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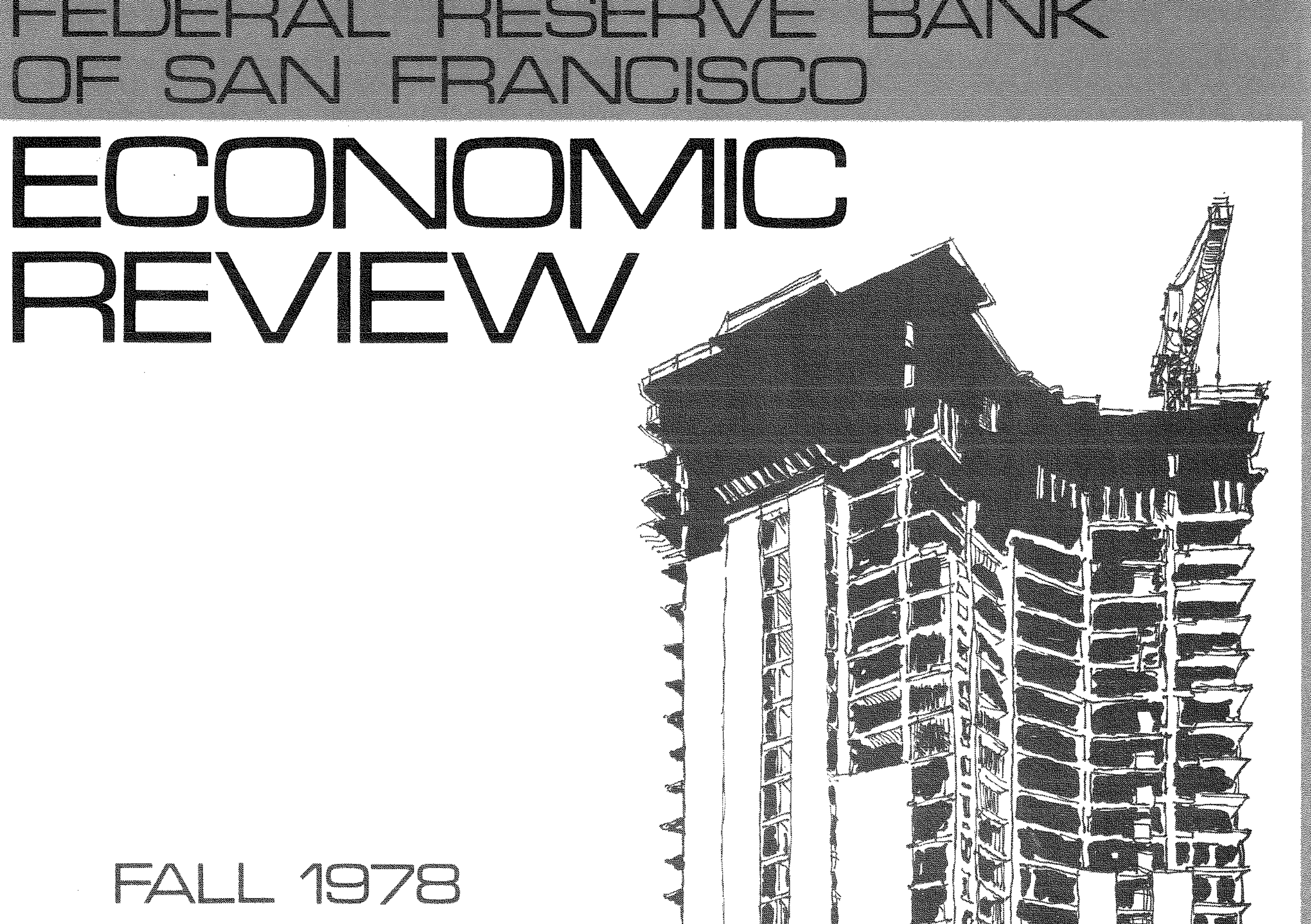

FALL 1978

INFLATION, UNCERTAINTY AND CAPACITY UTILIZATION

Estimating a Stable-Inflation Capacity-Utilization Rate

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Since Phillips' seminal paper in 1958,[1] the economics profession has devoted considerable effort to the study of the linkage between inflation and unemployment rates. That linkage, popularly known as the Phillips Curve, is the result of combining a price and a wage equation. Because wages are related to the unemployment rate, that approach establishes a direct link between unemployment and final-product prices, which are considered to be a variable markup on unit labor costs. Other variables, of course, also appear in the combined price equation. One of these—the capacity-utilization rate—reflects aggregate-demand pressures on existing capacity, and thus is included in the equation because these pressures determine the value of the price/labor-cost markup. Consequently, the combined price equation will contain two excess-demand variables—the unemployment rate, reflecting excess demand in labor markets, and the capacity-utilization rate, reflecting excess demand in final-product markets. This result presents both a problem and an opportunity for those interested in estimating the impact of these variables upon inflation.

