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Inflation, Supply Shocks and the Stable-Inflation Rate of Capacity Utilization

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Conventional Phillips Curve models emphasize the relationship between inflation and the unemployment rate. From these models, analysts derive the natural rate or stable-inflation unemployment rate. This is a rate which, if maintained, is associated with no change in the inflation rate. In this paper we focus upon inflation and the capacity utilization rate, and derive a stable-inflation capacity utilization rate which is about 82 percent (with its 95 percent confidence interval between 78.5 and 83.5 percent.) Evidence is presented that capacity utilization is a more informative inflationary signal than the unemployment rate.

The rate of inflation declined substantially between 1981 and 1983, from 9.6 percent to 3.8 percent. This reduction accompanied a recession that was the worst since the Second World War in terms of unemployment and unused manufacturing capacity. The jobless rate averaged 9.7 percent and the capacity utilization rate 71.1 percent in 1982. We must look back to 1941 to find a comparable unemployment rate of 9.9 percent, and to 1975 for the previous post-war low of 72.9 percent in the capacity utilization rate.

After paying such substantial real costs to bring inflation down, a concern has arisen that subsequent economic growth may start another inflationary spiral. Just how far can growth proceed before inflationary pressures are likely to rebuild? This is the major question addressed in this paper.

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Our starting point in answering this question is a traditional pricing model in which prices are determined as a mark-up on unit production costs. In an earlier version of this model (McElhattan, 1978), I estimated the inflationary impact of excess demand pressures, as measured by capacity utilization in U.S. manufacturing industries, and found that, on average, during the 1954–1977 period, stable inflation was associated with a capacity utilization rate of about 82 percent. Demand pressures tended to raise inflation when utilization rates rose much above 82 percent; inflation tended to fall when utilization rates fell below that critical value.

Since that earlier paper, the U.S. has experienced sharp and repeated changes in energy prices and substantial changes in the international value of the dollar. In addition, the capacity utilization series has been revised. The objectives of this paper therefore are to update and expand the earlier model by adding supply-side shocks, and to determine the degree to which the stable-inflation capacity utilization rate may have changed.

Section I presents an overview of the basic inflation model and the determination of the stable-inflation rate of capacity utilization. Section II considers the estimation of inflation and the inflationary impact of the following supply-side shocks: Nixon-era wage and price controls, changes in the real price of crude oil, and changes in the international value of the dollar. Section III provides estimates of the Stable-Inflation Rate of Capacity Utilization from the expanded inflation model and compares these to earlier estimates. Section IV compares capacity utilization and unemployment rates as signals of impending inflation. Section V discusses economic and policy implications of the stable-inflation capacity utilization rate concept, and the final section provides a summary.

I. The Inflation Model

The inflation equation used in this paper is derived from a traditional price mark-up model found in most econometric macro forecasting models and studies of inflation.[1] The model itself determines an aggregate inflation rate as measured here by changes in the GNP Implicit Price Deflator. Inflation behavior is described in terms of a wage and a price equation. The price equation relates prices to a mark-up on standard production costs, with wages as the major cost component. Wages, in turn, are determined by excess demand in labor markets and by expected inflation.

The mark-up of final product prices over production costs is related to excess demand pressures in final product markets. These pressures are most often measured by the GNP gap between actual and potential GNP or by capacity utilization rates. As aggregate demand builds and utilization rates increase, the mark-up increases as final product prices adjust to eliminate excess demand. The higher mark-up also may reflect noncompetitive pricing behavior by some firms that feel they can raise prices without a serious loss in sales during periods of increasing demand.[2]

In a typical price mark-up equation, the aggregate inflation rate (IR) is determined by changes in standard unit labor costs, measured by changes in nominal wages ($\dot{W}$) and a trend rate of labor productivity ($\dot{T}$), and by excess aggregate demand, expressed here as a function of capacity utilization, f(CU):

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

In Equation 1, dots over the variables indicate rates of change in that variable, and the subscript, t, refers to a period of time. Upward pressure is placed upon inflation when capacity utilization increases; that is, the change in IR_t with respect to $f(CU_t)$ is positive.

In Equation 2, the rate of change in nominal wages of labor are determined by the expected inflation rate (IR*), by the trend rate of growth of labor productivity and by excess demand in labor markets, expressed as a function of the unemployment rate, h(u).

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

Rising unemployment places downward pressure on wages, and a decrease in the unemployment rate represents an increase in wage pressures, that is, $h' < 0$. According to Equation 2, inflation-adjusted wage changes ($\dot{W} - a_{21}IR^*$) will rise in proportion to labor productivity for given levels of unemployment.

Substituting Equation 2 into Equation 1, we obtain Equation 3, in which the inflation rate is determined by expected inflation, labor productivity and the two excess demand variables, unemployment and capacity utilization rates:

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

Focus on Capacity Utilization

Because of the high correlation between the unemployment and capacity utilization rates, empirical estimation of Equation 3, or specifications similar to it, generally include only one of these variables, the unemployment rate.[3] The resulting negative relationship between the unemployment rate and inflation, popularly known as the Phillips Curve, has received wide attention.

In our model we focus upon the inflationary consequences associated with capacity utilization and drop the unemployment rate because the capacity utilization rate provides a more reliable signal of inflation than the unemployment rate, as shown in Section IV. Consequently, in our model, capacity utilization proxies for aggregate demand pressures in general as these affect both the price mark-up and the determination of wages.

Major changes that occurred in the post-war period have altered the unemployment rate associated with a given degree of inflationary pressure. For instance, many economists contend that demographic changes since the mid-1960s (particularly the presence of more women and young people in the labor force) have resulted in a higher average "natural" unemployment rate (a rate consistent with no change in inflation). There remains, however, a good deal of disagreement and uncertainty among economists over how much the natural rate of unemployment has changed.

This uncertainty about the natural rate of unemployment has public policy as well as academic implications. Some economists argue that it has led to some inflationary bias in past policy decisions. There was a natural tendency, they argued, to err on the side of underestimating the unemployment rate consistent with stable inflation and, therefore, to advocate policies which in retrospect were too stimulative and inflationary.[4] If this assessment were correct, the use of capacity utilization to gauge inflationary pressures may be helpful. It would at least serve as an independent check on assessments of inflation based on unemployment measures.

