A Reexamination of the Relationship between Capacity Utilization and Inflation

by Paul W. Bauer

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Introduction

The Federal Reserve places a high priority on controlling inflation and ensuring full employment of economic resources. Thus, empirical relationships that can better inform policymakers about the prospects of these two key economic variables are eagerly sought. One such relationship that has received attention over the years is that between capacity utilization and inflation (McElhattan [1978, 1985], Tatom [1979], and Gittings [1989]). Although these authors have employed various theoretical and empirical methods, in general they all have found evidence for a "steady state" or "natural rate" of capacity utilization of about 80 percent to 82 percent. Deviations from this rate are directly related to changes in the inflation rate.

Most of these models posit a single equation in which capacity utilization is assumed to be an exogenous variable that explains changes in the inflation rate. However, economic theory and Granger causality tests suggest that both capacity utilization and inflation are endogenous. This empirical finding is incorporated here by construction of a two-equation structural model based on the work of Haynes and Stone (1985). Though parsimonious, the model imposes no explicit macroeconomic world view and yet provides a reasonable fit for the movements of capacity and inflation in the U.S. economy. In addition, the full sample period from 1953 to 1989 can be employed, since no evidence of structural change is found. Although the resulting estimate of the steady-state capacity utilization rate is consistent with previous research, the structural approach permits us to examine the dynamics of the relationship, as revealed through simulated aggregate demand and supply shocks.

I. Theoretical Foundations

Capacity utilization is defined as actual production divided by capacity (section II briefly reviews the problem of adequately defining these terms). The belief that high capacity utilization levels lead to an accelerated rate of inflation is based on the assumption that high capacity utilization levels are related to increasing marginal costs of production in the short run. In the long run, high capacity utilization may prompt new investment, thereby expanding capacity and relieving price pressures.

McElhattan (1978) was the first to develop a model linking inflation and capacity utilization. The model is composed of two basic structural equations, one that relates prices to a markup on unit labor costs, and another that relates wage changes to labor-market excess demand and expected inflation. The markup equation can be written as

$$(1) \quad IR(t) = a_{12}\, W(t) - a_{13}\, T(t) + f\,[CU(t)],$$

where IR is the inflation rate, W is the rate of change of nominal wages, T is the growth rate of labor productivity, and $f\,[CU(t)] = [b_0 + b_1 CU\,(t)]$ is a measure of excess aggregate demand that is an increasing function of capacity utilization (CU).

The second equation relates the rate of change in nominal wages to the expected inflation rate (IR^*), the growth rate of labor productivity $[T(t)]$, and the excess demand in the labor markets $\{b\,[u\,(t)\,]\}$. It can be written as

$$(2) \quad W(t) = a_{21}\, IR^*(t) + a_{23}\, T(t) - b[u(t)],$$

where $b\,(u)$ is a decreasing function in the unemployment rate (u). With this specification, inflation-adjusted wage changes ($W - a_{21} IR^*$) rise in proportion to labor productivity for a given level of unemployment.

Substituting equation (2) into equation (1) and simplifying yields

$$(3) \quad IR(t) = a_{12}\, a_{21}\, IR^*(t) + (a_{12}\, a_{23} - a_{13})\; T(t) - a_{12}\, b\,[u(t)] + f\,[CU(t)].$$

A number of restrictions are imposed by McElhattan in order to estimate equation (3). First, given the high correlation between unemployment and capacity utilization rates, only one of these variables is included.[1] McElhattan argues that retaining the capacity utilization rate is preferable because the natural rate of unemployment may be affected by demographic changes, whereas capacity utilization is not.

Next, a formulation for inflation expectations must be imposed. As is common in price-markup models, inflation expectations are modeled as a weighted average of past inflation. McElhattan finds that only the one-year lag is statistically significant, and that its estimated coefficient is close to one. Because this coefficient must equal one for there to be no long-run Phillips curve type of trade-off between inflation and capacity utilization, this constraint is imposed as well.

Given these restrictions (and a few other minor ones), the reduced-form equation in McElhattan's model can be rewritten as

$$(4) \quad CIR(t) = a\,[CU(t) - CU^e] + v(t), \quad a > 0,$$

where $CIR(t)$ is the change in the inflation rate, $CU(t)$ is the capacity utilization rate, CU^e is the natural rate of capacity utilization, and $v(t)$ is statistical noise. With this formulation, it is easy to see that when $CU(t)$ is larger (smaller) than CU^e, the inflation rate will increase (decrease), and that when $CU(t)$ is equal to CU^e, the inflation rate will remain unchanged. This can be viewed as an output-gap model, with capacity utilization playing the role usually reserved for the unemployment rate.[2]

Gittings (1989) basically follows McElhattan's approach, but argues informally that there are two reasons for the existence of inflationary pressures when capacity utilization is high. First, as capacity constraints are reached, firms are better able to increase their prices in the face of strong demand; however, these same firms' customers may find themselves in a similar position. The second argument is that aggregate-demand growth raises the demand and prices for new capital goods, along with the costs of financing those goods, relatively more when there is less idle capital to employ. Thus, over the business cycle, the rental price of capital rises relative to that of labor.

