Crude Oil Prices and U.S. Economic Performance: Where Does the Asymmetry Reside?

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Abstract

Sustained decreases in crude oil prices appear to affect the U.S. economy differently than sustained increases. This paper shows that a significant part of the observed asymmetry is due to adjustments within the energy sector and not within the rest of the economy. In particular, sustained decreases in petroleum product or general energy prices do not appear to have qualitatively different macroeconomic impacts than do sustained price increases. The singular focus on crude oil price changes in previous studies is misplaced. Moreover, the 1986 oil price collapse did not operate in isolation from other important events. As crude oil prices fell in this period, other factors caused a major devaluation of the US dollar that had potentially important effects on the US economy.

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INTRODUCTION

An oil price shock has preceded all but one post-war recession (Hamilton, 1983). Yet, a robust economic recovery did not follow the 1986 oil price collapse. This apparent asymmetry has led many researchers (Mork 1989; Mory 1993; Mork et al 1994; Lee et al 1996; Hooker 1996; Hamilton 1996) to investigate once again the transmission mechanisms for oil price shocks. Some have even questioned the notion that oil price shocks can have a direct effect on macroeconomic activity (Bohi 1991; Bohi and Toman 1993).

Most researchers focus exclusively on the relationship between *crude* oil prices and aggregate economic *output* (or employment). However, oil price shocks have also had significant effects on wages and prices throughout the economy. It is important to consider these inflationary pressures as well, because policies for mitigating the output impacts will often worsen the price impacts. Monetary policy is a case in point. Expanding the money supply or targeting interest rates can soften the impact on aggregate output, but will place upward pressure on prices. Inflationary fears led many countries away from trying to accommodate past oil shocks. Policymakers face a dilemma in the form of a tradeoff between two competing and highly valued objectives.

In addition, oil price shocks are essentially *energy* price shocks. When crude oil prices rise, the prices of refined petroleum products increase. With strong substitutability between competing fuels, other energy prices rise as well. However, the singular focus on *crude* oil price changes misses this important dimension of the problem. Essentially, other researchers have been assuming that crude oil prices are passed symmetrically through the energy system. This assumption requires explicit testing.

This paper reconsiders this asymmetry issue within the context of the broader impacts on prices as well as on output in the economy. It also asks to what extent are the observed asymmetric responses to crude oil price shocks due to adjustments within the energy system itself. The next section discusses several alternative explanations for why oil price shocks can harm the economy and shows why a framework based upon an aggregate neoclassical production function is insufficient to explain the observed effects. After a brief discussion of the data and methodology, the paper reports results of an oil price shock on energy prices, on the prices of other goods and services, and on gross domestic product (GDP). Next the paper considers possible interactions between the output and inflation impacts. A final section contains the key summary points of the analysis.

EXPLANATIONS FOR OIL SHOCKS

The economy's short-run response to energy price shocks is considerably more complicated than simple shifts along an aggregate production function for the nation. The aggregate production function framework predicts small effects that would be reversed with energy price decreases. Moreover, the analysis focuses exclusively on changes in relative prices with no upward shift in the aggregate price level necessarily.

The transmission mechanisms for oil shocks in most large-scale macroeconometric models (as explained in Hickman, 1987) is essentially the aggregate supply and demand model found in many textbooks (e.g., see Dornbusch and Fischer, 1994, and Hall and Taylor, 1993), which emphasizes the real balance effect through the interaction of the goods and money markets. This framework relies mostly on upward shifts in the aggregate price level, which reduces the real monetary balances, rather than relative price adjustments. Shifts in short-run aggregate supply and demand curves push interest rates and prices upward while retarding economic growth. Energy price shocks in such a framework can have large macroeconomic effects and these effects need not be reversible with energy price decreases, if wages and other prices in the economy are downward sticky.

Recent explanations have emphasized the adjustment costs associated with shifts among economic sectors in response to a supply shock (Lilien 1982; Loungani 1986; Hamilton 1988). These adjustment costs occur regardless of the direction of the shock. Hence, these costs operate for both price increases and decreases and can also explain the asymmetric nature of the macroeconomic response to energy prices.

Recent empirical tests have used vector autoregressive (VAR) techniques to explain the economy's response to oil shocks. This approach does not impose an *a priori* structure on the oil price transmission mechanism, and hence, does not differentiate between these possible explanations. Nonetheless, most researchers have explained their VAR results in terms of the adjustment-cost thesis rather than the real monetary balance thesis.

DATA AND METHODOLOGY

Our focus here is to decompose the macroeconomic response into several channels to examine where one can detect asymmetries. By providing a little more structure to the problem, we can explicitly examine several possible effects that should be important, if the real-balance effect is consistent with the observed asymmetries in the system.

