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John A. Tatom

The purpose of this paper is to outline the effects of energy price shocks in a small reduced-form model of the economy. First, the model is detailed. Essentially, energy shocks affect the economy through effects on aggregate supply. Two complementary modeling approaches that were developed to test the theory are discussed. These two approaches lead to the equation estimates used for the EMF7 simulations and are summarized in Tatom (1981).

The next two sections briefly describe the properties of the model and the general characteristics of the simulation results for energy price shocks. We then turn to a discussion of two issues raised in the study design. The first issue is the optimal policy response to energy shocks and the possibilities for monetary accommodation are examined. Second, the natural gas price shock simulation (as well as the stockpile release) was intended to shed some light on the response differences due to foreign versus domestic energy market shocks. Such shocks are inseparable, if effective, so that the assumptions in the natural gas shock simulation may be inconsistent. An alternative to the domestic natural gas price increase scenario is developed to illustrate the analytical problems of such comparisons. Finally, a discrepancy between the potential output effects of energy price shocks based on productivity studies and the permanent real GNP effects of such shocks that arise in the short-run macromodel simulation is explored.

The Model

The model is based on two earlier modeling efforts. First, the Andersen-Jordan GNP equation (1968) expressed in growth rates (Δln) is augmented to account for effects of energy price changes. Such effects could, in principle, be permanent or transitory but the estimates reveal that statistically significant effects can be restricted to be transitory. Second, the price equation for the GNP deflator is a variant of a reduced-form equation developed by Karnosky (1976). The principal determinant of inflation in this model is the rate of growth of the money stock M1, but price controls and energy price shocks influence the level of prices and, temporarily, the inflation rate. Real GNP, X, is simply found as the ratio of GNP to P; its growth rate, ΔlnX, is the difference ($\Delta lnGNP-\Delta lnP$). The estimated equations are given in the appendix to this paper.

The GNP equation also includes a strike measure. This variable, S_t, is the change in the quarterly average of day lost due to strikes deflated by the civilian labor force.[1/] Money (M1) growth, $\dot{M}$, high-employment federal expenditure growth, $\dot{E}$, and GNP growth, $\dot{GNP}$, are measured at annual rates

($400\Delta \ln$), as are changes in the relative price of energy, $\dot{p}^e$, where p^e is the quarterly average producer price index for fuels, related products and power deflated by the business sector implicit price deflator. The coefficients on $\dot{M}$ and $\dot{E}$ are estimated using fourth degree polynomials with five lags and head and tail constraints. The current and six lagged $\dot{p}^e$ coefficients are estimated using a third degree polynomial without endpoint constraints but constrained to sum to zero.[2/] Finally, a dummy variable for the 1980 credit control program is included that is one in II/1980 and minus one in III/1980.

The price equation includes current and twenty lagged growth rates of the money stock M1; these coefficients are estimated using a third degree polynomial with a tail constraint. In addition, dummy variables for wage-price controls (D1 is one for III/1971 to I/1973) and decontrol period (D2 is one for I/1973 to I/1975) are included. Energy price effects are included using an ordinary distributed lag on $\dot{p}^e$ over the past four quarters.

In the personal consumption expenditure deflator equation, shorter lags are optimal. There, current and nine lagged values of monetary growth are used, current and two lagged values of $\dot{p}^e$ and decontrol effects, indicated by D4, end in IV/1974. Both price equations are estimated using generalized least squares with first-order autocorrelation corrections.

The unemployment equation determines UN (U-UF) the excess of the unemployment rate, U, over a full-employment unemployment level, UF. All of the exogenous variables in the model could enter this equation in principle, but only past monetary growth and energy prices prove significant. Current and twenty-one lagged levels of the money stock are included with coefficients estimated using a third degree polynomial with a tail constraint. The past six quarters of energy prices, p^e_{t-1}, are included with the sum effect constrained to zero and the coefficients estimated using a second degree polynomial. This equation is the level variant of the first-difference equation presented in the appendix to Tatom (1981). Generalized least squares is used to estimate the equation with second-order autocorrelation correction.