An entirely different approach is taken by Tatom (1979), who sets up a partial adjustment model in which changes in capacity utilization are the result of monetary surprises. This relationship can be written as

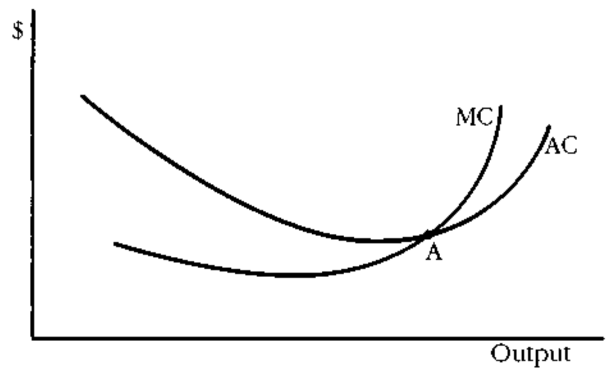
$$(5) \quad dCU(t) = a\,[CU^e - CU(t\text{-}1)] + b\{\, m(t) - E_{t\text{-}1}\,[m(t)]\,\},$$

1 The correlation between unemployment and capacity utilization is -0.875 using yearly data from 1953 to 1989.

2 See appendix B in Hallman, Porter, and Small (1989) for an overview of output-gap and price-gap models.

FIGURE 1

Short-Run Cost Curves



SOURCE: Author's calculations.

where $dCU(t)$ is the change in the capacity utilization rate, $m(t)$ is the actual rate of monetary growth, and $E_{t-1}[m(t)]$ is the anticipated rate of monetary growth in the previous period. Here, capacity utilization adjusts to its equilibrium level (CU^e) with a lag, and departures from CU^e occur as a result of monetary surprises.

This model is fundamentally different from those underlying McElhattan's and Gittings's work. In Tatom's model, money causes inflation, and only monetary surprises cause changes in capacity utilization. There is no structural link between capacity utilization and inflation, and the natural rate of capacity utilization is achieved as a result of an absence of shocks.

II. Definition and Measurement of Capacity Utilization

At first glance, the concepts of capacity and capacity utilization are easily defined.[3] Capacity is the potential output that an economic unit (for example, a plant, a firm, an industry, or an economy) can produce during a given period, and capacity utilization is simply actual output divided by potential output. However, these seemingly straightforward definitions gloss over a number of problems, the greatest of which is that they fail to take account of operating costs as output varies. Output can be increased by employing workers and machines for longer hours, but this results in overtime and higher maintenance costs.

One alternative is to define capacity as the level of output at which short-run average cost (AC), total cost divided by output, is minimized (point A in figure 1).[4] This definition has the somewhat peculiar property that an economic unit might produce at a rate greater than "capacity," but it does result in a much more informative measure of capacity utilization. At output levels below capacity (to the left of point A in figure 1), output can be increased without a significant increase in marginal cost (MC), the extra cost incurred to produce one more unit of output. However, when output exceeds capacity (to the right of point A in figure 1), increases in output are associated with more rapid increases in MC. This definition of capacity links capacity utilization with MC, and thus is one conceivable microeconomic foundation for the belief that a connection between price movements and capacity utilization exists.

Unfortunately, economic data do not fall like manna from heaven, but must be painstakingly compiled. In the case of capacity (and hence capacity utilization), the usual data collection and aggregation problems are aggravated because capacity is essentially unobserved—unlike actual output. Another complicating factor is the lack of a generally accepted definition of capacity, as noted above.

Most studies that attempt to relate inflation to capacity utilization employ the Federal Reserve's capacity utilization series. In light of the empirical results presented below, it would be useful to have at least a cursory understanding of how this series is constructed. (For a more detailed discussion, see Raddock [1985, 1990].)

The Federal Reserve's goal is to provide capacity utilization estimates that reflect the same degree of "tightness" over time for a given rate. No primary data is collected, as the Federal Reserve relies instead on annual surveys produced by McGraw-Hill and the Census Bureau, and on various industry sources. Strangely, McGraw-Hill offers no definition of capacity utilization to its survey respondents. The Census Bureau offers definitions for its two measures of

3 For a general overview of the problem of defining capacity, see Bauer and Deily (June 15, 1988). For a more detailed treatment, see Klein and Long (1973), Rasche and Tatom (1977), and Berndt, Morrison, and Wood (1983).

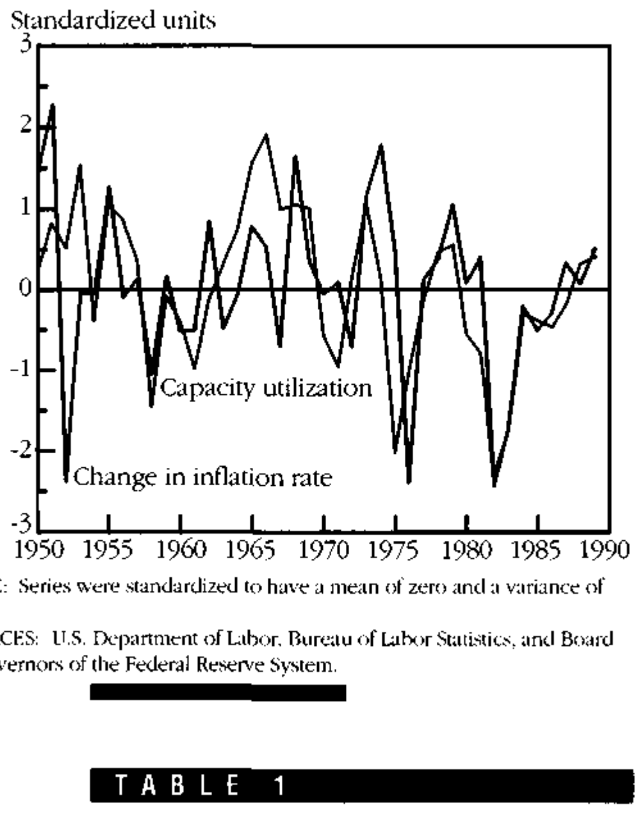
4 Other authors (for example, Tatom [1979] and Rasche and Tatom [1977]) advocate defining capacity utilization as the level of output at which short-run and long-run average costs are equal, so that a firm's demand for any fixed inputs just equals the amount it actually possesses. Although this definition has some theoretical advantages, no organization that produces capacity estimates uses it. Thus, the relative merits of alternative definitions are mentioned only briefly here.