The capacity utilization data do not represent capacity measurements in some absolute or engineering sense.[5] Instead, they depend to a degree on the judgment of the respondents providing the data. Such judgment, nevertheless, represents an economic concept that bears on pricing decisions, just as inflation expectations, which also are difficult to measure, bear on pricing decisions. Moreover, the capacity utilization series has had a stable and close correlation with changes in the inflation rate throughout the post-war period. It therefore merits serious consideration as an empirical signal of inflation.

Formulation

In view of the above considerations, we may rewrite Equation 3 with capacity utilization as the sole excess demand variable. In addition, we express the general form, f(CU), as approximated by the linear relationship, $b_0 + b_1 CU_t$, to obtain Equation 4.

$$IR_t = a_{12}a_{21} IR^*_t + (a_{12}a_{23} - a_{13})\dot{T}_t + b_0 + b_1 CU_t \quad (4)$$

We regard inflation expectations, IR*, as a weighted average of past actual inflation. This is a general specification of the formation of inflation expectations and a common one in price mark-up models; it is shown in Equation 5.

$$IR^*_t = \sum_{i=1}^{k} b_i (IR_{t-i}) \quad (5)$$

where $\sum_{i=1}^{k} b_i = 1$, $b_i \geqslant 0$ for all i.

Substituting Equation 5 into Equation 4 yields the reduced form equation of the wage-price sector of a more complete model of the U.S. economy. In the reduced-form specification, Equation 6, the trend rate of change in productivity of labor ($\dot{T}$) and capacity utilization (CU) are regarded as exogenous variables.

$$IR_t = a_{12}a_{21}\sum_{i=1}^{k} b_i IR_{t-i} + (a_{12}a_{23} - a_{13})\dot{T}_t + b_0 + b_1 CU_t \quad (6)$$

Equation 6 provides the short-run relationship between inflation and its determinants. A stable, long-run relationship exists only if the value of $(a_{12}a_{21})$ is less than unity. Under that condition, any gap between inflation and its expected rate, for given values of capacity utilization and productivity, will become smaller over time. Eventually, actual and expected inflation will be the same and will be associated with a specific capacity utilization rate. In the context of unemployment and inflation, the condition that $(a_{12}a_{21})$ is less than unity implies a stable, long-run Phillips Curve. By the same reasoning, a permanently lower capacity utilization rate would be needed to achieve a permanently lower inflation rate.

On balance, econometric evidence since the mid-1970s suggests that the value of a_{21} is unity and that the value of $a_{12} = a_{13} = 1$. This leads to the result that $(a_{12}a_{21})$ is unity.[6] In the case of the coefficient, a_{21}, the unity estimate suggests that inflation expectations are fully reflected in wages over time (see Equation 2). According to Equation 1, the estimate $a_{12} = a_{13} = 1$, suggests that the relevant long-run determinant of inflation is the rate of change in standard unit labor costs $(\dot{W} - \dot{T})$ that is fully incorporated in final prices.

These considerations enable us to rewrite the reduced-form inflation model (Equation 6) in terms of the difference between actual and expected inflation:

$$IR_t - IR_t^* = (a_{12}a_{23} - a_{13})\,\dot{T}_t + b_0 + b_1\,CU_t \quad (7)$$

Equation 7 indicates that a stable relationship exists between the difference of actual and expected inflation and capacity utilization and labor productivity.

Adding Supply-Side Shocks

Since the early 1970s, a number of events have significantly affected U.S. prices. These include the Nixon-era wage and price controls, changes in the international value of the dollar and the OPEC changes in the price of oil. We shall refer to these events as supply-side shocks.

In the context of our model, the latter two events affect final prices through their impact on the the mark-up of domestic prices over costs. We recall that the inflation rate is measured by the GNP Implicit Deflator. The GNP Deflator is a value-added concept—it measures the value of goods and services produced in the U.S. Therefore, it directly excludes the value of imports. For example, although the value of imports is included in personal consumption spending, it is subtracted from GNP in the import account. As a result, imports have no direct net effect on GNP or the Deflator. However, changes in the price of imported items may be correlated with changes in the GNP Deflator to the extent that changes in foreign prices, through competitive pressures, lead to changes in the U.S. prices of traded products produced in the U.S.

Equation 8 includes a function of the vector Z to incorporate these supply-side shock variables as determinants of U.S. inflation.

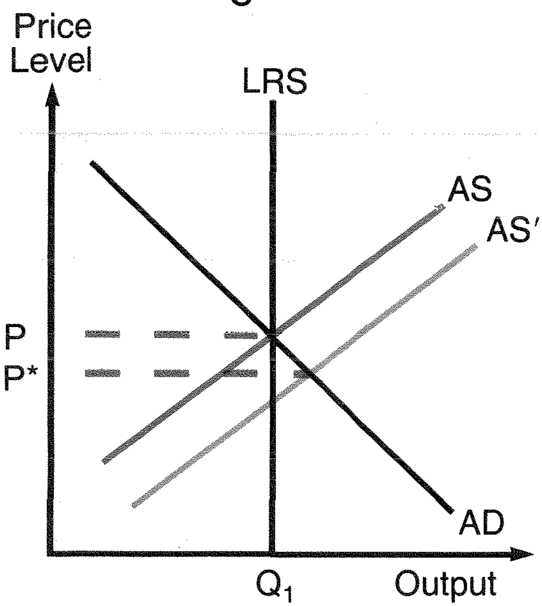
$$IR_t - IR_t^* = (a_{12}a_{23} - a_{13})\,\dot{T}_t + b_0 + b_1\,CU_t + k(Z) \quad (8)$$

In the short-run, supply-side price shocks are likely to be positively correlated with inflation. Such shocks would have no transitory effect on the aggregate price level if other prices were perfectly flexible (and if the productive capacity of the economy were unaffected). However, we generally do not observe perfectly flexible prices over short periods of time so some positive correlation between movements in supply-side price shocks and the aggregate price level appears most likely.

What ultimately happens to U.S. prices following a price shock depends upon whether there are any related changes in (a) real GNP and/or (b) the money supply. We assume first that there is no long-run effect on the level of real GNP. Given this assumption, the ultimate impact on the GNP Deflator will depend upon the monetary response to the initial price shock.