First, there is a problem because, with the close historical association between unemployment and capacity utilization, we may not be able with one equation to separate statistically the effects of these two variables upon inflation. The high historical correlation is in part related to the fact that labor demand is a derived demand, so that excess demand in the final-product market tends to produce excess demand in the labor sector. In addition, as recent empirical studies suggest, there may be limited substitutability between capacity and labor utilization. More intensive use of plant and equipment requires more intensive utilization of labor. In general, this results in higher employment (hence, lower unemployment) when capacity utilization rates are rising. In one recent study, Modigliani and Papademos stated that because of the high correlation between the two excess-demand variables, they were unable to estimate separate influences.[2] They therefore dropped capacity utilization from consideration, because they were primarily interested in measuring the inflationary impact of alternative unemployment rates. In this paper, in contrast, we focus upon the inflationary impact of alternative capacity-utilization rates.

Thus, we have the opportunity with our combined price equation, which connects inflation and capacity utilization, to make some interesting comparisons with the inflation/unemployment relation so often discussed in the literature. Two schools of thought may be distinguished in the literature. The "natural rate of unemployment" school believes that there is only one full employment-unemployment rate, towards which the economy tends over time. If government policy attempts to maintain a rate lower than the natural rate, inflationary pressures will accelerate as long as that lower rate is maintained. According to this school of thought, there is no long-run tradeoff between inflation and unemployment. In contrast, the "non-accelerating-inflation rate of unemployment" school takes an eclectic approach to the question of a trade-off. In this view, there may be several equilibrium points, and there may also be unstable inflationary conditions at relatively low unemployment rates, so that no permanent trade-off exists.

Our study suggests the existence of a full-

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capacity utilization rate which is consistent with the "natural rate of unemployment" concept. We can detect no permanent, stable relation between inflation and capacity utilization existing in this country since the early 1950's. Attempts to maintain a capacity-utilization rate above the estimated full-capacity equilibrium rate appear to be associated with a steadily increasing inflation rate.

This raises the question of the actual level of the stable-inflation capacity-utilization rate. In other words, at what point in the use of the nation's industrial capacity are inflationary pressures likely to increase? The recent rate of capacity utilization—still below 85 percent in August, according to the Federal Reserve series—would seem to indicate some slack when compared with the 87-88 percent post-World War II peacetime peaks. Indeed, according to Senate Banking Committee Chairman Proxmire, most witnesses at a recent committee hearing felt that inflationary pressures would not build until those previous peak operating rates had been surpassed.[3] But our historical experience since the early 1950's does not substantiate such a conclusion. Inflation has tended to accelerate well before previous peak rates have been reached; a utilization rate compatible with price stability appears to be a good deal lower than those peak rates.

Our statistical estimates suggest that the equilibrium rate of capacity utilization consistent with a stable rate of inflation falls around 82 percent, or within the range of 80-83½ percent. (In other words, 80 and 83½ percent represent the 95-percent confidence limits of our 82-percent point estimate.) Historically, the rate of inflation increases when capacity utilization rises above 83½ percent, while the rate of inflation declines when capacity utilization falls below 80 percent.

One point should be clarified at the outset. The relationship that we examine between inflation and capacity utilization is one in which overall inflationary pressures are closely linked with those in the U.S. manufacturing sector. If unusual pricing behavior occurs in the farm or import sector, our model will not capture all of the initial inflationary response, and we can observe increasing inflation although capacity utilization rates are within the full capacity limits. In other words, recent increases in inflation which have been attributed to increases in food prices have occurred regardless of aggregate demand pressures on available capacity. Nonetheless, should capacity-utilization rates continue above the 83½-percent upper limit of utilization, we could expect additional inflationary pressures to be generated by the nonfarm business sector of the U.S. economy.

The next section of this paper provides a simple testable model relating inflation and capacity utilization. The following sections present the statistical results and the conclusions of our analysis.

I. Relationship Between Inflation and Capacity Utilization

We are accustomed to think about inflation in terms of the inflation/unemployment relation, referred to as the Phillips Curve.[4] The association between capacity-utilization rates and inflation can be viewed within the context of that relation. As an illustration, we derive here a modified Phillips Curve, which is a general form of those incorporated in most large structural econometric models and recently in several monetarist models of the U.S. economy.[5]

The Phillips Curve is derived from the interaction of two basic structural equations: (1) a price equation relating prices to a markup on unit labor costs and (2) a wage equation relating wage changes to labor-market excess demand and expected inflation. Aggregate-demand pressures—as represented by capacity-utilization rates—affect the markup by which prices are related to unit labor costs. As demand builds and utilization rates increase, for example, the markup on costs may increase as final product prices adjust to eliminate excess demand. An increase in the markup during periods of increasing demand may also reflect noncompetitive pricing behavior by some firms who feel they can raise prices without a serious loss in sales.[6]

A general form of the price equation which incorporates this behavior may be written:

$$IR_t = a_{12}\dot{W}_t - a_{13}\dot{T}_t + f(CU_t - CU^e_t) \quad (1)$$

where a_{12} and a_{13} are estimated coefficients and "f" denotes a functional relationship. The inflation rate (IR) in the current period (t) is related to the rate of change in nominal wages ($\dot{W}$), the trend rate of productivity growth ($\dot{T}$), and a function (f) of the actual measured rate of capacity utilization (CU) relative to its expected normal or equilibrium value (CU^e). The value of f(CU-CU^e) will be zero when measured capacity utilization is equal to its equilibrium rate; rates of utilization above CU^e will lead to higher inflation and rates below equilibrium will lead to reduced inflation.