capacity, but most respondents apparently ignore them (see Bauer and Deily [July 1, 1988]).

After a preliminary end-of-year index of industrial capacity is calculated, data are adjusted to remove apparently excessive fluctuations and short-term peak capacity. As a result, capacity figures reflect maximum "sustainable" capacity. Monthly and quarterly estimates are generally straight-line interpolations from past end-of-year estimates and are based on projections of capacity growth for the current year. Because capacity is unlikely to grow at a constant rate throughout the year, the monthly and quarterly estimates should be treated with more caution than the yearly estimates.[5] For this reason, only annual data are analyzed here.

FIGURE 2

Change in Inflation and Capacity Utilization Rates, 1950-88



NOTE: Series were standardized to have a mean of zero and a variance of one.

SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, and Board of Governors of the Federal Reserve System.

TABLE 1

Correlation between the Change in U.S. Inflation and Capacity Utilization Rates and Lagged Capacity Utilization

CIR (*t*)	*CU* (*t*)	*CU* (*t* -1)
1980-89	0.885	0.530
1970-79	0.407	0.825
1960-69	0.461	0.090
1950-59	0.315	–0.439

SOURCE: Author's calculations.

III. Empirical Findings: Puzzles and Possible Explanations

Figure 2 plots changes in the inflation and the capacity utilization rates from 1950 to 1988. It appears that the two series are related—at least indirectly—as manifested by the way in which they tend to move together. Gittings, who only reports results for the 1971 to 1988 period, asserts that there is a fairly uniform one-year lag between the two series. Although this appears to be true for most of the 1970s, it does not seem to apply to the 1980s. Simple correlation among changes in the inflation and the capacity utilization rates confirms this (table 1). Note that during the 1950s there was actually a negative correlation between changes in the inflation rate and the lagged value of capacity utilization. This simple analysis reveals that, whatever the relationship between capacity utilization and inflation, it appears to vary over time.

Figure 3 plots the change in the inflation rate against the capacity utilization rate. Although a straight line appears to fit these data well, clearly a great deal of noise exists in the relationship. Table 2 reports estimates of the McElhattan model (equation [3]) using various sample periods.

Although the point estimate of the noninflationary rate of capacity utilization ranges only from 80.0 percent to 81.9 percent, when the 95 percent confidence interval can be computed, it suggests a range of from approximately 78 percent to 83 percent. The extent to which a change in inflation is associated with a given deviation of capacity utilization from the natural rate (the b coefficient) also appears to vary over time. The "penalty" for a divergence from the equilibrium rate of capacity utilization was 71 percent

5 Gittings (1989) attributes the failure to find any correlation between the change in inflation rates and capacity utilization in the monthly series to noise in the price series. However, the failure could also be a result of problems in the monthly estimates of capacity utilization.

TABLE 2

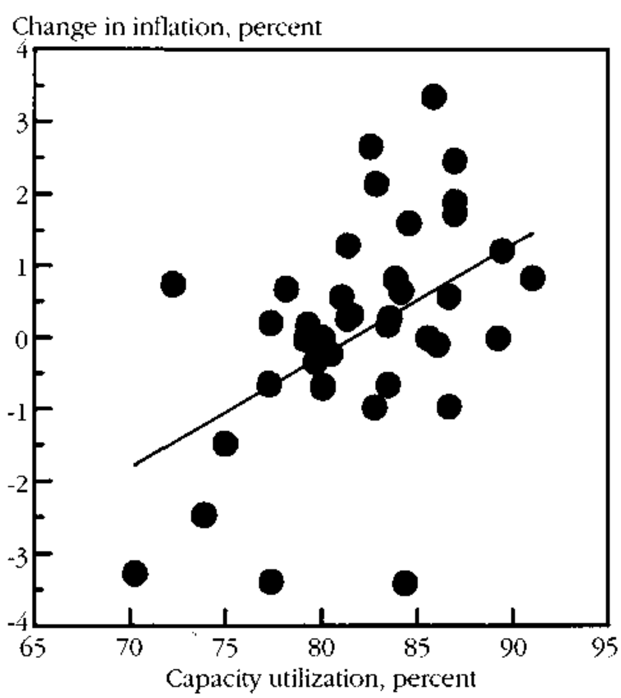
OLS Results for the McElhattan Model Using Various Time Periods