We may distinguish two types of monetary responses to a one-time decrease in the relative price of crude oil. (A price increase has the same effects, but of opposite sign.) In the first case, the decrease in the general price level due to the oil price decline is met by no change in the money supply. This case is illustrated in Figure 1 in a simple aggregate demand-aggregate supply paradigm of economic behavior.

Figure 1



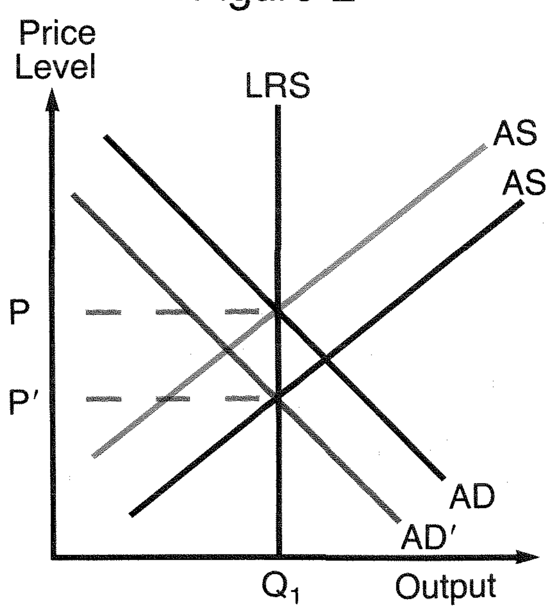
In this paradigm, the aggregate demand schedule (AD) slopes downward and to the right, signifying that greater quantities of output are demanded at lower price levels. This occurs because lower prices mean larger real money balances in private wealth portfolios, which stimulate demand in general. The quantity of output a nation can produce is ultimately constrained by the quantity and quality of real economic factors, including the productivity of its labor and population growth. In the long-run, because of these real constraints, the quantity of real GNP produced is regarded as independent of the price level. These considerations are expressed in the vertical, long-run supply curve, LRS. For short periods of time, however, greater quantities of output may be supplied at higher prices, as expressed in the upward sloping aggregate supply curve, AS. Changes in price expectations or supply-side price shocks, will shift the AS schedule.

Beginning at full-employment equilibrium, a decline in the OPEC price of crude oil means a downward shift in AS, say, to AS′ in Figure 1. In the absence of a monetary response, aggregate demand does not shift. The downward shift in aggregate supply means that the original quantity demanded, Q1, may be sold at a lower aggregate price, P* in Figure 1. That price level cannot be sustained, however. Over time, prices on other goods and services would rise. These revisions produce upward shifts in AS′ back to its original position, AS. At that final point, the price level for the quantity, Q1, is determined by the unchanged money supply and is equal to its original level, P.

In Figure 2, the shift in aggregate supply is met by a decline in the money supply. As a result, aggregate demand will shift downward, say, to AD′.[7] An equal shift in demand and supply denotes a fully "accommodative" monetary policy in the sense that the contraction in money constrains the level of prices for other goods from rising and thus prevents the aggregate supply schedule from shifting from AS′ back to AS. Ultimately, the price level is lower (P′) following the negative shock, its decline determined by the extent of the monetary "accommodation."

These cases illustrate the transitory effect of price shocks on domestic prices. Aggregate price changes occur during the transition period following the supply-side shock. In the subsequent equilibrium (P* or P′ in the prior ex-

Figure 2



amples), there will be no further change in the price level, or in the rate of inflation, as a result of the supply-side shock. A partially accommodative monetary policy will lead to a final price level somewhere between the P* and the P′ of our two examples, and would require some upward shift in the aggregate supply schedule from AS′. For how long, and by what magnitude, prices and the rate of inflation in the U.S. respond to different supply-side shocks is an empirical matter discussed in the following section.

The preceding discussion has assumed that the supply-side price shocks have no long-run effects on the level of real GNP—an assumption some economists have challenged in the case of oil-price shocks.[8] In the event that a permanent change in a supply-side variable alters the level of potential output, the price level will be changed in the long-run from what it otherwise would be independent of whether there is any monetary accommodation. Nevertheless, as in our example, even if the supply-side shock has a permanent effect on the price level, it would not permanently change the rate of inflation.

II. Estimation of the Inflation Model

The general form of the inflation model is expressed in Equation 8. All estimations in this paper use annual data since 1954, unless otherwise specified. The expected rate of inflation in Equation 8 was replaced with the value of the inflation rate lagged one period. This was done because in estimations of Equation 6 only the previous year's inflation rate is statistically significant, as was found in our earlier paper (see Appendix 3). Adding more values of past inflation did not significantly improve the determination of inflation according to the "F" test. Moreover, we found that the estimated coefficient associated with the previous year's inflation rate is not significantly different from unity.[9]

In addition, in this section, the results are reported with the productivity term ($\dot{T}$) omitted. The reason for doing so is that changes in labor productivity, measured by the trend rate of growth in real GNP per hour of employment, has no significant effect on the rate of inflation. This result accords with our earlier study and is generally found in estimations of reduced-form equations similar to the above. The economic significance of this result may best be understood by referring to the components of the productivity parameter in Equation 8. That parameter is derived from the parameters in the price mark-up and wage equation, $(a_{12}a_{23} - a_{13})$. As noted above, the parameters a_{12} and a_{13} from the price equation generally are found in empirical research to be equal to unity. This indicates that the relevant measure in pricing decisions is standard unit labor costs. In the wage equation, a_{23} also is expected to equal unity, reflecting that, on average, the rate of change in real wages is equal to the rate of change in labor productivity. Consequently, the productivity parameter is expected, from an economic point of view, to have a zero value.

With the estimated coefficient of productivity not significantly different from zero, and the coefficient on the previous year's inflation equal to unity, we may re-write the general inflation model (Equation 8) in terms of the change in the inflation rate:

$$\begin{aligned} DIR_t &= IR_t - IR_{t-1} \\ &= b_0 + b_1CU_t + k(Z)_t \qquad (9) \end{aligned}$$

Regression results of Equation 9 are provided in Table 1, at first without supply-side shocks (Column I) and then with wage and price controls (Column II), changes in real oil prices (Columns III and IV), and changes in the international value of the dollar (Columns V and VI) progressively introduced. The dependent variable is the change in the inflation rate, with the latter measured by the year-over-year percentage change in the GNP Implicit Price Deflator. Capacity utilization, CU, is measured as the annual rate in total U.S. manufacturing, a series published by the Federal Reserve Board of Governors.