The determinants of the relative price of energy are the real prices of crude oil and domestic natural gas. The sample period for the equations in the model used for the EMF simulations is I/1955 to IV/1981, except for the price of energy; for real energy prices, the sample period is II/1974 to IV/1981. The energy price is the producer price of fuel power and related products deflated by the implicit price deflator for business sector output. The nominal price of oil used is the quarterly average of the <u>composite</u> refiner acquisition cost of crude oil because of the entitlement system in effect over most of the past decade. Neither imported oil prices nor domestic oil prices accurately capture the cost of oil during that period. The nominal price of natural gas has also been controlled over the sample period and is measured here by the producer price index for gas fuels. Both oil and gas nominal prices are deflated by the price index for business sector output. The equation is estimated in logarithmic difference form for all variables and includes contemporaneous terms for oil and gas and one significant lagged value for the change in the price of oil; tests of additional lags, a constant, or omitted prices for other sources of energy yielded the reported equation.

This reduced-form model [see Tatom (1981)] was developed to examine the short-run macroeconomic response to energy price shocks and to test long-run hypotheses that previously had been tested successfully using a production function approach for the U.S. and other countries [see Rasche and Tatom (1977a and b) (1981) and Tatom (1982)]. Economic theory suggests, and production function estimates confirm, that a rise in the relative prices of energy resources reduces output by creating incentives to change production methods to reduce energy usage including the diversion labor and capital resources to uses that economize on energy costs. As a result, some firms shut-down or exit from their industries while other manifest the loss in economic capacity of existing resources through increased scrappage or obsolescence. Generally, the marginal productivity of existing capital and labor decline immediately and these are reflected, in the long-run, in a lower real wage, capital stock and capital-labor ratio [see, for example, Tatom (1979) and (1982)].

To incorporate the empirical estimates for the U.S. business sector of these effects on the nation's potential output, an updated quarterly production for business sector output was estimated. In the absence of energy price shocks, potential output growth in the control simulation was set at a 3.5 percent rate. This is roughly the post-World War II trend, but a conservative estimate based on the growth of resources and productivity that can be expected from 1980 to 1986.[3/]

According to the U.S. business sector production function estimate for the period I/1948-IV/1981, the immediate impact of a 100 percent ($\Delta \ln$) rise in energy prices is to lower business sector output by about 9.3 percent ($\Delta \ln$). Over the long-run (assumed to be three years here), output is further reduced by 2.9 percent due to a reduction of the capital stock per hour of employment of about 12.2 percent.[4/] Potential output growth does not enter the remainder of the model used, however, so that these results are included only to provide a benchmark for assessing the long-run results of the simulations.

Finally, to implement the EMF7 simulations, an additional assumption was necessary. Since energy prices are measured relative to the price of business sector output, the latter was chained to the simulated GNP deflator in the simulations.

The Energy Price Shock Results

In this model, the effects of energy price changes are linear, in that responses are proportional to the magnitudes of the change in the real price of energy. In all of the energy shock simulations, the results are characterized by long-run neutrality in the sense that nominal GNP, employment, and unemployment are unaffected after 1-1/2 years. The price level and real output are affected adversely and permanently by higher real energy prices, however. Thus, real output and, implicitly, high employment productivity are lower following a rise in the price of energy.

The long-run response of the price level, and real GNP for the four simulations involving oil price shocks are given in Table 1. In each case, the change is measured relative to the outcome in the control simulation in the fourth quarter of 1986. The results in Table 1 are referred to as long-run effects because GNP and, more important, the unemployment rate are unaffected by the end of simulation period. The results are symmetric (exactly in $\Delta \ln$), in that: (1) price increases (decreases) are matched by offsetting decreases (increases) in real GNP, (2) the percentage changes in price and output are of the same magnitude for the 20 percent oil price increase or decrease cases, and (3) the 50 percent price increase results are about 2-1/2 times the 20 percent increase results. At the bottom of each column the change in the relative price of energy for each simulation is given for IV/1986 since that is the principal measure of the shock in each case.

The oil stockpile release program offsets some of the energy price increase effects shown for the 50 percent oil price rise simulation (about 1/4 of the end results) because it is relatively small and so has little effect on the world price of oil. It should be borne in mind, however, that in the stockpile release case the results in IV/1986 are not equilibrium results. After four years of such a release, the existing stock of oil that could be released is likely to be depleted, so that the remainder of the oil price increase from the 50 percent case would likely reappear. Apparently a stockpile release is a more effective operation when the scale of release is increased substantially, but of necessity for a shorter period, in the face of an oil price shock that is expected to be of shorter duration than the four years in simulations 2 and 10.