Variable	Full Sample	1950-69	1960-79	1970-89
CU	0.00154	0.00127	0.00106	0.00217
	(3.52)	(1.60)	(1.75)	(3.55)
Constant	-0.125	-0.104	-0.848	-0.174
	(-3.48)	(-1.56)	(-1.68)	(-3.56)
CU^e	81.4	81.9	80.0	80.3
	[78.7, 83.6][a]	—[b]	—[b]	[78.2, 82.5][a]
R^2	0.246	0.125	0.145	0.411

a. 95 percent confidence intervals computed following McElhattan (1978).
b. The procedure fails when both parameter estimates are not statistically significant at the confidence level selected (see Scadding [1973]).
NOTE: $CIR(t) = a + b\,CU(t) + e(t)$. T-statistics are indicated in parentheses.
SOURCE: Author's calculations.

FIGURE 3

Change in Inflation Rate vs. Capacity Utilization



NOTE: Yearly data.
SOURCES: U.S. Department of Labor, Bureau of Labor Statistics, and Board of Governors of the Federal Reserve System.

higher in the 1970s and 1980s than in the 1950s and 1960s, although the difference does not appear to be statistically significant.

If capacity utilization is a true measure of capacity constraints that result in higher inflation, then one would expect the Federal Reserve's capacity utilization series (which covers only manufacturing, mining, and utilities) to predict more accurately the price pressure for goods than for goods and services or just services. The empirical evidence for this conjecture is mixed, however (see table 3).

As expected, the worst fit is found between capacity utilization and the change in the inflation rate for services, although indirect effects are observed. The better fit (at least as measured by the R^2 coefficient and the statistical significance of the coefficients) between capacity utilization and changes in the overall implicit price deflator relative to goods only is unexpected, however. Capacity utilization should be more directly related to changes in the price of goods than to changes in the prices for all goods and services. This finding could be a result of the variance of the goods implicit price deflator being four times larger than the one for services.

At this point, it is appropriate to ask whether capacity utilization should be treated as an exogenous variable. Models can easily be developed in which both capacity utilization and changes in inflation are jointly endogenous. Granger causality tests can then be employed to examine this view, although the results must be interpreted cautiously (see Conway, Swamy, and Yanagida [1983]).

TABLE 3

OLS Estimates of McElhattan's Model Using Various Measures of Inflation

Variable	Goods and Services	Goods	Services
CU	0.172	0.199	0.071
	(4.24)	(3.21)	(1.91)
Constant	-14.0	-16.2	-5.76
	(-4.21)	(-3.21)	(-1.90)
CU^e	81.4	81.7	81.3
	[79.2, 83.4][a]	[78.8, 84.8][a]	[70.6, 89.3][a]
R^2	0.360	0.249	0.105

a. 95 percent confidence interval.
NOTE: Implicit price deflator = 31. T-statistics are indicated in parentheses.
SOURCE: Author's calculations.

TABLE 4

Granger Causality Tests

H_0: Capacity utilization does not Granger-cause changes in inflation

Lag Lengths	lnL_u	lnL_c	Likelihood Ratio[a]
1	-50.34	-56.21	11.74
2	-46.88	-52.99	12.22
3	-42.43	-49.34	13.82
4	-38.47	-45.17	13.40
5	-32.39	-40.55	16.32
6	-26.35	-35.91	19.12

H_0: Changes in inflation do not Granger-cause capacity utilization

Lag Lengths	lnL_u	lnL_c	Likelihood Ratio[b]
1	-88.80	-91.24	4.88
2	-82.39	-84.84	4.90
3	-73.74	-77.25	7.07
4	-65.63	-69.77	8.28
5	-58.12	-64.11	11.98
6	-53.13	-58.99	11.72

a. Statistically significant at the alpha = 0.01 level.
b. Statistically significant at the alpha = 0.1 level.
SOURCE: Author's calculations.

For this study, the tests are performed as suggested by Guilkey and Salemi (1982), with both a time trend and an equal number of lags of the two right-side variables. The number of lags was varied in order to check for robustness (see table 4). Within the framework of the Granger causality test, a variable x does not Granger-cause y if the coefficients on the lags of x are all not statistically different from zero. This hypothesis can be easily examined using a likelihood-ratio test.[6]

The second and third columns indicate the value of the likelihood function of the unconstrained model and the constrained model, respectively (for the latter, coefficients of the lag of the nondependent variable are constrained to equal zero). The last column lists the value of the test statistics and indicates whether the hypothesis of no unidirectional Granger causality can be rejected. These results suggest that there is bidirectional causality between the two time series, although the link from capacity utilization to changes in the inflation rate appears to be stronger (or at least easier to confirm statistically).

Bidirectional causality between capacity utilization and changes in the inflation rate is more consistent with Tatom's approach than with those of McElhattan and Gittings. However, a more complete analysis of the relationship can be obtained through use of a more fully specified structural model that relates the two time series explicitly. The work of Haynes and Stone (1985) provides the basis for one such model.