TABLE 1
Regression Results for Change in the Inflation Rate
(Measured by the GNP Implicit Deflator*)

Independent Variables	Equations					
	I	II	III	IV	V	VI
Constant						
C (b_0)	−15.518	−18.322	−11.748	−13.626	−10.283	−12.090
	(−4.0)	(−5.4)	(−3.7)	(−4.4)	(−3.3)	(−4.2)
Capacity Utilization Rate						
CU (b_1)	.190	.222	.145	.167	.127	.148
	(4.0)	(5.4)	(3.8)	(4.8)	(3.4)	(4.3)
Wage/Price Controls "On"						
WPON		−1.04	−1.21	−1.10	−1.52	−1.44
		(−1.0)	(−1.6)	(−1.4)	(−2.0)	(−1.9)
Wage/Price Controls "Off"						
WPOFF		2.67	1.18	.93	.97	.95
		(3.5)	(1.7)	(1.4)	(1.5)	(1.4)
Change in Real Price of Oil						
DIPE			.027			
			(2.1)			
DIPE Lagged One Year						
$DIPE_{-1}$			−.001			
			(−0.1)			
DIPE Lagged Two Years						
$DIPE_{-2}$			−.054			
			(4.2)			
Acceleration in Relative Price of Oil						
DDIPE				.036	.045	.039
				(3.4)	(3.8)	(3.6)
DDIPE Lagged One Year						
$DDIPE_{-1}$				.044	.053	.058
				(4.2)	(4.9)	(5.4)
Acceleration in Exchange Rate of U.S. Dollar						
DDEX of U.S. Dollar					.091**	.059***
					(2.2)	(1.2)
DDEX Lagged One Year						
$DDEX_{-1}$					.054**	.107***
					(1.0)	(2.4)
Stable Inflation Capacity Utilization Rate						
CU^e ($= -b_0/b_1$)	81.7	82.5	81.0	81.6	81.0	81.7
95% Confidence Interval†	78.7–84.6	80.5–84.6	76.5–83.3	79.4–83.7	76.2–83.5	78.5–83.6
Summary Statistics						
R^2	.35	.55	.76	.76	.80	.80
DW	1.97	1.73	2.20	2.22	2.29	2.24
SE	1.22	1.02	.74	.75	.70	.69

* Estimation period is 1954–83 for equations (I) through (IV) and 1959–1983 for equations (V) and (VI). Figures in parentheses are t-statistics.
** Nominal exchange rate
*** Real exchange rate
† The derivation of confidence limits for the ratio of two estimators is described in Scadding (1973).

Wage and Price Controls

In Equation II, Table 1, wage and price controls are included in the determination of the change in the inflation rate. These controls were applied in several stages from August 1971 through April 1974, when they were removed entirely. The "on" effect is represented by the dummy variable WPON, which is unity in 1972 and zero elsewhere, and the "off" effect, by the dummy variable WPOFF, which is unity in 1974 and 1975.[10]

Controls, according to the estimates in Column II, tended to lower the measured inflation rate about 1.0 percentage points in 1972; their removal tended to increase inflation about 2.7 percentage points in both 1974 and 1975. Other studies also have found a greater price increase when controls were removed than a price decrease—reduction in inflation—when they were imposed. However, such estimates are suspect since a number of other events influenced the economy in 1974 and 1975. If not explicitly included in the estimation, their influence will tend to be captured by the dummy variable. The dollar depreciation in 1973 represents one such influence that, due to adjustment lags, could have increased domestic inflation the following year. Another important influence was the OPEC quadrupling of oil prices beginning in December 1973, which led to unprecedented increases in domestic energy prices shortly thereafter. We will consider first the introduction of energy shocks, and then changes in the international value of the dollar.

The Real Price of Crude Oil

To estimate the impact of oil price changes upon the GNP deflator, we used a measure of the real (or relative) price of crude oil that consists of the ratio of the producer price index for crude petroleum to the aggregate producer price index. The producer price index is not based on a value added in production concept, as is the Deflator, so it reflects price changes in crude petroleum used in the U.S. whether imported or domestically produced. The data on the annual percent rates of change in the relative price of crude oil used in this section are presented in Appendix 1.

Equation III of Table 1 adds the contemporaneous, first and second year lagged values of the percentage change in the real price of crude petroleum (DIPE). (Additional lags did not add significantly to the estimation.) These changes in relative prices are statistically significant in the determination of inflation. Including them reduced the standard error of the estimation from 1.02 percentage points (Equation II) to .74 percentage points.

It is important to consider the sum of the coefficients associated with changes in the real price of oil. A sum significantly different from zero implies that a one-time change in the real price of crude would have a *permanent* impact on the rate of inflation. Rather, we would expect a one-time change in oil prices to have a transitory impact on the rate of inflation as far as its direct effect on price indices is concerned. In addition, there may be indirect effects that are longer lasting. Depending on how monetary policy responds, the shock may get embedded in inflation expectations, for example. This indirect effect, however, would be caught by the lagged inflation terms in our regressions. Similar reasoning applies to the indirect effects caused by the price shocks' impacts on the effective capacity utilization rate.

We therefore tested whether the sum of the coefficients in Equation III of Table 1 is significantly different from zero. We did so by specifying accelerations in the real price of crude oil in Equation IV of Table 1: DDIPE = DIPE-$DIPE_{-1}$. The accelerations were entered contemporaneously and with a one-year lag. This constrained estimation was then compared with Equation III. The "F" test statistic indicated that there is no significant difference between the two estimations at the 95 percent level of significance. In light of this, we concluded that the statistical results indicate oil prices have only temporary inflation effects. We subsequently specified the energy variable in later estimations as accelerations in the real price of oil.[11]

Table 2 illustrates the estimated impact of a one-time 10 percent increase in the real price of crude oil upon the aggregate price level, the rate of inflation and the change in the rate of inflation according to the estimates of Equation IV of Table 1.

During the first year of the shock, the price level and inflation rate increase .36 percentage points. The cumulative effect on the price level is .8 percentage points, which is reached in the second year. The rate of inflation is .36 percentage points higher in the first year and .44 percentage points higher in the second year; it shows no effect of the energy price change in the third year. The volatility in the inflation rate is illustrated by the change in the inflation rate. After increasing in the first and second year by a total of .44 percentage points, the inflation rate declines .44 percentage points in the third year.[12] This fairly abrupt change in the inflation rate is associated with the full adjustment to the oil shock that has occurred in the level of the price deflator.