Some perspective on the results in Table 1 can be gained by comparing the results with earlier energy price shocks. From the third quarter of 1973 to the third quarter of 1974, the logarithm of the relative price of energy rose 40.7 percent so that the relative price of energy was 50.2 percent higher. From the first quarter of 1979 to the second quarter of 1980, energy prices rose similarly: 40.3 percent ($\Delta \ln$), or an actual rise of 49.6 percent. Thus, in each case, the energy shock was essentially the same. Moreover, the macroeconomic effects in each case were nearly twice as large as those in the 50 percent oil price rise case modeled in simulation 2, where the relative price of energy rises only 26 percent.

The Short-Run Effects of Energy Price Shocks

The results illustrated in Table 1 provide little information on the dynamic paths of output, prices and unemployment due to the shocks. These paths are not smooth so that some insight into the model can be obtained from a closer look at them.

The general results of an energy price shock can be observed most simply in Figure 1. There, a rise in the relative price of energy displaces the aggregate supply curve from SS to S'S'. At the initial equilibrium point A, full employment output obtains, X. The rise in the relative price of energy raises supply prices and reduces potential output to X_1. As constructed, the new equilibrium involves proportionately higher prices (P_1), lower actual and potential output (X_1), and unchanged unemployment.

As indicated in the figure, however, the adjustment to the new equilibrium need not be instantaneous; the adjustment path looks like the arrowed path from A to B. In the model, potential output and real GNP decline sharply initially with relatively less upward pressure on prices. Indeed, initially real output declines less than potential output or productivity, putting upward pressure on prices. Subsequently, real output declines more than potential output so that the unemployment rate rises. In the later stages of adjustment (about six quarters after the shock) producers respond to the upward movement in prices expanding supply (and employment) to point B, so that the adjustment is completed.

These are the adjustment paths that arise in simulations such as the 50 percent oil price shock. Table 2 presents the difference between the GNP, prices, real output and unemployment compared with the control solution for the 50 percent oil price increase simulation for the period I/1983-IV/1986.

Is There A Policy Response To Energy Price Shocks?

Answers to this question of EMF7 are presumably to be found from the various demand-oriented policy responses in simulations 4, 5, 8 and 9. Little empirical investigation has been conducted for fiscal policy using the reduced-form model. Only high-employment expenditure growth has been examined and found to be insignificant in the price and unemployment equations and to have no permanent impact in the GNP equation. It was not considered appropriate to alter the existing model to analyze tax policy changes. The model, however, does provide information on monetary accommodation (simulation 4) especially indicating the difficulty of designing an optimal demand management response.

In the monetary accommodation case, there is some temporary offset to the adverse output and unemployment developments from the 50 percent oil price. In Table 3, the unemployment effect of the 50 percent oil price shock is contrasted with the results with monetary accommodation. Initially (the first four quarters), unemployment falls the same or more than without the monetary accommodation. This illustrates that the timing and direction of "accommodation" is off. Initially, a slightly tighter (slower money growth) policy would be "accommodating" and would avoid some of the price increase that otherwise occurs. Later (in the first three quarters of 1984), when the adverse unemployment effects of the oil shock occur, the monetary policy in simulation 4 more than accommodates it. By the end of 1984 when the transitory unemployment rate developments associated with the oil price shock have disappeared, the monetary accommodation reaches its maximum impact reducing the unemployment rate by 1.1 percentage points. Moreover, after that period, the effect of the money growth surge has a dwindling effect on unemployment until, beginning in early 1986, the effect reverses and unemployment begins to rise sharply above the control, recouping its earlier gains (although not by the end of 1986).

In the model, money growth has no permanent effect on unemployment, but positive permanent effects on inflation so that the surge in money growth in 1983 leaves the price level in I/1986 4.2 percent above the control solution compared with 1.6 percent higher without monetary accommodation.

An optimal monetary policy response would require initially some tightening of money and therefore extremely sharp easing early in 1984 to avoid the steep but temporary energy induced run-up in unemployment; subsequently further sharp policy reversals would be necessary to keep inflation and the unemployment rate unaffected by the past policies themselves. Such an erratic path of money raises doubts about the meaning of an "optimal" policy, once the uncertainty attached to sharp swings in monetary growth is factored into account.[5/]

The Natural Gas Price Shock

There is a policy response that appears more readily than demand management policy, however. Since an oil price shock initially affects the energy market, an energy policy response can be considered. The limitations (opportunities if the external shock is temporary) of a stockpile draw down were detailed above. Another policy, however, would be to lessen regulatory controls on domestic energy markets such as natural gas. Such a response is not obvious in the EMF simulation for the natural gas price shock due to restrictions imposed in the simulation design.