IV. A Structural Approach

Haynes and Stone construct a model of aggregate demand and supply that is identified by its dynamics: In the short run, quantity sold is demand determined, but price is supply determined. Given this assumption, shifts in aggregate demand trace out aggregate supply, affecting output before prices and leading to an inverse relationship between inflation and lagged unemployment. Haynes and Stone's aggregate supply equation can be written as

$$(6) \quad I(t) = -1/a\, U(t-i) - b/a\, dI(t) + e(t), \quad i > 0,$$

6 The test statistic $2(ln_u - lnL_c)$ is distributed chi-squared with k degrees of freedom under the null hypothesis, where k is the number of constraints placed on the model (the number of lags set to zero).

TABLE 5

Estimates of Aggregate Supply and Demand

Parameter	Estimate	Standard Error	T-Statistic
a	-0.108	0.0306	-3.52
b	0.866	0.0703	12.32
c	0.0013	0.0004	3.48
d	0.151	0.0582	2.61
A	21.7	9.07	2.39
B	-89.0	17.2	-5.17
C	0.716	0.106	6.79
$D1$	104.4	20.0	5.22
$D2$	-33.2	19.6	-1.70
$RHO\,1$[a]	-0.265	0.172	-1.54
$RHO\,2$[a]	-0.308	0.168	-1.83

a. *RHO* 1 and *RHO* 2 are the autocorrelation coefficients in equations (8) and (9).
NOTE: Value of the likelihood function = 30.05183.
SOURCE: Author's calculations.

where $I(t)$ is the inflation rate, U is the unemployment rate, d is the difference operator, e is an error term, and a and b are positive constants. $U(t-i)$ is a generalized delay of i periods, and $dI(t)$ is an adaptive representation of inflationary expectations. Supply shocks enter the system through $e(t)$.

Similarly, short-run shifts in aggregate supply trace out aggregate demand. These shifts affect prices before output, leading to a direct relationship between unemployment and lagged inflation. Haynes and Stone model aggregate demand as

$$(7) \quad U(t) = c + fI(t-j) + gU(t-i) + v(t),\ j > 0,$$

where c, f, and g are parameters, and demand shocks enter the system through $v(t)$. The authors assume that the response of unemployment to a supply shock occurs after the price response, so unemployment is related only to lagged inflation.

The Haynes-Stone framework is modified here to use the capacity utilization rate rather than the unemployment rate. It is also augmented to include the lagged value of M2 growth as an explanatory variable in each equation. Inclusion of M2 growth allows for both a varying monetary policy, certainly an important influence on the inflation rate, and links between money and capacity utilization and inflation, along the lines of Tatom (1979).[7]

In both equations, lag lengths of one year for capacity utilization and inflation yield the lowest mean-squared error (the specification criterion employed by Haynes and Stone). In the case of M2 growth, allowing for a lag length of two years in the supply equation and of both one and two years in the demand equation yields the lowest mean-squared error. Equations (8) and (9) are estimated with an allowance for autocorrelation and cross-equation correlations. Results are presented in table 5.

$$(8) \quad ir(t) = a + b\,ir(t-1) + c\,cu(t-1) + d\,gm2(t-2) + e(t)$$

$$(9) \quad cu(t) = A + B\,ir(t-1) + C\,cu(t-1) + D1\,gm2(t-1) + D2\,gm2(t-2) + v(t)$$

Given the dynamic assumptions that identify the model, the coefficient on lagged capacity utilization should be positive in the supply equation (8), and the coefficient on lagged inflation should be negative in the demand equation (9). Both coefficients are of the expected sign and are statistically significant, so reasonable supply and demand relationships appear to have been estimated.

In the short run, faster M2 growth leads to higher inflation and higher capacity utilization (possibly by stimulating aggregate demand, but perhaps through monetary shocks, as suggested by Tatom). However, solving this two-equation system for the long-run steady state indicates that the gain in steady-state capacity utilization is quite modest. In fact, the system can be reestimated with the constraint that M2 growth not affect steady-state capacity utilization by setting

$$(10) \quad D1 + D2 = -Bd/(1-b).$$

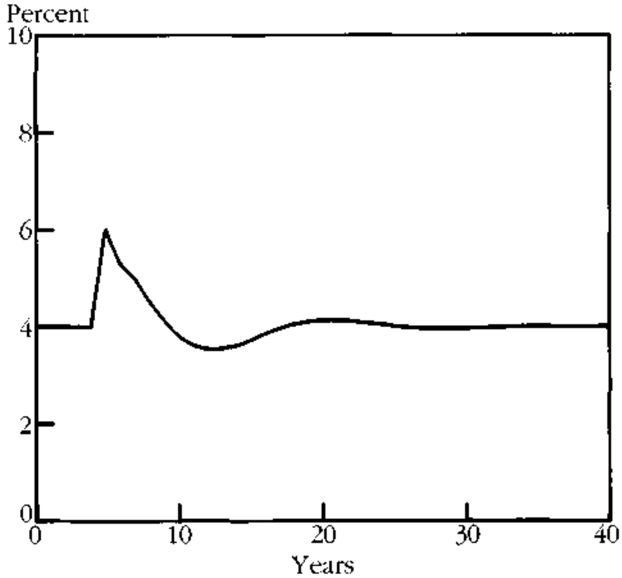
This constraint cannot be rejected at any reasonable confidence level, and thus provides evidence of a natural-rate hypothesis for capacity utilization.[8] This suggests that the Federal Reserve is fairly successful in ensuring that a given capac-

7 Although it is difficult to conceive of a rationale for including M2 growth in the supply equation, the coefficient is statistically significant. Perhaps it influences the real cost of financing in the short run. Alternatively, this two-equation system could be reinterpreted as a VAR model.