Inclusion of these energy prices in the estimation substantially reduces the estimation errors, particularly after 1974. Also, as shown in Table 1, after including changes in the real price of crude oil, less of the increase in prices in 1974 and 1975 is attributable to the removal of wage and price controls, "WPOFF." Before the consideration of energy prices, the removal of controls was associated with an increase in the inflation rate of 2.67 percentage points in both 1974 and 1975 (Equation 2). By expressly incorporating real energy prices in Equation 4, this is reduced to .93 percentage points.[13]

The International Value of the Dollar

Changes in the international value of the dollar have recently been included in price-markup models[14] because they are believed to affect the mark-up of domestic prices over domestic production costs. In addition, changes in the international value of the dollar may affect directly the determination of wages. For instance, competitive pressures may induce workers in industries competing in foreign trade to change their wage demands. Consequently, in our reduced-form model, which combines the price mark-up and wage equations, changes in the international value of the dollar may affect both the mark-up on domestic costs and domestic costs themselves.

The international value of the dollar may be expressed in nominal or real terms. The nominal value is simply the trade weighted average of the dollar's value in terms of foreign currencies. The "real" exchange rate is obtained by adjusting the nominal rate for differences in domestic and foreign prices. It is the real exchange rate that appears more relevant in the price-mark-up and wage equations because appreciation of the dollar does not necessarily lead to cheaper foreign products if foreign prices have risen proportionally to offset the appreciation. However, since no convention appears in the literature establishing the appropriate measure of exchange rates in empirical estimation, we present empirical results for both the nominal and real exchange rates.

TABLE 2
Effects of One-Time Ten-Percent Rise in the Real Price of Crude Oil*
(percentage points)

	Change in the Inflation Rate	Inflation Rate	Cumulative Percentage Change in Price Level
First Year of the Shock	.36	.36	.36
Second Year	.08	.44	.80
Third Year	−.44	-0-	.80

* Based on Equation IV of Table 1. Inflation measured by GNP Implicit Deflator

We anticipate that a one-time change in the dollar's exchange rate will lead to transitory changes in the U.S. inflation rate but not to a permanent change. This suggests that the estimated coefficients associated with changes in the dollar's exchange rate in our inflation model should sum to zero, as was the case for oil price shocks. We therefore constrained the sum to zero by specifying accelerations in the exchange rate, as we did in the previous estimation for the effects of oil price shocks. We let DEX represent the yearly percentage change in the exchange rate of the dollar. The acceleration in the exchange rate, DDEX, thus was the difference in the yearly percentage changes in DEX, $DDEX_t = DEX_t - DEX_{t-1}$.

Table 1 provides the empirical results from the estimation of Equation 9 using two values of the dollar's exchange rate—the nominal effective bilateral exchange rate, EXB, and the real effective bilateral exchange rate, REXB. Data for both EXB and REXB are provided in Appendix 2[15].

We anticipate that an appreciation (depreciation) of the dollar would be correlated with a decline (increase) in U.S. prices, and therefore that the sign associated with the estimated parameters would be positive. Equations V and VI in Table 1 include the acceleration in the two exchange rates in the contemporaneous year (DDEX) and lagged one year ($DDEX_{-1}$). The estimated coefficients are all of the expected sign. In each case, the exchange rate adds significantly (at the 5 percent level of significance according to the F statistic) to the determination of U.S. prices when both the contemporaneous and one-year lagged accelerations are included. Based on the results from Equation VI, a 10 percent real appreciation of the dollar is correlated with changes in the level and rate of change in the GNP Implicit Deflator, as shown in Table 3.

According to this estimated response in the U.S. price level, the period required to adjust to changes in the dollar's exchange rate is two years. Within the first year after a 10-percent appreciation, the U.S. price level is .6 percentage points below what it would be otherwise. By the second year, it is 1.7 percentage points lower. The rate of inflation is correspondingly .6 percentage points lower within the first year of appreciation, and it is 1.1 percentage points lower than it otherwise would be during the second year. The inflation rate during the third year shows no effect related to the one-time change in the dollar's international value.

The change in the inflation rate illustrates the variation in inflation in response to changes in the international value of the dollar. The inflation rate is .6 percentage points lower within the first year than it was the year before the dollar's appreciation. It continues to fall in the second year by .5 percentage points. By the third year, after the price level has fully adjusted, the inflation rate increases by 1.1 percentage points. In that third year, the inflation rate is back to what it would have been if the dollar had not appreciated.

TABLE 3
Effects of a Ten-Percent Appreciation in the Real Bilateral Exchange Rate*
(percentage points)

	Change in the Inflation Rate	Inflation Rate	Cumulative Percentage Change in the Price Level
Year of the appreciation	−0.6	−0.6	−0.6
Second Year	−0.5	−1.1	−1.7
Third Year	+1.1	-0-	−1.7

* Based on Equation VI of Table 1. Inflation measured by GNP Implicit Deflator

III. Estimates of the Stable-Inflation Capacity Utilization Rate

A purpose of this study is to estimate the stable-inflation capacity utilization rate with the additional data since 1977 and the expanded specification which includes both energy price shocks and changes in the international value of the dollar. The additional variables played a significant role in determining inflation, particularly since mid-1975 as we have discussed above, and, if not expressly included in the econometric specification, could bias our estimation. Moreover, the additional data cover a period in which inflation was extraordinarily volatile.

Following McElhattan (1978), the stable inflation capacity utilization rate, CU^e, is estimated as

$$CU^e = -b_0/b_1 ,$$

where b_0 and b_1 are estimated from Equation 9. Since capacity utilization is positive, this suggests that the constant term in Equation 9 should be negative and the coefficient on CU should be positive, which they are in Table 1. Referring to Equation 9 again, this estimate of CU^e also assumes that supply shocks have no inflationary impact in the long run, which is consistent with the results reported in Table 1.[16]

The regression estimates in Table 1 indicate a remarkable stability in CU^e with respect to model specification. In addition, CU^e has been stable over time. As shown in Table 4, the estimate of this rate was 81.9 percent in my earlier study for the period 1954–1973. The model for that period included the simple relationship only between the change in the inflation rate and the level of capacity utilization. The same simple relationship, but with an expanded estimation period of from 1954–1977, also yielded an 81.9 percent stable-inflation capacity utilization rate. However, as indicated by the wider 95 percent confidence interval, the additional data introduced greater uncertainty with regard to the population value of the stable-inflation capacity utilization rate. That uncertainty is related to the sharp variations in inflation that occurred at the same time as the removal of wage and price controls, the quadrupling of the OPEC oil prices and the sizable changes in the international value of the dollar.