A general form of the wage equation may be written:

$$\dot{W}_t = a_{21}IR^*_t + a_{23}\dot{T}_t - h(u - u^e)_t \quad (2)$$

where a_{21} and a_{23} are estimated coefficients and "h" denotes a functional relationship. IR* represents the expected inflation rate, u is the measured unemployment rate and u^e is its equilibrium value. The difference $(u - u^e)$ represents that part of unemployment most responsive to changes in excess-demand pressures. Here, as in the rest of the paper, excess demand may be positive (reflecting greater quantity demanded than supplied) or negative (reflecting greater supply). The unemployment rate, or more exactly, $(u - u^e)$, enters the wage-adjustment equation as a proxy variable representing excess labor demand. According to the equation, when excess demand for labor is zero, inflation-adjusted wages ($\dot{W}_t - a_{21}IR^*_t$) will rise in proportion to the trend rate of growth in labor productivity, $\dot{T}$.[7]

We may derive a semi-reduced-form relationship for the inflation rate by substituting equation (2) into (1):

$$IR_t = a_{12}a_{21}IR^*_t + (a_{12}a_{23} - a_{13})\dot{T}_t - a_{12}h\,(u - u^e) + f(CU - CU^e) \quad (3)$$

Equation (3), the general form of the Phillips relation, provides the framework for the statistical tests in this paper. But before we can estimate that equation, we must first specify the functional forms "h" and "f" and the variables in the equation. We assume that the functions "h" and "f" are linear, and we define the variables as follows:

$IR^*_t = IR_{t-1}$

Last period's inflation rate, measured by the percentage change in the GNP implicit price deflator, represents this period's expected rate.

$\dot{T}$ = TIME.

The trend rate of labor productivity (output per worker hour) is represented initially by a simple linear time trend; and alternatively by a two-year and a three-year moving average of output per worker-hour.

CU = Federal Reserve capacity-utilization series for total manufacturing.

u = unemployment rate of prime-age males (25-54)

This rate appears to be a better cyclical indicator of demand pressure than the overall unemployment rate, which has tended in the past decade to reflect the changing structure in labor markets.[8]

All estimates use annual data. We further assume that the equilibrium rates of unemployment for prime-age males (u^e), and capacity utilization (CU^e), have been constant over the 1953-77 sample period. Regarding the prime-age unemployment rate, available data suggest that the rate averages roughly 3 percent at peacetime cyclical peaks, with no discernible trend. Regarding the capacity-utilization rate, recent theoretical studies suggest that the equilibrium rate of utilization is dependent upon economic costs and the degree of labor-capital substitutability, and therefore may vary over time.[9] However, we maintain the hypothesis of a constant CU^e on the basis of our initial estimates of the impact upon that rate of such economic variables as the relative cost of capital to labor which were statistically insignificant. (This point is reinforced by Joseph Bisignano's article in this *Review*.) With these specifications, and with the incorporation of both equilibrium values in a constant term, equation (3) may be written:

$$IR_t = b_o + b_1 IR_{t-1} + b_2 TIME - b_3 u_t + b_4 CU_t \quad (3')$$

where

$$b_o = (b_3 u^e - b_4 CU^e)$$
$$b_1 = a_{12} a_{21}$$
$$b_2 = (a_{12} a_{23} - a_{13})$$

Economic theory and statistical results reported in the literature suggest the values of some of the coefficients in equation (3′). We expect that the coefficient of the trend term in labor productivity, b_2, will not differ significantly from zero. This can be seen from the elements of b_2. The values a_{12} and a_{13}, derived from the price markup equation (1), are the coefficients associated with the change in nominal wages ($\dot{W}$) and productivity ($\dot{T}$), respectively. In statistical tests of the price equation, these coefficient values generally are equal and are close to unity.[10] This indicates that the relevant measure for pricing decisions is a measure of standard unit labor costs ($\dot{W} - \dot{T}$); consequently, changes in money wages and trend productivity would have the same quantitative impact (but in the opposite direction) and would be completely passed through to final prices. In addition, we expect $a_{23} = 1$. This reflects the assumption that, in equilibrium, the rate of change in real wages is equal to the rate of change in labor productivity.

We expect to find a close, although not perfect, association between changes in unemployment (u) and capacity utilization (CU), since both reflect pressures originating from excess demand in product markets.[11] In addition, recent empirical evidence suggests that there is limited substitutability between capacity and labor utilization. The high correlation between the two may prevent our obtaining independent estimates of the impact of either one on the inflation rate in equation (3′).[12]

Our estimate of equation (3′) did, in fact, substantiate our expectations concerning the significance of the independent variables. In particular, the trend coefficient, b_2, was not significantly different from zero, and neither excess-demand variable added significantly to the determination of inflation. Each was significant, however, when equations were estimated with only one or the other included. These results are shown in Appendix 1.