8 This hypothesis was tested using a likelihood-ratio test that is distributed chi-squared with one degree of freedom. The test statistic was 0.62, with a 1 percent critical value of 6.645 (the critical value for a 5 percent test was 3.84).

FIGURE 4

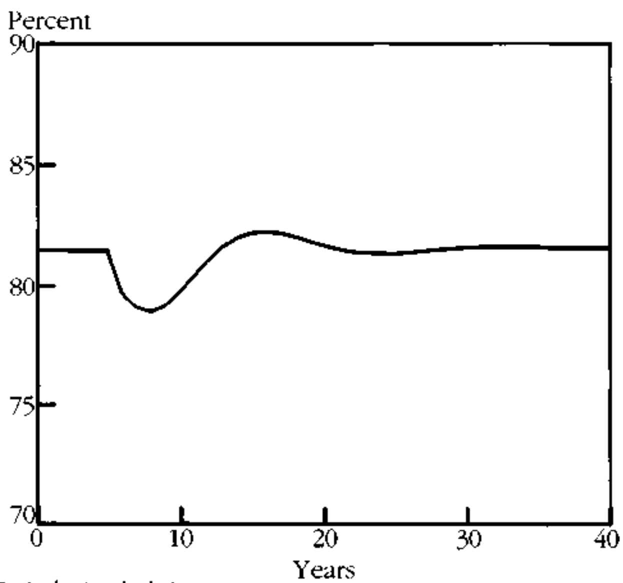
Effect of a Supply-Side Shock on Inflation



SOURCE: Author's calculations.

FIGURE 5

Effect of a Supply-Side Shock on Capacity Utilization



SOURCE: Author's calculations.

ity utilization rate does reflect the same degree of "tightness" over time (unlike earlier research based on models such as equation [3], where the "penalty" for deviations from the steady-state capacity utilization rate varied over time).

Given that M2 velocity is roughly constant in the long run, we would also expect that the steady-state inflation rate would mirror increases in M2 growth.[9] This property is equivalent to imposing

$$(11) \quad c = (1 - C)(1 - b - d)/(B + D1 + D2)$$

A likelihood-ratio test fails to reject this null hypothesis at any reasonable level of significance (the value of the test statistic is 0.32), confirming expectations.[10]

One advantage of this model over the single-equation type represented by equation (4) is that no significant structural change seems to occur over the sample period. This hypothesis was tested by dividing the sample into two periods, 1953-71 and 1972-89, and reestimating the model for each. A likelihood-ratio test was then performed to see whether the null hypothesis of no structural change could be rejected. The chi-squared test statistic with 13 degrees of freedom was 25.0, with a 1 percent critical value of 27.7. At this level of significance, it was found that the null hypothesis cannot be rejected.[11]

The long-term behavior of this two-equation system can now be investigated by solving for its steady-state solution. The steady-state capacity utilization rate is 81.5 percent when M2 grows at a yearly rate of 7 percent—an estimate that is very close to those reported for the single-equation model (tables 2 and 3).[12] The steady-state inflation rate is determined by the growth rate of M2.

The dynamics of the two-equation model can be illustrated through an examination of two simulations. The first introduces a 2 percent supply shock to the supply equation in the tenth period. (This could represent a sudden increase in the price of oil, for example.) The effects of this shock on inflation and capacity utilization are illustrated in figures 4 and 5. Initially, inflation increases while capacity utilization remains unaffected (because only the lags of variables

■ **9** In the steady-state reduced form, inflation is equal to the M2 growth rate minus the growth rate of real output. The model's estimate of average real GNP growth over this period is 2.2 percent—a little less than its 2.9 percent average annualized growth rate estimate.

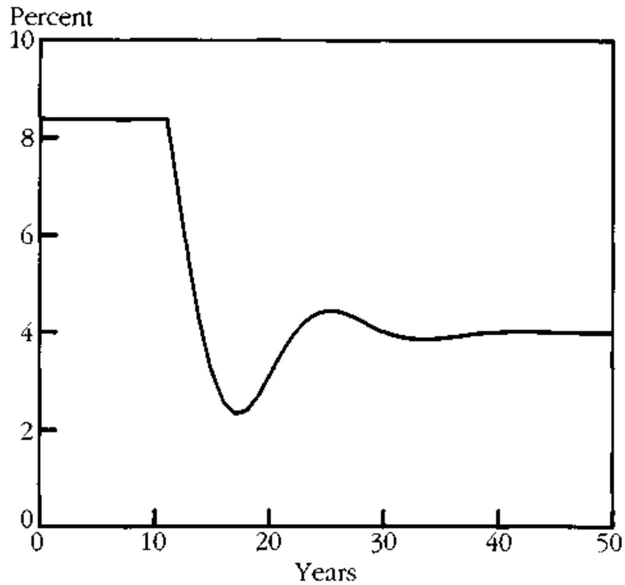
■ **10** An unfortunate feature of this model is that it is impossible to impose simultaneously the constraints that 1) steady-state capacity utilization not depend on M2 growth and 2) steady-state inflation increase in tandem with M2 growth.

■ **11** Although the null hypothesis would be rejected at the 5 percent level (the critical value here is only 22.4), given the large number of parameters that are allowed to vary and the extremely limited number of observations, a relatively tight level of significance is justified.