In our current study, with annual data from 1959–1983 and with the inclusion of the three types of price-shocks mentioned above, the stable-inflation capacity utilization rate estimate is 81.7 percent. In addition, the precision of this estimate is improved over the 1954–1977 period as illustrated by the fairly narrow 95 percent confidence interval of 78.5 percent to 83.6 percent.

The stability of the estimate for CU^e over time is particularly notable given the behavior of inflation. After the mid-1970s, inflation was much higher and more variable than in the earlier period. Inflation averaged 3.0 percent per

TABLE 4
Estimates of the Stable-Inflation Capacity Utilization Rate
(Annual Data)

	Estimation Periods*		
	1954–1973	1954–1977	1959–1983
Stable-Inflation Capacity Utilization Rate	81.9	81.9	81.7
95% Confidence Limits	79.6–83.5	74.9–86.0	78.5–83.6

* Equations associated with these estimates:
1954–1973, see McElhattan (1978), Equation (1), Table 1
1954–1977, see McElhattan (1978), Equation (2), Table 1
1959–1983 Equation VI, Table 1

year between 1954 and 1973. Its standard deviation during that time was 1.5 percentage points, or 50 percent of its mean value. Over the entire 1954–1983 period, the variation in inflation rose to 61.4 percent of its mean value. According to our estimates, neither the substantially higher average inflation rate nor the increased uncertainty with regard to that rate apparently altered the stable-inflation capacity utilization rate.

TABLE 5
Comparison of Capacity Utilization and Unemployment Rates in the Inflation Model: 1959–1983

	Equation I	Equation II	Equation III
Constant	−12.090 (−4.2)	2.087 (2.9)	−14.809 (−2.4)
Capacity Utilization Rate	.148 (4.3)	—	.175 (2.7)
Unemployment Rate	—	−.329 (−2.7)	.091 (.5)
Wage & Price Controls:			
On	−1.436 (−1.9)	−1.174 (−1.3)	−1.476 (−1.9)
Off	.950 (1.4)	.725 (.9)	.911 (.13)
Acceleration in the Relative Price of Oil:			
Current year	.039 (3.6)	.042 (3.2)	.040 (3.6)
Last year	.058 (5.4)	.051 (3.8)	.060 (5.0)
Acceleration in the Real Bilateral Value of the Dollar:			
Current year	.059 (1.2)	.021 (.4)	.066 (1.3)
Last year	.107 (2.4)	.101 (1.9)	.110 (2.4)
Stable-Inflation Rate	81.7	6.3	—
95% Confidence Intervals	78.5–83.6	5.1–9.1	—

Summary Statistics

	Equation I	Equation II	Equation III
$\bar{R}^2$	.80	.72	.80
Standard Error	.69	.83	.71

IV. Comparison of Capacity Utilization and Unemployment Rates as Inflation Signals

We suggested earlier that as a signal of inflation, capacity utilization may be a more reliable policy guide than the unemployment rate. To examine that proposition more formally, we next compare the performance of unemployment and capacity utilization rates in determining inflation. For convenience, Equation I of Table 5 repeats Equation VI from Table 1. In Equation II of Table 5, the unemployment rate replaces the capacity utilization rate as the proxy for excess demand. In Equation III, both the capacity utilization and unemployment rates are included.

In comparing Equations I and II of Table 5, we find that the standard error of the regression is less and the correlation is higher when capacity utilization is the proxy for excess demand in the estimation. The larger standard error and uncertainty associated with the unemployment rate estimates also is reflected in the fairly wide 95 percent confidence interval for the natural rate of unemployment, 5.1 percent to 9.1 percent. This appears too wide a range to provide a very useful policy guide.

The statistical F-test enables us to determine whether adding capacity utilization to Equation II to obtain Equation III would significantly improve the determination of changes in the inflation rate. The F-statistic of 7.4 compared to the critical value of 4.5 suggests that capacity utilization does add significantly to the determination of changes in inflation, above and beyond any information provided by the unemployment rate.

However, when unemployment is added to Equation I to get Equation III, the comparable F-statistic is only .24. This means that the civilian unemployment rate does not provide any statistically significant information once we use the capacity utilization rate in the same determination of changes in the inflation rate. We interpret this as evidence that capacity utilization has been a more informative inflationary signal than the unemployment rate.

V. Inflation In the 1980s and Policy Implications

This section details how the change in inflation in the 1980s is explained by the inflation model as estimated in Equation VI Table 1. In 1980 and 1981, inflation increased continuously and reached a record high of 9.6 percent in 1981, despite weak aggregate demand that was working to reduce the inflation rate in those years (illustrated in Table 6). Capacity utilization averaged 79.6 percent and 79.4 percent in 1980 and 1981, respectively, holding the inflation rate down .3 percentage points in each year. In addition, the continued appreciation of the dollar added downward pressure on inflation. The 13 percent (as measured by the real effective bilateral exchange rate) increase in its value is estimated to have reduced inflation by a total of 1.5 percentage points over the 1980–81 period. However, the depressing effects of both the domestic economy and the international value of the dollar were more than offset by the increase in the relative price of oil which, in 1980 and 1981, was 70 percent. The fast rising oil price alone pushed inflation up by 2.8 percentage points in 1980 and 1981. Other factors (representing the estimation error) added .2 percentage points. On balance, inflation increased .9 percentage points between 1979 and 1981, although the dollar appreciated and the economy was producing below its potential.

Between 1981 and 1983, the inflation rate reversed course, declining from 9.6 percent to 3.8 percent. That reduction was associated with a fall in capacity utilization to a post-war low in 1982 and a partial recovery during 1983. The relatively low capacity utilization over those years reduced the inflation rate by 2.5 percentage points. In addition, the real price of crude oil dropped almost 20 percent. This decline, coupled with the fact that the large energy price increases in 1980 and 1981 had largely worked their way through to a higher price level by 1983, resulted in a sharp deceleration in the change in the price of crude oil. Alone, the deceleration in energy prices decreased the aggregate inflation rate by a total of 4.3 percentage points in 1982 and 1983.