Given the above conclusions, we may drop the time trend from equation (3′) and include capacity utilization as the sole proxy for excess demand in the model. Other analysts, more interested in the unemployment/inflation relation, have dropped capacity utilization from their models.[13] Our interest, however, lies with the capacity-utilization variables, which leads us to replace equation (3′) with the following general form:

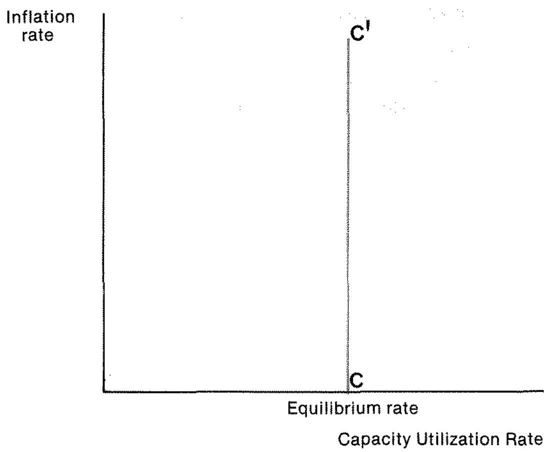
$$IR_t = d_1(CU_t - CU^e) + d_2 IR_{t-1} \quad (4)$$

According to this specification, capacity utilization and inflation rates are linked in the current period through the value d_1, but it is not a unique contemporaneous relationship, since current inflation depends also on past inflation through the lagged inflation-rate term. Our ability to associate a certain inflation rate with a certain level of capacity utilization depends upon the value of $d_1/(1\text{-}d_2)$, and crucially upon the value of d_2, the coefficient of past inflation.[14] If d_2 is less than unity, past inflation rates will become less and less important over time, and eventually will tend to have no impact on current inflation. Under such circumstances, we will observe in the long-run a unique, stable relationship developing between capacity utilization and inflation. A higher rate of capacity utilization will become associated with a higher rate of inflation, and conversely. It would be possible, then, for an economy to lower its inflation rate by maintaining over time a lower average rate of capacity utilization.[15]

On the other hand, when d_2 is equal to one, the expression $d_1/(1\text{-}d_2)$ is infinite, so that no unique association exists, even in the long-run, between capacity utilization and inflation. A long-run curve relating the two variables is vertical, as illustrated by the line cc′ in Chart 1. Under these circumstances, a given operating rate will be consistent with any rate of inflation, and the equilibrium inflation rate will be determined by other factors.[16]

In statistical tests of equation (4)—under a variety of specifications for the lagged structure, the sample period and the inflation aggregate—

Chart 1
Inflation–Capacity Utilization Equilibrium Relationship
When Coefficient on Past Inflation is Unity



we found that the coefficient on past inflation, d_2, was not significantly different from unity. These results are reported in Appendix 2 for U.S. data since the early 1950's. It appears, therefore, that the level of capacity utilization is not uniquely related with any particular rate of inflation. On the other hand, when d_2 is equal to unity, there is a permanent and stable relationship between *changes* in the inflation rate and capacity-utilization rates. Inflation thus tends to accelerate when capacity utilization surpasses a particular level. To illustrate this, we may write equation (4) in terms of the change in the inflation rate, CIR, by moving past inflation to the left-hand side since its coefficient value is one:

$$CIR_t = a(CU_t - CU^e) \quad (5)$$

Thus, if actual utilization (CU_t) is maintained above the equilibrium rate, the rate of inflation will steadily increase; the inflation rate will rise each period by "a" percentage for each percentage point the current operating rate exceeds the equilibrium rate. Conversely, at utilization rates below CU^e, inflation will generally decline over time. Only at the equilibrium operating rate will the change in inflation be zero, with stability in the inflation rate.

II. Estimating a Stable-Inflation Capacity-Utilization Rate

Equation (5), which is in terms of the change in the inflation rate (CIR), is our basic model for estimating the equilibrium rate of capacity utilization.

$$CIR_t = a(CU_t - CU^e) \quad (5)$$

By incorporating the CU^e in the constant term, the equation can be written:

$$CIR_t = -k + aCU_t \quad (5')$$

where $k = aCU^e$. Once we obtain an estimate of "a" , an estimate of CU^e may be derived by dividing the constant term by that value, i.e.,

$$\hat{CU}^e = \frac{\hat{k}}{\hat{a}}$$

The equilibrium rate is the full-capacity utilization rate associated with stability in the inflation rate; that is, the change in the inflation rate will be zero, on average, when $CU_t = CU^e$. All statistical tests, unless otherwise stated, utilize annual data.

We first developed a regression for the 1954-73 sample period (Line 1 of Table 1). We omitted the more recent years from this first estimation because of the unusual price factors which surfaced during this period, such as the oil price hike, agricultural shortages, and the overall effects of imported inflation.[17] The estimate of CU^e is 81.95 for the 1954-73 period.

For the entire 1954-77 period, we would expect greater variance because of the unusual price factors just cited—and this is exactly what we see (Line 2). The standard error has about doubled, yet the estimate of the CU^e (81.92) remains virtually unchanged. The constant term is negative, as posited by our model, and the estimate of the "a" coefficient is statistically significant at the 5-percent level. We made alternative specifications of the basic model in order to test the robustness of the CU^e estimate, yet in each case the estimate remained close to 82 percent.

Again, our estimates generally remained unaffected when we substituted a manufacturing wholesale-price index in the price series, and when we substituted fourth-quarter to fourth-quarter for annual-average price data.

