor equations, which is a non-trivial exercise. The importance of such constraints can be seen in R. M. Coen and B. H. Hickman, "Constrained Joint Estimation of Factor Demand and Production Functions," **Review of Economics and Statistics** (August 1970).

15. Kenneth R. Smith has shown that if the firm produces with a Cobb-Douglas production function, uncertainty with respect to the demand for the firm's output (i.e., when the demand curve is random) will have

the effect of reducing the firm's optimal capital stock. See "The Effect of Uncertainty of Monopoly Price, Capital Stock and Utilization of Capital," **Journal of Economic Theory** (1969). One of the most interesting empirical studies on the role of price expectations in investment demand is Albert K. Ando, Franco Modigliani, Robert Rasche, and Stephen J. Turnovsky, "On the Role of Expectations of Price and Technological Change in an Investment Function," **International Economic Review** (June 1974).

16. The output series used is the sum of manufacturers' shipments and the changes in manufacturers' inventory, both for finished goods and work in progress. This series is then deflated by the wholesale price index for manufacturing to obtain the final real output series. The source of this data is U.S. Department of Commerce, **Manufacturers' Shipments, Inventories and Orders.** See the appendix to this paper on the derivation of the rental price of capital. Capital stock data were provided by Professor Frank Brechling of Northwestern University. These capital-stock data utilize benchmarks of 1948 and 1966. The benchmarks are derived from the **net** capital stocks based on double-declining-balance depreciation (at 1958 dollars) regularly published in the **Survey of Current Business.** Professor Brechling also supplied the estimated price index of investment goods in manufacturing. The utilization rate is the capacity-utilization rate published by the Federal Reserve. Total production workers in manufacturing and the corresponding average workweek may be found in **Employment and Earnings, 1909-75,** U.S. Bureau of Labor Statistics.

17. Stability of the dynamic system is determined by examining the characteristic roots of $(I-\beta)$, where I is the identify matrix and β the (4×4) adjustment matrix. Stability requires that the absolute value of the modulus of the largest root be less than unity. The characteristic roots of the $(I-\beta)$ matrix shown in Table 1 are .901, .129, .290 ± .098i. Since no root exceeds unity the interrelated adjustment system is stable. The hypothesis that the estimated coefficients remained the same over the entire sample period was tested by estimating the model over 1959.3-1968.4 and 1969.1-1975.4, and using an F-test (Chow test) for equality of coefficients during the two sub-sample periods. These F-tests appear below, where

$$F = \frac{(SSR(H_0)-SSR(H_1))/k}{SSR(H_1)/(T_1+T_2-2k)}$$

where SSR = sum of squared residuals
H_0 = hypothesis that coefficients are the same over the two sub-sample periods
H_1 = hypothesis that coefficients are not the same over the two sub-sample periods
T_1, T_2 = number of observations for sub-sample periods
k = number of estimated parameters

F-Tests for Equality of Coefficients

Factor	Calculated F-statistic	Critical $F^{12}_{42}(.05)$
Capital	1.698	1.99
Labor force	0.673	1.99
Hours	0.887	1.99
Utilization	1.270	1.99

The F-tests indicate that we cannot reject the hypothesis that the coefficients remained the same over the two sub-sample periods.

18. The adjustment paths, or more correctly, the impulse-response functions, are calculated as $(I-\beta)^k \beta A$, for k = 0,1,2,..., where β is the adjustment matrix and βA the matrix of estimated coefficients on the exogenous variables.

19. Let F_i and A_i be the forecast and actual percent changes, respectively, for period i, where the forecasts range from 1 to m. Theil's U (inequality) coefficient is here defined as

$$U = \frac{\sqrt{\frac{1}{m}\sum_{i=1}^{m}(A_i - F_i)^2}}{\sqrt{\frac{1}{m}\sum_{i=1}^{m}A_i^2}}$$

The numerator is seen to be the root-mean-square error of the forecast (in percentage change), while the denominator is the root-mean-square error assuming zero forecasted change. Perfect forecasts would yield a U = 0, while U = 1 implies a status quo (no change) forecast. A U greater than 1 implies that the forecasts are worse than the status-quo forecasts. See H. Theil, **Economic Forecasts and Policy,** North-Holland Publishing Company (1965).

20. Theil's U-coefficient was decomposed into three components as follows. The first component, called "unequal central tendency," measures the squared difference in the mean of the actual percentage change to the mean of the forecasted percentage change; it is a measure of forecast bias. The second component, described as "unequal variation," measures the squared difference in the standard deviations of the actual percentage changes and forecasted percentage change. The third component utilizes the correlation between the actual and forecast percentage changes and measures "imperfect covariation" between the two. The first two terms capture systematic errors that should be avoided in the forecasts, while the last involves nonsystematic random error. As we have computed them, the three components do not sum to the aggregate U-coefficient.

APPENDIX FOOTNOTES

1. R. W. Kopcke, "The Behavior of Investment Spending during the Recession and Recovery, 1973-76," **New England Economic Review**, November/December 1977.
2. Securities and Exchange Commission, **Quarterly Financial Reports.**
3. **Federal Reserve Bulletin,** Table 1.36.
4. Securities and Exchange Commission, "Balance Sheet of Manufacturing Corporations," **Quarterly Financial Reports.**
5. R. A. Ibbotson and R. A. Sinquefield, "Stocks, Bonds, Bills and Inflation: Year-by-Year Historical Returns, 1926-1974," **Journal of Business,** January 1976.