Consider the reduced form model simulations for the natural gas price shock, simulation 6. In that shock, U.S. natural gas prices are allowed to rise in the first quarter of 1983 to sell at the equivalent of fuel oil; the producer price index for gas fuels rises 50 percent compared to the control solution, while the path of the oil price is undisturbed. The design of this simulation assumes an excise tax on existing and prospective gas producers so that none of the price increase can accrue to producers. Production incentives are eliminated so as to avoid repercussions from increased competition or supply in the natural gas and world energy markets. In addition, efficiency gains from natural gas price decontrol are ignored in simulation 6.

In the reported results for the reduced form model, simulation 6 raises the relative price of energy by about 6.5 percent (Δln) or 6.7 percent (the IV/1986 change from the control path). This is about one-fourth the shock that occurs from a 50 percent oil price increase, since oil is relatively more important in business sector production than natural gas. For example, on a BTU basis U.S. production of natural gas and oil are roughly the same, but U.S. consumption of oil far exceeds that of gas. In addition, the mix of use is different, a large share of gas is piped to residential users while very little oil is sold directly to residential users. As a result, production costs for business sector output are much more adversely affected by a given percentage rise in oil prices as compared with the same percentage rise in natural gas prices.

The reported output loss and price level increase in IV/1986 for simulation 6 compared to the control case are -0.4 percent and +0.4 percent, respectively. These results compare proportionately with the results in Table 1 for the oil price shocks and show the natural gas shock to be roughly the equivalent of a 12.5 percent oil price disruption.

These results for the natural gas price increase in simulation 6 are implausible, however, because assumptions in the simulation are mutually inconsistent. In particular, it is implausible that a gas price increase can occur without leading to reallocations of constrained natural gas use and therefore efficiency gains. Moreover, these efficiency gains depress demand for OPEC oil and lower the optimal OPEC price. Thus, movements upward in regulated natural gas prices must be associated with reductions in oil prices. For plausible parameter values, the oil price effect dominants the upward movement in natural gas prices, so that real energy prices fall when regulated gas prices increases. Thus, a regulatory increase in regulated gas prices raises output and lowers the price level, contrary to the results in simulation 6. In addition, any supply response of U.S. natural gas producers, assumed away in simulation 6, reinforces these results.

To illustrate these conclusions, an alternative simulation 6 is constructed, called simulation 6A, that maintains the absence of a supply response by natural gas producers, but allows users of gas to substitute among fuels given the gas price rise. The particular changes in this simulation take into account that the magnitude of the natural gas shock in I/1983 is roughly equivalent to natural gas decontrol so that the analysis of decontrol in Ott and Tatom (1982a, b) can be used. That analysis indicates, even without a supply response by producers, oil prices would decline 25.5 percent and natural gas prices paid by electric utilities would rise 31.5 percent, instead of the 50-60 percent assumed for PPI gas fuels in a conventional analysis.

Adjusting the prices of oil and gas fuels accordingly for I/1983 and then indexing both thereafter to the GNP deflator resulted in the differences shown in Table 4 between simulation 6 and decontrol, simulation 6A. As indicated above, efficiency gains from decontrol lead to lower prices and higher output with initially positive and then negative impacts on unemployment. The difference in the simulations appear to indicate permanent gains in unemployment but that arises from the difference in the path of real energy prices during each simulation as compared with the control simulation. In the decontrol simulation, real energy prices are fixed after I/1983, while in the control simulation and in simulation 6, real energy prices rise moderately throughout the remainder of the simulation period. The most significant point in Table 4 is that by the end of 1986, the differences shown more than offset the price level rise and output loss reported for the natural gas shock in simulation 6.