■ **12** See also McElhattan (1978, 1985), Tatom (1979), and Gittings (1989).

FIGURE 6

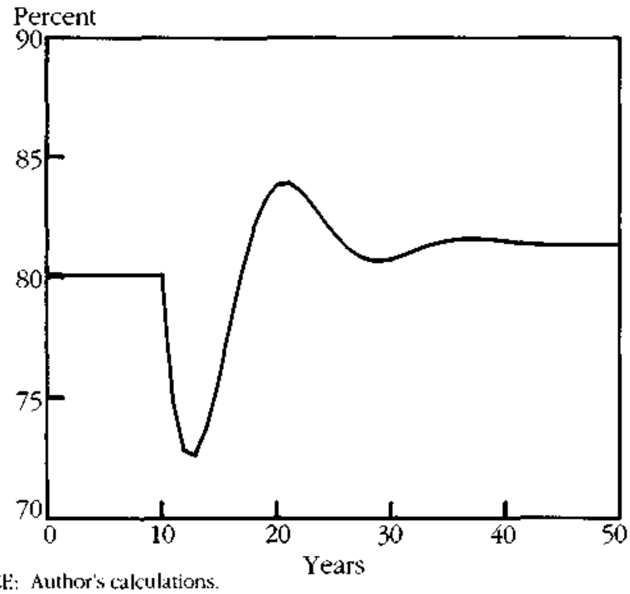
Effect of a Reduction in M2 Growth on Inflation



SOURCE: Author's calculations.

FIGURE 7

Effect of a Reduction in M2 Growth on Capacity Utilization



SOURCE: Author's calculations.

appear on the right side of equations (8) and (9). In the next period, inflation begins to decline toward its long-run steady state (in part because the shock is no longer present), and capacity utilization decreases because the preceding period's higher inflation reduces demand. Capacity utilization continues to decline for three periods and then rebounds toward its long-run steady state. Although the model does experience some "overshooting," the system is more highly damped than many large macroeconomic models.[13]

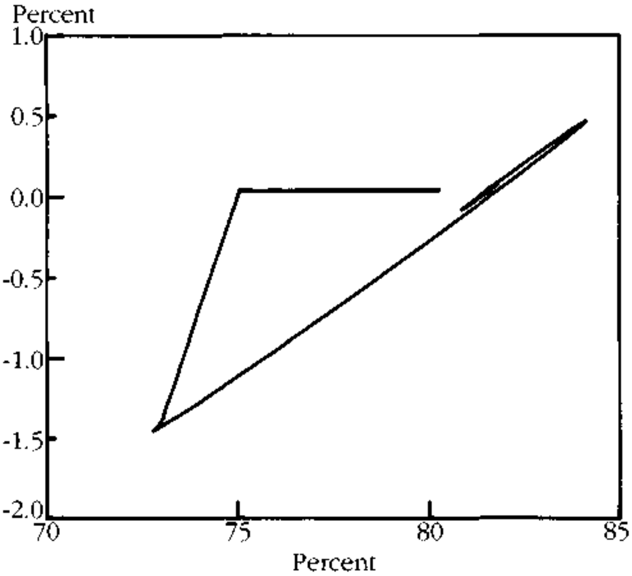
In the second simulation, inflation and capacity utilization rates are examined as the rate of M2 growth is reduced from 12 percent to 7 percent in the tenth year (see figures 6 and 7). At the beginning, the steady-state inflation and capacity utilization rates are 8.4 percent and 80.1 percent, respectively. Given the lag structures in equations (7) and (8), the initial effect is felt as a reduction in capacity utilization the following year, a decline that continues over the next three years. Inflation remains unaffected until the second year after the policy change, and then falls throughout each of the next six years. Even though the system is highly damped, there is still some overshooting in both the inflation and capacity utilization rates. Ultimately, the system reaches a new steady state with nearly the same capacity utilization rate (81.5 percent—not a statistically significant difference), but with an inflation rate of only 4.0 percent.

Figure 8 provides some insight into why the McElhattan-type "misspecified" model (at least in reference to the current one) yields reasonable results despite the apparent structural change over time. The figure plots the change in the inflation rate against the capacity utilization rate as the system returns to equilibrium following a reduction in the growth rate of M2. Clearly, a world with many such shocks could easily generate a plot similar to that of figure 3. A direct relationship between capacity utilization and changes in inflation would always be found, but depending on the latest shocks to the system, the actual estimated parameter

■ **13** Judd and Trehan's (1989) approach also finds relatively damped cycles, and is similar in spirit to this study in that it does not subscribe to any particular macroeconomic theory. The authors identify supply and demand shocks for a five-variable VAR system (unemployment rate, real GNP, nominal interest rate, labor supply, and foreign trade) using rather uncontroversial restrictions. Their approach yields even shorter cycles that exhibit much less overshooting. This could be the result of more detailed modeling (the inclusion of five variables) or of the use of quarterly rather than annual data. Because their study includes unemployment data, it is not limited by the capacity utilization problems discussed earlier.

FIGURE 8

Simulated McElhattan-Type Plot



SOURCE: Author's calculations.

values of the regression line would change. This is consistent with results presented earlier.