We introduced dummy variables into our equations to adjust for the unusual price behavior of the 1974-76 period and for the price controls of the 1972 period (Lines 5 and 6). These adjustments led to a substantial drop in the standard error, to a point about equal to that reported for the original (1954-73) regression, and with coefficient estimates similar to the earlier period also.

Our preferred regression (Line 6) indicates that for every percentage-point increase above 81.9 percent of capacity utilization, the inflation rate tends to increase by .12 percentage points. For example, with an increase in utilization from 81.9 percent to 83.9 percent, we would expect the inflation rate to increase by .24 percentage points. If capacity utilization rose to 83.9 percent in year 2, the inflation rate would rise from (say) 6.00 percent to 6.24 percent—and if capacity utilization remained at 83.9 percent in year 3, the inflation rate would rise further to 6.48 percent.

This result also held in the shorter (1954-73) period, and therefore appears stable over different time spans.[18]

We also tried various lag structures for the variables CU and IR. However, the results for the additional lagged values were not significant at the 5-percent level.[19]

We next estimated the 95-percent confidence interval for the CU^e,[20] realizing that policymakers obtain little benefit from knowing the average utilization rate which leads to increased inflation if there is a wide band of uncertainty associated with that average estimate. The 95-percent confidence interval is 79.6-83.5 percent for the 1954-73 period (Line 1). Relatively wide confidence intervals are associated with the extension of the estimating period to cover the 1973-77 period, but we can obtain a narrower confidence interval by incorporating dummy variables to account for the special price factors which dominated those years. With those adjustments, the 95-confidence interval for the CU^e for the 1954-77 period is 79.8-83.4 percent (Line 6). This range appears narrow enough, relative to historical utilization rates, to provide a meaningful signal of potential inflationary pressures.

Table 1
Estimates of Change in Inflation Rate‡
(Annual Data, 1954-77)

Change in Inflation Rate	Constant	Capacity Utilization CU (t)	D^1	D^2	D^3	Stable-Inflation Capacity-Utilization Rate CU^e	95-percent Confidence Limits for CU^e	Standard Error	D.W.	p	R^2	Estimation Procedure
CIR* (1)	-9.88369	.120612				81.95	79.62-83.53	.59	2.2	-.46	.55	CORC
	(-4.76)	(4.85)										
CIR (2)	-13.7149	.167421				81.92	74-86-86.02	1.33	2.0		.21	OLSQ
	(-2.67)	(2.70)										
CIRW (3)	-36.2811	.439590				82.53	75.70-88.57	2.98	1.8	.12	.27	CORC
	(-2.96)	(2.99)										
CIR** (4)	-18.8944	.230581				81.94	77.94-84.81	1.43	1.9		.32	OLSQ
	(-3.40)	(3.44)										
CIR (5)	-9.84463	.12079	-.755	4.334	-3.796	81.50	79.16-83.15	.57	2.1	-.42	.86	CORC
	(-5.22)	(5.35)	(-1.36)	(7.84)	(-6.60)							
CIR (6)	-9.9206	.12119		4.448	-3.698	81.86	79.79-83.39	.58	2.2	-.48	.85	CORC
	(-5.33)	(5.44)		(8.09)	(-6.45)							

‡ t-statistics in parentheses
* Estimation period is 1954-73
** Fourth quarter to fourth quarter
CU Capacity utilization for total manufacturing
CIR G.N.P. implicit deflator used for change in inflation rate
CIRW Wholesale-price index (manufacturing) used for change in inflation rate
D^1 1 in 1972 and 0 elsewhere
D^2 1 in 1974 and 0 elsewhere
D^3 1 in 1976 and 0 elsewhere

III. Instability Between Inflation Rate and Capacity Utilization

The relationship which we estimated between the change in the inflation rate and capacity utilization can be written in the following terms. To simplify the discussion, we have not included any dummy variables.

$$IR_t = .12(CU_t - 82.0) + IR_{t-1} \qquad (6)$$

This relationship may also be illustrated graphically (Chart 2). At the capacity-utilization rate equal to equilibrium, CU^e, the vertical line illustrates the lack of a long-run stable relationship between the rate of inflation and the capacity-utilization rate. Essentially this means that once an economy departs from its equilibrium value, it may return to it, but at a rate of inflation different from its initial value.

If the capacity utilization rate is above CU^e, the inflation rate is expected to increase steadily. If last year's rate of inflation remained constant, the relationship between capacity utilization and the current inflation rate would trace the path denoted by SS′ in the chart, where "a" represents the point where this year's inflation is equal to last year's rate.

But according to equation 6, a deviation of capacity utilization from CU^e will in fact change this year's inflation rate, which will alter next period's rate, and so on—so that the line SS′ keeps shifting as long as the inflation rate keeps changing. Consequently, we expect the relationship to trace a counterclockwise loop. This behavior is analogous to what we find in the inflation/unemployment relation, as rising inflation expectations shift the inflation/unemployment curve over time.