The impact of the natural gas price shock, including the efficiency gains, is shown in Table 5, where decontrol is compared with the control simulation results. It should be emphasized that these results ignore the direct supply response of U.S. gas producers and the indirect effect of a positive own-price elasticity of supply on the world oil price. Nonetheless, the magnitude of the responses approaches the inverse of the 50 percent oil price shock. In combination, then, decontrol in the face of a 50 percent oil shock could reverse much of the price level surge and real output loss associated with such an oil shock.[6/] An important benefit of such a policy response would be that the timing of the policy effects matches up better with the timing of the oil price shock effects.[7/]

The Potential Output Results

There is a remaining noteworthy discrepancy in the simulations of this model that requires comment. The potential output effects of the oil shocks differ from the permanent real

GNP effects in the model. These results are arrived at independently, i.e. they do not influence each other in the model. The source of the discrepancy is fairly easy to identify, however.

The sum of the energy price coefficients in the price equation indicates that a 10 percent (Δln) rise in real energy prices ultimately raises the price level by 0.67 percent and, since GNP is unaffected, lowers real output permanently by that amount. In the production function framework, the same 10 percent rise in the real price of energy lowers real output immediately by 0.93 percent, and subsequently by an additional 0.29 percent, so that after three years the permanent effect is much larger, 1.22 percent. In a statistical sense, this discrepancy is not significant; yet for the range of energy shocks considered the results are not trivial. The permanent real output changes in Table 1 are only about half the size of the potential output changes simulated from the business sector productivity analysis.

Table 7 shows the potential output changes by IV/1986 for the energy shock simulations reported in Table 1, and they exceed the real output losses in Table 1 by a substantial amount. It is understandable that the price equation cannot pick up a statistically significant but very small impact of energy price changes that accrues in each quarter over a period as long or longer than three years due to modest temporary reductions in the growth of the high employment capital-labor ratio. The remaining discrepancy (0.067 versus 0.093) is simply too small to attach much importance to. Based on the superior statistical quality of the productivity studies compared with the price equation, the results from the latter should be regarded as "better" estimates of the permanent losses. The results in Table 6 are also "better estimates" in that unusual in-sample and out-of-sample productivity do not result when estimates of these magnitudes are used while they are likely to with the smaller estimates in Table 1.

FOOTNOTES

1/ In Tatom (1981) and for these simulations the strike measures uses "days lost" for employers with 6 or more workers. Reporting changes in the U.S. Department of Labor requires that "days lost" for firms employing 1,000 or more workers be substituted. Preliminary work indicates that this substitution has no effect on the coefficient estimates.

2/ This is the specification in equation 1.1 in the Appendix to Tatom (1981, p. 17), except for the constraint on the sum of $\dot{p}^e$ coefficients which is supported by an F-test criterion and was apparent in the earlier unconstrained version.

3/ The range of estimates consistent with expected resource growth and historical trends in productivity, <u>ignoring</u> future improvements due to energy shocks, is 3.80 to 4.5 percent. See Tatom (1982, p. 10-11).

4/ See Tatom (1979, pp. 10-11) for a derivation of this result. The 3 year adjustment period was chosen by assuming that the 1975-78 adjustment following the 1973-74 shock was representative. This requires that all of the observed slowing in the growth of the high-employment K/L ratio that occurred up to 1978 was associated with the energy shock, which may appear to be a strong assumption. For about a year prior to OPEC II, however, the capital-labor ratio resumed its historical trend rate of growth.

5/ Recall also that the 50 percent oil price shock examined here is only about half the size of the OPEC I (1973-74) and II (1979-80) shocks experienced in the past. Thus, similar accommodation to that used in simulation 4 would require almost double the surge in money growth used in the simulation.

6/ In Ott and Tatom (1982a and b), the benefits from decontrol for a range of supply responses by U.S. natural gas producers including even pessimistic estimates could be larger than the adverse effects shown for the 50 percent oil price shock in Table 1. In particular, the price level falls by 1.1 to 2.2 percent while potential output rises 1.5 to 3.0 percent.

7/ It should be emphasized that such a policy, natural gas decontrol, has these positive benefits at any time, not simply at the time of an oil shock. It should also be recognized that the magnitude of these favorable responses diminishes with the lessening of the oil price/natural gas price discrepancy so that these results are particular to the point of decontrol, I/1983, and based on parameter values in the fourth quarter of 1981. Actual benefits of further decontrol have been substantially reduced by intervening developments such as continuing deregulation and falling oil prices.