The important and strongly debated issue is whether a sustained, unexpected increase in the price of oil contributes to economic recessions within the first year or two of the shock, holding constant government fiscal and monetary policy. Thus, the focus here is on testing whether there are significant short-run effects during the first two years after a disruption and not on trying to identify the cyclical pattern, i.e., whether the impacts in the second quarter are larger than those in the fourth quarter.

For this purpose, we investigate the relationship using annual U.S. economic data available from the U.S. Bureau of the Census, *Survey of Current Business*, through the electronic bulletin board. The annual data set possesses several important advantages. First, the analysis can focus squarely on unanticipated and sustained changes in energy prices, events that clearly could upset investment, wage negotiations and other long-term commitments. The use of higher frequency data would shift the emphasis to monthly or quarterly oil price volatility, which by definition consists of repeated events that rational agents should anticipate and incorporate in their decisions.

Second, given our rudimentary knowledge of the transmission process, it is more important at this stage to identify whether oil price increases and decreases are fundamentally different events. Subtle changes in the timing of these impacts distributed over different quarters of the business cycle could appear as asymmetric responses, even if the basic causal relationships continue to operate for both oil price increases and decreases. There exists no well-defined economic theory on the timing of price pass-throughs, and yet this pattern can be important and quite variable.

There is a common presumption that annual data systematically excludes energy price declines except for the oil price collapse in 1986. However, Table 1 shows that energy price declines are reasonably frequent and important, even on an annual basis, and that the 1986 oil price collapse is far from the only such occurrence. More than one third of the price changes for crude oil, refined petroleum products, or total energy in the 1948-93 period have been downward. Although the mean changes have been smaller for price decreases than for price increases, they are not trivial. Standard deviations are similar for crude oil price changes and only somewhat smaller for petroleum products and for energy. Thus, the 1948-93 period contains years in which energy prices both increase and decrease. While the experience is characterized by a few large energy price increases and decreases, we show later in this paper that the estimated relationship between energy price changes and real GDP is not contingent solely upon these large price changes.

The analysis consists of estimating OLS equations (for the most part) that explain aggregate output and prices as a function of energy prices and other key economic variables.[1] Following the standard practice of other researchers on this topic, all variables, except the unemployment rate, are expressed in percent change terms.

Tests for asymmetric responses consisted of adding a separate variable for energy (or oil) price decreases that equaled the price change if negative and zero if positive. If this coefficient is significant, symmetry can be rejected. In these cases, we also estimate an equation with separate variables for price increases and decreases. While these two equations are equivalent to each other, the coefficients in this second equation are easier to interpret, particularly when the relationship involves lagged values.

We refer to changes in the real gross domestic product (1987 dollars) as output changes. This series extends from 1949 through 1993, thus allowing a sample of 44 years.

We refer to changes in the average producer price index (PPI) for domestic crude oil as *crude* price changes, changes in the average PPI for refined petroleum products as *product* price changes, changes in the average wholesale price for fuel and power as *energy* price changes, and changes in the implicit price deflator for personal consumption as *consumer* price changes. For analysis of oil price shocks, the personal consumption deflator is a better measure of the aggregate price level than is the GDP deflator, which excludes the direct effects of imported oil (Hickman et al 1987, pp. 24-29).

Product price changes are a volume-weighted index of the PPIs for kerosene, distillate fuel oil, residual fuel oil, and after 1958, regular gasoline prices. Expenditure data for constructing a Divisia index of product prices are not available for the full sample period.

During a shock, monetary authorities could target either the money supply or interest rates. In our analysis, we have controlled for the money supply (measured as nominal M1). During past shocks, authorities in different countries have both expanded and contracted money supplies, depending upon their proclivity to fight inflation or soften the recessionary impacts. The equations thus allow one to consider either policy in a very transparent way.

Moreover, the principal transmission mechanism of an oil shock in the standard aggregate supply and demand macroeconomic model is through interest rates, as price level increases cause real money balances to contract even if nominal balances are left unchanged. Thus, the proper treatment of interest rates would be to include them as another dependent variable within a larger system of equations, not as an independent variable. Such an approach unnecessarily complicates the analysis without providing clarity to the asymmetry issue. Our concern here is not to predict what the appropriate monetary response should (or would) be, but to provide a consistent control for monetary policy that can be applied to all equations.

ENERGY PRICE RESPONSES

There exists an important asymmetry in the response of refined product price to changes in the crude oil price. Compared to price increases, crude oil price cuts have a smaller impact on product prices in the first year but a larger impact in the second year.