Consider an initial equilibrium at point a. Suppose there is a disturbance which results in capacity utilization increasing relative to CU^e. The rate of inflation will then follow the path a to b. If capacity utilization begins to decline from point b back towards its equilibrium value, the inflation rate will follow the path b to c. Note that the equilibrium inflation rate consistent with a return to CU^e is higher than its initial rate. This is because the economy maintains a capacity-utilization rate always greater than CU^e; hence, the current year's inflation is always greater than last period's. To return to the initial inflation rate, a, capacity utilization must fall relative to CU^e; for example, tracing the path c to d, and then returning to a. Inflation need not, however, ever return to its initial equilibrium value if events prevent capacity utilization from remaining less than CU^e for a sufficient *time or amount* to lower the inflation rate to point a.

Chart 2

Capacity Utilization Rate and Change in Inflation Rate

Graphical Illustration

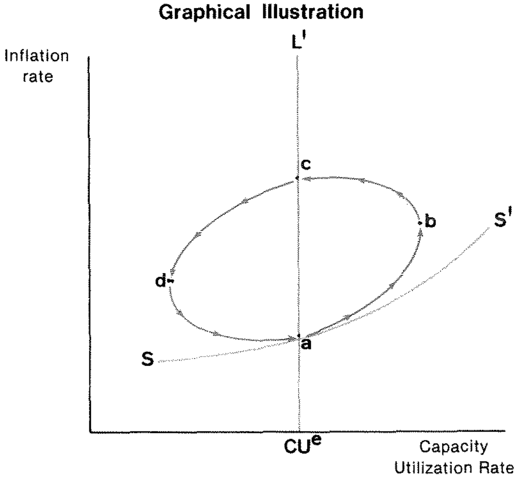
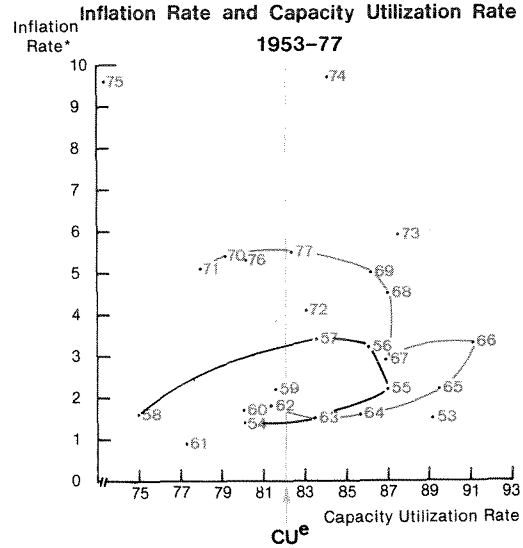


Chart 3

Inflation Rate and Capacity Utilization Rate

1953–77



*Annual Percent Change in GNP Implicit Deflator

These counterclockwise loops may be illustrated with recent U.S. historical data (Chart 3). The colored line first traces the recovery which began in 1954, with an inflation rate averaging less than two percent. During the recovery, the inflation rate increased as capacity utilization rose and remained above equilibrium, so that the return towards 82 percent was accompanied with a higher inflation than at the start of the recovery. The business contraction in 1958 resulted in inflation returning to about the 1954 value.

Again, the long recovery of the 1960's started out with a relatively low inflation rate. Between 1969 and 1970, the economy turned down and crossed the 82-percent capacity-utilization line with more than double the initial rate of inflation. The contraction which followed was relatively short lived, and consequently the inflation rate dropped very little.

The current recovery is apparently beginning its counterclockwise loop. The price movements of 1976 and 1977 appear closely associated with the imbedded inflation from the pressures generated in the previous years of high capacity utilization. If 1978 carries the economy to utilization rates beyond equilibrium, we may find the next return to equilibrium at higher inflation rates than we are now experiencing.

IV. Summary and Conclusions

In this paper, we have combined a wage and a price equation to derive a semi-reduced-form model of inflation. Our equation for the CU^e relates changes in the inflation rate to deviations of capacity utilization from its equilibrium value. According to that equation, a stable inflation rate is consistent with a full-capacity utilization rate of 82 percent—or within the 80-to-$83\frac{1}{2}$ percent range provided by our 95-percent confidence limits. These results were robust under changes in the estimation period, the lag structure and the chosen inflation rate.

Many economists believe that the yardstick for full use of the nation's productive resources is provided by the historical peak of capacity utilization—specifically, the 87-to-88 percent level of the 1973 period. Our analysis suggests, however, that the full-capacity utilization rate is reached at a somewhat lower level, so that there is less non-inflationary slack in the present economy than is commonly believed. Indeed, inflation tends to accelerate when the operating rate surpasses 82 percent—or more generally, the range of 80 to $83\frac{1}{2}$ percent. Once beyond that range, excess demand generates inflationary pressures as less efficient labor and capital resources are called into use. Thus, since utilization rates recently have approached 85 percent, we could expect mounting inflationary pressures from the domestic, nonfarm business sector of our economy.

Once capacity utilization exceeds the range indicated, the increased inflation tends to become imbedded in future inflation, with the current period's higher prices being reflected in the next period's expectations. Our analysis suggests that when the operating rate rises above the full-capacity range, its return to that range will be accompanied by a higher rate of inflation. For the inflation rate to decline, therefore, capacity utilization would have to fall below its equilibrium value, such as generally happens in a business recession.