TABLE 1
The Effects of Oil Price Changes

	50 Percent Rise	20 Percent Decline	20 Percent Rise	Stockpile Release 1/
GNP	0%	0%	0%	0%
P	+1.60	-0.85	+0.71	1.24
X	-1.58	+0.86	-0.71	-1.22
U	0	0	0	0
P^e/p	+26.0	-11.7	+10.9	19.6

1/ The stockpile release reduces a 50 percent oil price shock to a 42.5 percent oil price shock due to world oil price reactions due to the release. See Appendix B, of Hickman and Huntington (September 1982).

TABLE 2
The Dynamics of a 50 Percent Oil Price Shock[1/]

	GNP	Price Level	Real GNP	Unemployment Rate [1/]
I/83	-0.4%	0.0%	-0.4%	0.0%
II/83	-0.7	0.0	-0.7	-0.3
III/83	-1.9	0.6	-1.4	-0.4
IV/83	-1.3	1.1	-2.3	0.0
I/84	-2.1	1.4	-3.2	0.6
II/84	-2.4	1.7	-3.9	0.9
III/84	-0.9	1.6	-2.5	0.4
IV/84	0.0	1.6	-1.5	0.0
I/85	0.0	1.6	-1.5	0.0
II/85	0.0	1.6	-1.5	0.0
III/85	0.0	1.6	-1.6	0.0
IV/85	0.0	1.6	-1.6	0.0
I/86	0.0	1.6	-1.6	0.0
II/86	0.0	1.6	-1.6	0.0
III/86	0.0	1.6	-1.6	0.0
IV/86	0.0	1.6	-1.6	0.0

[1/]In each case, the entry is the difference in the simulation 2 result expressed as a percent of the simulation 1 outcome, except for U, where unemployment rate in simulation 2 minus that in simulation 1 is shown.

TABLE 3
Unemployment Rate Effects With and Without
Monetary Accommodation

	Without Monetary Accommodation	With Monetary Accommodation
I/1983	0.0%	-0.1%
II/1983	-0.3	-0.6
III/1983	-0.4	-1.0
IV/1983	0.0	-0.8
I/1984	+0.6	-0.3
II/1984	+0.9	-0.1
III/1984	+0.4	-0.6
IV/1984	0.0	-1.1
I/1985	0.0	-0.9
II/1985	0.0	-0.7
III/1985	0.0	-0.5
IV/1985	0.0	-0.3
I/1986	0.0	-0.1
II/1986	0.0	+0.2
III/1986	0.0	+0.3
IV/1986	0.0	+0.5

TABLE 4

Difference Due to Natural Gas Decontrol vs. Simulation 6[1/]

	Price Level	Real GNP	Unemployment Rate
I/1983	0.0%	0.3%	0.0
II/1983	0.0	0.5	+0.2
III/1983	-0.4	1.0	+0.3
IV/1983	-0.7	1.6	0.0
I/1984	-0.9	2.4	-0.4
II/1984	-1.2	2.9	-0.6
III/1984	-1.2	2.1	-0.3
IV/1984	-1.2	1.4	-0.1
I/1985	-1.3	1.4	0.0
II/1985	-1.3	1.4	0.0
III/1985	-1.3	1.4	0.0
IV/1985	-1.3	1.5	0.0
I/1986	-1.4	1.6	0.0
II/1986	-1.4	1.6	0.0
III/1986	-1.4	1.7	0.0
IV/1986	-1.5	1.7	0.0

[1/]Expressed as a percentage of levels in simulation 6, except for the unemployment rate which is computed as the difference in the unemployment rate.

TABLE 5
The Effect of Natural Gas Decontrol on the Economy[1]
(Without Supply Response)

	Price Level	Real GNP	Unemployment Rate
I/1983	0.0%	0.1%	0.0
II/1983	0.0	0.3	+0.2
III/1983	-0.1	0.4	+0.2
IV/1983	-0.4	0.9	+0.1
I/1984	-0.5	1.3	-0.1
II/1984	-0.7	1.8	-0.3
III/1984	-0.8	1.7	-0.3
IV/1984	-0.8	1.0	-0.1
I/1985	-0.8	1.0	0.0
II/1985	-0.8	1.0	0.0
III/1985	-0.9	1.0	0.0
IV/1985	-0.9	1.1	0.0
I/1986	-0.9	1.1	0.0
II/1986	-1.0	1.2	0.0
III/1986	-1.0	1.2	0.0
IV/1986	-1.0	1.2	0.0

[1] Excess of level in simulation 6A over the level in the control simulation, except for unemployment where percentage point differences are given.