The international value of the dollar continued to appreciate in 1982 and 1983 but by a substantially smaller amount than in 1981. This meant that the depressing effects on the aggregate inflation rate in 1983 were significantly less than in 1981 and 1982. On balance, the contribution of an appreciating dollar to holding down inflation was 0.9 percentage points less in 1983 than in previous years.

Over 1982 and 1983, our inflation model overestimated the 5.8 percentage point decline in inflation by only .3 percentage points. The results clearly highlight the importance of economic slack and supply-side price movements in both the decline and volatility of inflation since 1981. The inflationary model of excess demand and supply-side shocks explains the sharp decline in inflation—even as the economy was experiencing its strongest cyclical recovery in the post-war period.

This discussion illustrates the applicability of conventional inflation models to describing the degree and volatility of inflation. It also illustrates the relevance of the important, but temporary, inflationary effects of supply-side shocks, such as changes in the real price of crude oil and in the international value of the dollar, to macro policy decisions. In essence, any inflationary increase due to a supply-side price shock will be temporary. Once the aggregate price level adjusts to a higher relative price, the inflation rate will drop back to levels that would have existed without those shocks and which reflect aggregate demand pressures. Conversely, any decline in inflation associated with an appreciation of the dollar or decline in the real price of crude oil will be temporary. Once the aggregate price level has adjusted for lower relative prices, the aggregate inflation rate will increase, reflecting the fact that the benefits from the lower energy and/or traded goods prices are over. Ultimately, the inflation rate will reflect aggregate demand pressures in the domestic economy. According to our estimates, adjustments to supply-side shocks take about two years to work their way through the price level.

TABLE 6
Inflation Since 1979

	Inflation Rate (Percent)	Percentage Point Changes in the Inflation Rate	Percentage Point changes in the inflation rate due to:			
			Capacity Utilization	Exchange Rate	Real Price Crude Oil	Other Factors
1979	8.7					
1980	9.2	0.5	−0.3	−0.9	1.5	0.2
1981	9.6	0.4	−0.3	−0.6	1.3	0
1982	6.6	−3.6	−1.6	−0.3	−1.7	−0.1
1983	3.8	−2.2	−0.9	0.9	−2.6	0.4
Cumulative Change		−4.9	−3.1	−0.9	−1.5	0.5

V. Summary

In this paper, we have derived an inflation model that is the reduced-form of conventional wage and price equations of a more complete structural model of the U.S. economy. The reduced-form contains at least two excess demand measures: the unemployment rate, which proxies for slack in the labor markets, and the capacity utilization rate, which proxies for excess demand in final product markets. Because of the close correlation between the two, either unemployment or capacity utilization may serve as a general measure of excess demand in the economy.

Conventional Phillips Curve models emphasize the relationship between inflation and the unemployment rate. We focus upon inflation and the capacity utilization rate. From the conventional Phillips Curve, analysts derive the natural rate or stable-inflation unemployment rate. This is a rate which, if maintained, is associated with no change in the inflation rate. Similarly, we have found a stable-inflation capacity utilization rate, and estimated this rate to be about 82 percent (with its 95 percent confidence interval between 78.5 percent and 83.5 percent).

In this paper, we also have introduced supply-side shocks into the conventional correlation between inflation and excess demand. These shocks include wage and price controls during the Nixon Administration, changes in the international value of the dollar, and changes in the real price of crude oil. We found that both changes in the exchange rate and real price of crude oil added significantly to the determination of inflation during the 1980s. Changes in the inflation rate over the past four years are due almost as much to these temporary price shocks as to the fundamental correlation between excess demand and inflation.

The negative relationship between unemployment and inflation has received wide attention, but we believe the capacity utilization rate may be a more reliable indicator of inflation. Our belief rests on the observation that the stable-inflation capacity utilization rate has remained steady over time, making it a reliable standard. In contrast, a good deal of uncertainty surrounds the estimate of the natural rate of unemployment. This uncertainty may have led to some inflationary bias in past policy decisions to the extent that policymakers and others have tended to underestimate the natural rate and recommend policy actions which in retrospect were too stimulative. The use of capacity utilization rates to gauge inflationary pressures therefore also may be helpful as an additional check on the inflation assessments based on unemployment measures.

APPENDIX 1

Percentage Change in the Real Price of Crude Oil

(Producer Price Index)

Year	Percentage Change	Year	Percentage Change	Year	Percentage Change
		1960	−0.7	1972	− 5.1
1949	3.7	1961	0.7	1973	− 2.4
1950	− 4.0	1962	0	1974	49.3
1951	−10.8	1963	−0.2	1975	6.7
1952	2.7	1964	−0.6	1976	− 1.4
1953	8.7	1965	−2.2	1977	2.0
1954	2.7	1966	−2.5	1978	1.7
1955	− .2	1967	0.9	1979	12.9
1956	− 2.7	1968	−1.7	1980	33.7
1957	7.4	1969	0.5	1981	35.3
1958	− 1.2	1970	−2.7	1982	−10.7
1959	− 3.5	1971	4.7	1983	− 8.3

APPENDIX 2

Percentage Change in Bilaterally Weighted Exchange Rate (EXB)

Year	Percentage Change	Year	Percentage Change
1957	−0.3	1971	3.2
1958	−1.0	1972	6.8
1959	−0.9	1973	8.1
1960	−0.2	1974	− 1.6
1961	−0.3	1975	0.9
1962	−1.2	1976	− 5.1
1963	−0.3	1977	1.5
1964	0	1978	7.7
1965	0	1979	3.1
1966	−0.1	1980	0.5
1967	−0.2	1981	−10.4
1968	−1.3	1982	− 7.7
1969	−0.6	1983	− 4.7
1970	1.6		

Percentage Change in the Real Bilateral Exchange Rate (REXB)

Year	Percentage Change	Year	Percentage Change
1957	−3.1	1971	3.0
1958	−3.6	1972	6.3
1959	−0.1	1973	6.6
1960	0.7	1974	1.3
1961	0.1	1975	1.3
1962	−0.6	1976	2.5
1963	2.0	1977	4.1
1964	1.9	1978	6.2
1965	−0.3	1979	− 1.5
1966	−0.9	1980	− 2.7
1967	0.2	1981	−10.0
1968	−2.7	1982	− 2.2
1969	−0.3	1983	− 0.6
1970	2.5		

Source: Board of Governors of the Federal Reserve System, MPS database.
REXB = PD/EXB*PF where PD represents U.S. prices
PF foreign prices.