We may conclude that, in the 1978 economy, there is no more non-inflationary slack available. The important policy task, therefore, is to steer a steady course which does not permit output growth to exceed its long-run potential. Under such circumstances, a stable rate of inflation can be maintained with both capital and labor at their full utilization rates.

Appendix Table 1
Estimates of Equation (3′) ‡
(Annual Data, 1953-77)

Dependent Variable	Constant	IR(t-1)	TIME	XM^2	XM^3	URM(t)	$\frac{1}{URM(t)}$	CU(t)	$\bar{R}^2$	Standard Error	DW	Estimation Procedure
IR (1)	4.004	.692	.075			-.507		-.024	.71	1.28	1.82	OLSQ
	(.35)	(3.29)	(1.20)			(-1.15)		-.20)				
IR* (2)	1.109	.718		.401		-.472		-.017	.70	1.31	1.82	OLSQ
	(.09)	(3.31)		(.974)		(-1.025)		(-.137)				
IR* (3)	1.566	.752			.324	-.506		-.016	.69	1.32	1.86	OLSQ
	(.13)	(3.49)			(.79)	(-1.09)		(-.12)				
CIR (4)	.018					-.537		.024	.19	1.28	2.11	OLSQ
	(.002)					(-1.25)		(.218)				
CIR (5)	-11.698							.143	.17	1.30	2.11	OLSQ
	(-2.40)							(2.44)				
CIR (6)	2.305					-.617			.22	1.26	2.09	OLSQ
	(2.91)					(-2.82)						
CIR (7)	-1.345						4.655		.12	1.34	2.09	OLSQ
	(-1.73)						(2.09)					

‡ t-statistics in parentheses
* Estimation period is 1954-77
IR Annual rate of change in GNP implicit deflator
CIR Change in IR
TIME Linear time trend
XM^2 Two-year moving average of output-manhours ratio. (Output includes nonfarm business sector and households; manhours includes private domestic nonfarm business sector, including proprietors and unpaid family workers.)
XM^3 Three-year moving average of output-manhours ratio
URM Unemployment rate of males aged 25-54
CU Federal Reserve capacity-utilization series

Appendix Table 2
Estimates of Inflation Rate‡
(Annual data, 1954-77)

Inflation Rate	Constant	Capacity Utilization CU(t)	Inflation Rate, Lagged	D^1	D^2	D^3	Stable-Inflation Capacity-Utilization Rate (CU^e)	Standard Error	D.W.	$\hat{\rho}$	R^2	Estimation Procedure
IR (1)	-11.9213	.149276	.919				79.86	1.34	1.96		.68	OLSQ
	(-2.00)	(2.16)	(7.15)									
IRW (2)	-29.3233	.364912	.781				80.36	2.97	1.81	.22	.56	CORC
	(-1.95)	(2.10)	(4.12)									
IR (3)	-10.6478	.12875	1.051	-.958	4.015	-4.250	82.70	.578	2.15	-.40	.94	CORC
	(-4.91)	(5.14)	(16.24)	(-1.57)	(5.92)	(-5.22)						
IR (4)	-10.0484	.122435	1.008		4.393	-3.77	82.07	.599	2.20	-.48	.94	CORC
	(-4.75)	(4.99)	(16.64)		(6.54)	(-4.71)						

‡ t-statistics in parentheses
IR (t) G.N.P. implicit deflator used for inflation rate
IRW (t) Wholesale-price index (manufacturing) used for inflation rate

D^1 = 1 in 1972 and 0 elsewhere
D^2 = 1 in 1974 and 0 elsewhere
D^3 = 1 in 1976 and 0 elsewhere

FOOTNOTES

1. See Phillips (1958).
2. See Modigliani and Papademos (1976).
3. "Required Reading," **American Banker,** May 3, 1978, page 4.
4. In the literature, the term Phillips curve refers to the relation between the unemployment rate and the rate of change in wages, but also to the relation between the unemployment rate and the rate of change of final-product prices. We shall use the term only in the latter sense.
5. See Eckstein (1972), Stein (1978) and Laidler (1973).
6. Numerous studies in the literature relate demand pressures to the inflation rate and use capacity utilization as a proxy for demand pressures within the context of a price-markup equation. See the articles in Eckstein (1972) and Hirsch (1977). One of the earliest studies is Eckstein and Fromm (1968).
7. For wage equations of this general form, see those incorporated in the models discussed in Eckstein (1972).
8. The unemployment rate of males, (25-54) is relatively insensitive to cyclical business conditions, so that changes in their unemployment rate basically reflect changes in job opportunities and in the demand for labor in general. For a review of the use of unemployment rates in labor market studies, see Mincer (1966). The aggregate unemployment rate, on the other hand, reflects the changing composition of the labor force, so that it may change even when demand pressures in labor markets do not. For example, teenagers and women historically have higher than average unemployment rates; thus, although their group unemployment rate may not change, an increase in their percentage in the labor force will increase the overall measured unemployment rate. Since the mid-1960's, both these groups have increased their labor-force participation substantially; consequently, the measured total unemployment rate has tended to overstate the amount of slack in labor markets. The reader will note that since equation (3) uses the variable $(u - u_e)$, the aggregate unemployment rate could be used as a proxy for excess demand provided we also included the equilibrium unemployment rate. Recent research indicates that the equilibrium rate has been increasing since the early 1950's, although there is a good deal of professional debate about its actual value. I have used the unemployment rate of males (25-54) in the text, since that group's equilibrium unemployment rate may be represented as a constant.
9. See Winston (1974) for a review of this literature.
10. See Tobin (1972).
11. For an analysis of the unemployment and capacity-utilization relationship over the business cycle, see Butler (1977).
12. Because the demand for labor is derived from the demand for final output, we may expect a high correlation between excess demand in the two markets. In addition, we may assume that once capital stock is in place, there is limited substitutability between capacity utilization and labor employment. Recent empirical evidence appears to substantiate this assumption (see Malcomson). This limited substitutability may be the major reason why we observe a high correlation between labor and capacity utilization in U.S. data.
13. Modigliani and Papademos (1976), using a quasi-reduced form similar to equation (3), dropped capacity utilization because of the high correlation between the unemployment-rate measure used in their equation and capacity utilization. Modigliani and Papademos then went on to measure the nonaccelerating inflation rate of unemployment.
14. Equation (4) states:

$$IR_t = d_1(CU_t - CU^e) + d_2 IR_{t-1} \quad (4)$$

Lagging equation (4), we obtain

$$IR_{t-1} = d_1\,(CU_{t-1} - CU^e) + d_2 IR_{t-2} \quad (4')$$

Substitute (4') into (4), to derive

$$IR_t = d_1\,(CU_t - CU^e) + d_1 d_2\,(CU_{t-1} - CU^e) + d_2^2\,IR_{t-2} \quad (5)$$

Continuing this process, current inflation is seen to be a distributed-lag of capacity utilization. Assuming a given level of CU through time, we obtain the infinite geometric series-

$$IR_t = d_1 \sum_{i=0}^{\infty} d_2^{i}\,(CU - CU^e) \quad (6)$$

$$\text{where } d_1 \sum_{i=0}^{\infty} d_2^{i} = \frac{d_1}{1-d_2} - \frac{d_1 d_2^{\infty}}{1-d_2} \quad (7)$$

If $d_2 < 1$, expression (7) converges to a finite number resulting, according to (6), in a stable, equilibrium association between IR and CU. If $d_2 > 1$, no stable solution exists; any gap between actual and expected inflation continually widens. If $d_2 = 1$, there is no long-run solution of equation (6); the equilibrium inflation rate is independent of the rate of capacity utilization.
15. The terms permanent, long-run and equilibrium are used interchangeably in his paper, in the sense of a situation that would exist indefinitely if not disturbed by "exogenous" forces, such as mandated energy-price increases or changes in fiscal and/or monetary policy.
16. For a similar derivation of the long and short-run impact of unemployment upon inflation, see Tobin (1972).
17. For an analysis of inflationary pressures over this period, see Keran and Riordan (1976).
18. One other estimate of the stable-inflation capacity-utilization rate was derived by Otto Eckstein and Gary Fromm in their 1968 article, "The Price Equation". Using quarterly data, 1954.1-1965.4, and the wholesale-price index, they estimated a price equation of the form (1) above. They found an equilibrium value for the capacity-utilization rate of 82 percent. The capacity-utilization index was the Klein-Summers estimate, which at the time of their study averaged about 2 points higher than the Federal Reserve Board Index used in this paper. They also found that every additional point of the operating rate raises prices by .03 percent a quarter, or .12 percent a year as we have found.

Eckstein and Fromm's results, however, are not strictly comparable to ours, since they used the wholesale-price index instead of the GNP implicit deflator as a measure of inflation. In addition, the capacity-utilization series have undergone substantial revisions since the time of their study, which could affect their estimates.

Nevertheless, both studies, using different but consistent models of pricing behavior—theirs a structural price equation and mine a reduced form equation—both similarly concluded that the stable-inflation full capacity utilization rate is substantially less than the estimated historical peak would indicate.

19. The reader will note that our estimation equation is but one relation in a complete model of the U.S. economy. In our estimations, we treat capacity utilization as an exogenous variable. In the context of a complete model, the operating rate would be determined by other economic variables including inflation. Consequently, our estimates may be subject to simultaneous-equation bias. We therefore estimated equations similar to those reported on lines 1 and 2, Table 1, using a two-stage least squares procedure where capacity utilization was a function of past money supply growth. Our results did not differ from those reported in Table 1; therefore, we continued to use ordinary least squares or Cochrane-Orcutt procedures.

20. The formula for calculating the confidence limits was supplied by John L. Scadding. The procedure for obtaining the formula is described in "The Sampling Distribution of the Liviatan Estimator of the Geometric Distributed Lag Parameter," by Scadding in **Econometrica**, May 1973.

The formula for the lower and upper confidence limits is

$$\frac{(2ab - 2t^2Sab) \pm \sqrt{(2ab - 2t^2Sab)^2 - 4(b^2 - t^2S_b^2)(a^2 - t^2S_a^2)}}{2(b^2 - t^2S_b^2)}$$

where

a = estimate of constant

b_2 = estimate of coefficient of capacity utilization

S_a^2 = square of standard error of estimated constant

S_a^2 = square of standard error of b

t = student t variable, $t_{n-2}^{\alpha/2}$

Sab = estimate of covariance between a and b

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