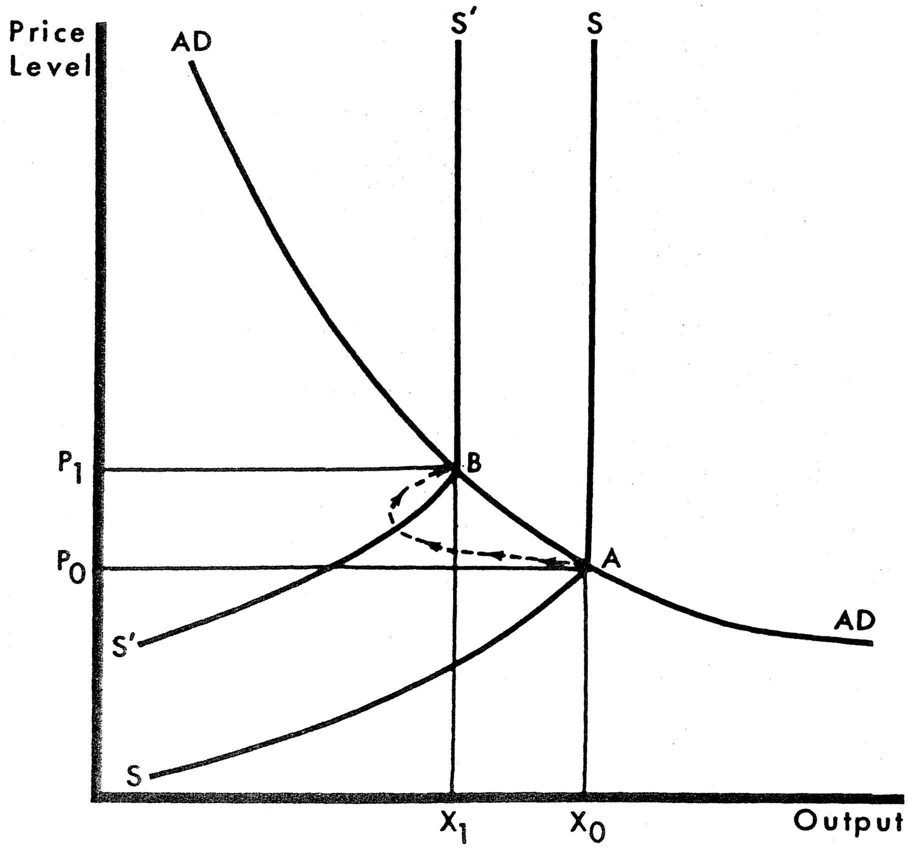
TABLE 6
Long-Run Potential Output Effects of Energy Price Shocks[1/]

50 Percent Oil Price Increase	20 Percent Oil Price Decrease	20 Percent Oil Price Rise	Stockpile Release
-2.8%	+1.5%	-1.3%	-2.2%

[1/]Percentage difference in potential output compared to potential output in control simulation.

Figure 1

The Effect of a Higher Relative Price of Energy on Output and the Price Level



APPENDIX

The Reduced Form Equation Estimates

1.[1/]

$$400\,\Delta \ln GNP = \underset{(3.29)^{2/}}{2.411} + \underset{(8.17)}{1.135} \sum_{i=0}^{4} w^{0}_{t-i}\, 400\,\Delta \ln M_{t-i}$$

$$+ \underset{(0.38)}{0.026} \sum_{j=0}^{4} w^{1}_{t-j}\, 400\,\Delta \ln E_{t-j} - \underset{(-4.02)}{0.484}\, S_t$$

$$- \underset{(-2.04)}{4.619}\, D3 - \underset{(-1.29)}{0.032}\,\Delta\, pep_t + \underset{(0.20)}{0.004}\,\Delta\, pep_{t-1}$$

$$- \underset{(-0.51)}{0.008}\,\Delta\, pep_{t-2} - \underset{(-2.08)}{0.032}\,\Delta\, pep_{t-3}$$

$$- \underset{(-2.11)}{0.038}\,\Delta\, pep_{t-4} + \underset{(0.28)}{0.010}\,\Delta\, pep_{t-5}$$

$$+ \underset{(3.20)}{0.096}\,\Delta\, pep_{t-6}$$

$\bar{R}^2 = 0.56$ S.E. = 2.96 D.W. = 2.05

2.