In short, as a rough approximation, this relatively simple model tracks the U.S. economy's response to the major economic events of the 1970s and 1980s reasonably well. It also provides some insight into why the basic relationship between capacity utilization and inflation appears to vary over time.

V. Conclusion

This paper examines the theoretical and empirical relationship between capacity utilization and inflation. Although there clearly is a connection between these two time series, earlier models suggest that structural changes occurred in the relationship over the 1953-89 period. Granger causality tests appear to confirm the suspicion that there is bidirectional causality between capacity utilization and a change in the inflation rate. One implication of this finding is that alternative models that treat both variables as endogenous should be employed.

A relatively simple two-equation structural model is developed here that is sufficient to explain the relationship. The dynamics of supply and demand relationships are employed to identify the system following Haynes and Stone (1985), with the model treating both capacity utilization and inflation as endogenous variables. No evidence of structural change is found from 1953 to 1989, but because of the relatively small number of yearly observations, only two subperiods are investigated.

The natural rate of capacity utilization is found to be about 81.5 percent and independent of the growth rate of M2. Although faster monetary growth increases both capacity utilization and inflation in the short run, only inflation is increased in the long run (moving in tandem with M2 growth). As a rough approximation, the model appears to track the real economy's reaction to supply and monetary shocks reasonably well. However, development of the proper framework for examining the endogenous relationship between capacity utilization and inflation is the most important contribution of this study.

References

Bauer, Paul W. and Deily, Mary E., "Measuring the Unseen: A Primer on Capacity Utilization," *Economic Commentary,* Federal Reserve Bank of Cleveland, June 15, 1988.

__________, "A User's Guide to Capacity-Utilization Measures," *Economic Commentary,* Federal Reserve Bank of Cleveland, July 1, 1988.

Berndt, Ernst R., Morrison, Catherine J., and Wood, David O., " The Modeling, Interpretation, and Measurement of Capacity Utilization," contract requisition 63-3-2, Washington, D.C.: U.S. Department of Commerce, Bureau of the Census, U.S. Government Printing Office, May 1983.

Conway, Roger K., Swamy, P.A.V.B., and Yanagida, John F., "The Impossibility of Causality Testing," Special Studies Paper No. 178, Washington, D.C.: Board of Governors of the Federal Reserve System, Division of Research and Statistics, July 1983.

Gittings, Thomas A., "Capacity Utilization and Inflation," *Economic Perspectives,* Federal Reserve Bank of Chicago, May/June 1989, 2–9.

Guilkey, David K. and Salemi, Michael K., "Small Sample Properties of Three Tests for Granger-Causal Ordering in a Bivariate Stochastic System," *Review of Economics and Statistics,* November 1982, *64,* 668–80.

Hallman, Jeffry J., Porter, Richard D., and Small, David H., *M2 per Unit of Potential GNP as an Anchor for the Price Level.* Staff Studies 157, Washington, D.C.: Board of Governors of the Federal Reserve System, April 1989.

Haynes, Stephen E. and Stone, Joe A., "A Neglected Method of Separating Demand and Supply in Time Series Regression," *Journal of Business & Economic Statistics,* July 1985, *3,* 238–43.

Judd, John P. and Trehan, Bharat, "Unemployment-Rate Dynamics: Aggregate-Demand and -Supply Interactions," *Economic Review,* Federal Reserve Bank of San Francisco, Fall 1989, 20–37.

Klein, Lawrence R. and Long, Virginia, "Capacity Utilization: Concept, Measurement, and Recent Estimates," *Brookings Papers on Economic Activity,* Washington, D.C.: The Brookings Institution, 1973, *3,* 743–56.

McElhattan, Rose, "Estimating a Stable-Inflation Capacity-Utilization Rate," *Economic Review,* Federal Reserve Bank of San Francisco, Fall 1978, 20–30.

________, "Inflation, Supply Shocks and the Stable-Inflation Rate of Capacity Utilization," *Economic Review,* Federal Reserve Bank of San Francisco, Winter 1985, 45–63.

Raddock, Richard D., "Revised Federal Reserve Rates of Capacity Utilization," *Federal Reserve Bulletin,* October 1985, *71,* 754–66.

_________, "Recent Developments in Industrial Capacity and Utilization," *Federal Reserve Bulletin,* June 1990, *76,* 411–35.

Rasche, H. Robert and Tatom, John A., "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," *Economic Review,* Federal Reserve Bank of St. Louis, May 1977, 2–12.

Scadding, John L., "The Sampling Distribution of the Liviatan Estimator of the Geometric Distributed Lag Parameter," *Econometrica,* May 1973, *41,* 503–508.

Shapiro, Matthew D., "Assessing the Federal Reserve's Measures of Capacity and Capacity Utilization," *Brookings Papers on Economic Activity,* Washington, D.C.: The Brookings Institution, *1,* 1989, 181–225.

Tatom, John A., "The Meaning and Measurement of Potential Output: A Comment on Perloff and Wachter Results," Three Aspects of Policy and Policymaking: Knowledge, Data, and Institutions, *Carnegie-Rochester Conference Series on Public Policy.* New York: North Holland Publishing Co., 1979, *10,* 165–78.

Thornton, Daniel L. and Batten, Dallas S., "Lag-Length Selection and Granger Causality," *Working Paper* 84-001, Federal Reserve Bank of St. Louis, 1983.