APPENDIX 3

(Dependent Variable: Rate of Inflation as Measured by the GNP Implicit Deflator Estimation Period: 1954–1982*)

Independent Variables	Equations (1)	(2)	(3)	(4)
Constant C	−14.578 (−4.0)	−14.395 (−3.1)	−14.061 (3.0)	−14.258 (3.0)
Capacity Utilization Rate CU	.180 (4.3)	.176 (3.3)	.173 (3.1)	.173 (3.2)
Inflation Lagged One Year IR_{-1}	.932 (11.8)	1.003 (10.7)	1.113 (6.0)	1.141 (6.2)
Wage/Price Controls "On" WPON	−.639 (−.7)			
Wage/Price Controls "Off" WPOFF	2.287 (3.1)			
Deviation of Productivity from Trend DPR	−.688 (−1.27)			
Inflation Lagged Two Years IR_{-2}			−.132 (−.7)	−.311 (−1.3)
Inflation Lagged Three Years IR_{-3}				.201 (1.3)
Summary Statistics				
$\overline{R}^2$	.88	.81	.80	.81
DW	2.09	2.02	2.12	2.23
SE	.912	1.19	1.20	1.19

* t-statistics in parentheses.

FOOTNOTES

1. See references in McElhattan, 1978, and in the international study by Tavlas.

2. For a view of the mark-up model that describes competitive market behavior, see Nordhaus. For a view that pertains to noncompetitive behavior, see Modigliani (1958).

3. See, for instance, Modigliani and Papademos, in which unemployment rather than capacity utilization is used in an inflation model.

4. See Scadding 1980.

5. For a description of how the capacity utilization rate series are constructed see the Federal Reserve Bulletin of February 1978 and July 1983.

6. See the discussion in Gordon and in Frye and Gordon.

7. For a discussion, See Dornbusch and Fischer.

8. See, for instance, John Tatom and Tavias' study of the OECD countries.

9. In recent studies of inflation models, Frye and Gordon have suggested that the productivity measure relevant in the price equation may differ from that in the wage equation because opposing sides in labor negotiations have different views of productivity. If that is the case, Frye and Gordon illustrate that the relevant measure of the deviation of productivity from its trend has a small but statistically significant effect upon inflation in the contemporaneous quarter. I have considered a similar measure in the estimation of Equation 1, in Appendix 3. DPR represents the deviation of actual from trend productivity, but it is not statistically significant in my estimation. Adding additional lags does not change that result. This finding may be due to inflation estimates that use annual data rather than quarterly data as did Frye and Gordon's work. Annual data allows time for offsetting quarterly effects to occur. Not finding productivity statistically significant, I have dropped the productivity term from further estimates and discussions of the inflation model in this paper.

10. A possible alternative to the dummy variable technique has been suggested by Blinder, as described in Frye and Gordon. Blinder constructed a variable to represent the impact of controls. It is equal to the fraction of the CPI subject to price controls in each month, based on government records for the period between August 1971 and May 1974. However, Frye and Gordon have compared the Blinder methodology with the simple dummy variable approach similar to that used in this paper and concluded that the Blinder series provided neither a better fit nor an evaluation of the controls that differs from the simple dummy variable approach. Therefore, I have applied only the dummy variable technique in assessing these controls.

11. This specification constrains the sum of coefficients of the rates of change in real oil prices, DIPE, to be zero. A constrained estimation based on this priori knowledge provides more efficient estimates than unconstrained estimates. This is our reason for continuing estimations with accelerations in real oil prices.

12. The change in the inflation rate in the second year is only .08 percentage points because the one-time 10 percent increase in the real price of crude oil in the first period means that in the second period the oil price decelerates by 10 percent. Relating this to the coefficients for DDIPE and $DDIPE_{-1}$ in Equation IV, the 10 percent acceleration in the first year and the subsequent 10 percent deceleration leads to a net second year impact on the change in inflation of (.44 − .36 =) .08.

13. Recently, it has been argued that due to differences in adjustment costs, inflationary responses will vary according to whether the real price of energy is increasing or falling (see Promboin). According to this argument, an energy price increase may render obsolete some portion of the capital stock. Also, an energy price decline may render obsolete certain capital items that might be energy-efficient but too expensive to operate if energy costs become less important. However, there is no reason to believe *a priori* that these costs are the same and that, therefore, energy price changes have symmetric inflationary effects. To test this hypothesis, Equation III from Table 1 was modified to include a variable that is equal to the change in energy prices when the change has been positive, and zero elsewhere. This added variable was entered contemporaneously and with the first and second year lagged values. The results indicate that there was no significant difference in the impact of changes in the real price of crude oil related to the sign of the change. The implication is that adjustment costs to energy shocks are not statistically different during the estimation period depending upon whether the energy shock increased or lowered the real price of crude oil.

14. The MPS model incorporates the real bilateral exchange rate and Gordon's work uses the effective multilateral exchange rate.

15. The exchange rate data is taken from the Board of Governors of the Federal Reserve System database for the MPS model. The Bilateral Exchange rate is a 10-country weighted index.

For the period 1955−1976 the series is a geometrically weighted average of exchange rates with the following countries. The weights are average bilateral trade shares (shares of trade with U.S.).

Country	Weight
Canada	.251
Germany	.160
Japan	.160
U.K.	.104
France	.085
Italy	.068
Netherlands	.061
Belgium	.055
Sweden	.028
Switzerland	.028

The exchange rate data were taken from IMF, *International Finance Statistics*.

16. In McElhattan (1978), the change in inflation was expressed as a function of the difference between actual capacity utilization (CU_t) and the stable inflation capacity utilization rate (CU^e).

$$DIR_t = b_1 (CU_t - CU^e).$$

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

$$DIR_t = b_0 + b_1 CU_t,$$

where $-b_0 = b_1 CU^e$. This leads to the expression $CU^e = -b_0/b_1$.

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