These findings are based upon an equation that regresses the percent change in product prices on the current and lagged percent changes in crude oil prices, as shown in Table 2.[2] The top equation assumes symmetry in the response to price increases and decreases, while the middle equation allows negative price shocks to have an additional term that must be added to the first price coefficients. The reported t-statistics (-2.56 and -3.02) for these additional terms indicate that the hypothesis of symmetric responses for both the current and lagged crude price change can be rejected at a 95% confidence level. Compared to price increases, crude oil price cuts have a smaller impact on product prices in the first year.

Product price changes affect energy prices, both directly as well as through the prices of coal, natural gas, and electricity. Unlike the relationship between crude oil and refined product prices, energy prices respond symmetrically to petroleum product prices.

Table 3 shows the results for equations in which current and lagged percent changes in refined product prices explain percent changes in energy prices. The reported t-statistics (-1.47 and -1.65) for the additional terms for price cuts indicate that the hypothesis of symmetric responses for both the current and lagged product price change cannot be rejected at a 95% confidence level. Thus, the asymmetry appears to be concentrated within the oil market as embodied in the previously discussed relationship between crude and product prices.

Table 4 summarizes the estimated responses within the energy sector. The asymmetric responses in each group are based upon the third equation in Tables 2 and 3, which provide a more accessible estimate of the separate effects of price increases and decreases. In the top half of Table 4, crude price increases are passed through refined product prices more quickly than are price decreases. As shown in the middle row of this group, a sustained 10% increase in the crude price raises refined prices by 11.9% in the first year, followed by 3.7% reduction in the second year.[3] Thus, the level of product prices is approximately 7.8% [=(1.119)(.963)-1] higher after two years. This pattern reflects some overshooting of product prices when crude oil prices increase, requiring a corrective adjustment in the second year.

A sustained 10% crude price decrease (bottom row of the upper half) reduces refined prices by 7.0 % in the first year and by 2.2% more in the second year. After two years, the level of product prices is approximately 9.3% [=(1.07)(1.022)-1] lower than otherwise. Thus, upward and downward changes in the crude oil price do not appear to have widely dissimilar effects on the product price level after two years. However, the timing, and indeed the pattern of product price movements, is fundamentally different. It appears plausible that the different patterns in crude and product prices are contributing to the observed asymmetry between GDP and crude oil prices. The analysis returns to this issue below.

The bottom half of Table 4 summarizes the responses of energy prices to petroleum product prices. A sustained 10% increase in product prices raises energy prices by 5.7% in the first year and by a smaller 2.1% in the second year. After two years, the energy price level has been changed by approximately 7.9%. While product price decreases appear to have a somewhat smaller effect on energy prices than do price increases, the difference between the two responses is small and not statistically significant.

CONSUMER PRICE EFFECTS

Consumer prices respond asymmetrically to energy prices, but this result is due to the 1986 experience. The economy appears to pass through the direct energy price changes to consumer prices completely during the same year; lagged direct effects of previous energy price changes are not statistically significant. However, energy price increases begin a process of higher prices and wages throughout the economy, resulting in future increases in consumer prices in the following year, although higher unemployment will reduce some of the pressure on wages and consumer prices.

These results are summarized in Table 5. Consumer price changes are explained in terms of their lagged value, changes in energy prices, and the difference in the unemployment rate (level) in the current and previous year. Wage rates, and hence consumer prices, increase less in periods when unemployment rises. Such a specification implies that changes in wages (and hence prices) respond to changes in the unemployment rate (as in the "wage curve" thesis advanced by Blanchflower and Oswald, 1994) rather than to the level of the unemployment rate (as in the expectations-augmented Phillips curve). Based upon an F-test of this constraint, this specification is preferred, although its adoption does not affect the results for the impact of energy prices.

Row 1 displays the asymmetric response when all years are included. Based upon the t-statistic (-3.04) for the coefficient on the negative price variable, symmetry can be rejected at the 95% level. A 10% increase in energy prices raises consumer prices by 1.4% in the first year. During the second year, the consumer price level rises another 0.8% (=.547 x 1.4%) as a result of the previous year's increase in the consumer price level. After two years, the consumer price level is approximately 2.2% higher, although increased unemployment will mitigate this upward pressure on prices somewhat. In contrast, a sustained 10% decrease in energy prices appears to have a negligible effect on consumer prices. This effect is derived by adding the coefficient of the additional variable for negative energy price changes to that for energy price changes. These two coefficients are virtually equal but with the opposite sign.