$$400\,\Delta \ln P = -\underset{(-3.42)}{1.999}\, D1 + \underset{(1.97)}{1.143}\, D2$$

$$+ \underset{(25.95)}{1.038} \sum_{i=0}^{21} w^{2}_{t-i}\, 400\,\Delta \ln M_{t-i}$$

$$- \underset{(-0.06)}{0.001}\,\Delta\, pep_{t-1} + \underset{(3.23)}{0.047}\,\Delta\, pep_{t-2}$$

$$- \underset{(-0.47)}{0.007}\,\Delta\, pep_{t-3} + \underset{(2.14)}{0.028}\,\Delta\, pep_{t-4}$$

$\bar{R}^2 = 0.76$ S.E. = 1.18 D.W. = 2.02 $\hat{p} = 0.19$

3.

$$400\,\Delta \ln PCEP_t = \underset{(0.26)}{0.128} + \underset{(8.19)}{0.901} \sum_{i=0}^{9} w^{3}_{t-i}\, 400\,\Delta \ln M_{t-j}$$

$$- \underset{(-2.44)}{1.745}\, D1 + \underset{(2.13)}{1.563}\, D4 + \underset{(3.02)}{0.037}\,\Delta\, pep_t$$

$$+ \underset{(0.10)}{0.001}\,\Delta\, pep_{t-1} + \underset{(2.86)}{0.037}\,\Delta\, pep_{t-2}$$

$\bar{R}^2 = 0.61$ S.E. = 1.14 D.W. = 2.19 $\hat{p} = 0.46$

4. $$(U-UF) = \underset{(1.98)}{0.403} \sum_{t=0}^{t-21} w_j \, 400 \ln M_{t-i} \underset{(-2.74)}{- 2.339} pep_{t-1}$$

$$+ \underset{(2.05)}{0.927} pep_{t-2} + \underset{(4.49)}{2.508} pep_{t-3} + \underset{(5.27)}{2.406} pep_{t-4}$$

$$+ \underset{(0.66)}{0.620} pep_{t-5} - \underset{(3.87)}{4.122} pep_{t-6}$$

$\bar{R}^2 = 0.39$ S.E. = 0.25 D.W. = 1.77 $\hat{p}_1 = 1.42$ $\hat{p}_2 = -0.48$

5.[3/] $$\Delta\, pep = \underset{(7.96)}{0.276}\; 400\; \Delta \ln (PO/BSP)_t$$

$$+ \underset{(10.52)}{0.263}\; 400\; \Delta \ln (PO/BSP)_{t-1}$$

$$+ \underset{(4.93)}{0.168}\; 400\; \Delta \ln (PG/BSP)_t$$

$\bar{R}^2 = 0.92$ S.E. = 4.46 D.W. = 2.08

6. $$400\; \Delta \ln XP = 3.44 - 0.093\; \Delta\, pep_t - 0.0024 \sum_{t=1}^{12} \Delta\, pep_{t-i}$$

1/ The sample period for equations 1-4 is I/1955-IV/1981.
2/ t-statistics are given in parentheses.
3/ Sample period: II/1974 - IV/1981

List of Variables

Y = nominal GNP

P = implicit price deflator for GNP

X = real GNP

PCEP = implicit price deflator for personal consumption expenditures

Pep = logarithm of the PPI for fuel, power and related products deflated by the implicit price deflator for business sector output

M = M1; prior to 1959, chained to old M1 measure by equating 400 d ln's

UN = excess unemployment, $U-U_F$, where U_F is the CEA full-employment unemployment rate estimate and U is the unemployment rate for the civilian labor force

XP = potential GNP

S_t = the change in the ratio of days lost due to strikes to the civilian labor force

E = high employment federal expenditures

D1 = wage-price control dummy variable: 1, III/1971-I/1973

D2 = decontrol dummy variable: 1, I/1973-I/1975

D3 = credit control dummy = 1, I/1980; -1, II/1980

D4 = decontrol dummy variable: 1, I/1973-IV/1974

PO = refiner acquisition cost of crude (composite)

BSP = business sector implicit price deflator

PG = PPI for gas fuels

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