Energy price decreases have been more frequent in the later than earlier years of the sample. Beginning in the 1980s, both energy prices and physical energy use per $ of GDP fell, causing energy's value share of GDP to decline as well. The smaller response to energy price increases, compared with those to price increases, could be reflecting a long-run decline in the relative importance of energy to the economy.

Initial tests do not appear to support this hypothesis, although further investigation is warranted. Energy's declining value share does not appear to be contributing to the asymmetry finding. The energy price series was respecified in terms of an energy-expenditure-weighted index of energy price changes. Energy's value share of GDP was measured as physical energy consumption per constant dollar of GDP, multiplied by the PPI for fuel and power. The energy price changes were then weighted by this measure of energy's value share. As reported in the appendix, the new energy price series was significant, but had a higher standard error than our original series. In addition, the equation's explanatory power was not as large. Similar results were obtained using the U.S. Department of Energy's series on final users' energy expenditures per dollar of GDP, which is available from only 1970-93.

However, the asymmetric results are strongly linked to the 1986 experience. Energy price declines can be separated into two distinct variables: the 1986 observation and the other 14 years experiencing energy price declines. The first variable is simply zero for all years except for 1986, when it equals the energy price change in that year. The second variable is the energy price change when prices are falling (except for 1986) and equals zero in 1986 and all other years. These results, shown in the second row of Table 5, indicate that the separate energy price decline variable (indicating asymmetry) is significant only for 1986 and not for the remaining 14 years. A 10 percent change in energy prices raises consumer prices by 1.4 percent. Below the specification is expanded to explain why the 1986 experience appears to show little effect on consumer prices.[4]

These results hold for other measures of consumer prices as well and are reported in the appendix. With the consumer price index for urban areas as the dependent variable, a 10% change in energy prices affects consumer prices by 2.0% in the initial year. With the consumer price index for urban areas excluding energy as the dependent variable, a 10% change in energy prices affects consumer prices by 1.1% in the initial year. The separate coefficient for the 1986 energy price decline becomes insignificant, once energy price declines are separated into two distinct components.

To understand why 1986 may have had a different effect, we consider another key condition that may have influenced the economy's performance at this time. During 1986, the United States experienced both an oil price collapse and a sharp devaluation in the dollar. The latter produced wealth losses that virtually offset any perceived wealth gain realized through lower imported oil prices. There were no favorable relative price effects on real domestic income during the oil price collapse of 1986.

This experience contrasts sharply with other sudden changes in the relative price of imported oil. During disruptions, the higher price of oil raised the prices of both U.S. exports and nonpetroleum imports by roughly similar amounts. In Figure 1, the first two bars for each reported year indicate that these price changes affect real income in opposing directions. In 1986, however, the dollar's devaluation caused the prices of exports to fall and the prices of nonpetroleum imports to rise. As a result, real U.S. income fell due to both imports and exports. These adjustments completely offset the wealth gains associated with falling imported oil prices, resulting in almost no gain in the U.S. real income from international trade. Unlike the other oil price shocks during this period, the real income effects of a change in the oil import price during 1986 were not a good indicator of what happened to the U.S.'s international wealth due to total trade. This observation is demonstrated by comparing the third and fourth bars for each reported year.

Changes in real income are different from changes in real output or GDP, because the latter exclude the gains or losses in real wealth through price changes in the foreign trade sector (Denison 1981). Nevertheless, reductions in the prices of nonpetroleum imports might have favorable effects on the economy by reducing the aggregate price level. When the price of nonpetroleum imports is added to the equation (as reported in the last row of Table 5), its coefficient is statistically significant at the 95% level. Its presence in the equation causes the asymmetric effect for energy price declines to become insignificant. Thus, the prices of nonpetroleum imports appear to be an important reason why consumer prices did not follow imported oil prices downward in 1986.

OUTPUT GROWTH

The standard aggregate supply and demand model predicts that energy price changes will reduce aggregate output, holding constant government spending and money supply. Current and lagged values for changes in energy prices, money supply, and government spending were initially entered along with lagged output growth in an equation explaining current output growth. Except for energy prices, lagged values were insignificant. In addition, current energy price changes were insignificant, while the preceding year's change causes a significant reduction in output growth. Thus, the aggregate price impacts (reported previously) of energy price shocks precede the aggregate output impacts (reported here).

In the first equation of Table 6, the output response to energy prices passes the significance test for symmetry. Moreover, the effect of the previous year's energy price change on aggregate output remains unaltered regardless of whether the 1970 experiences with the large oil price shocks are removed from consideration.

Figure 2 displays the striking stability of the output responses to energy price increases for these specifications. The heavy vertical lines indicate the upper and lower bounds for the 95% confidence interval for each equation, while the short horizontal cross-lines indicate the value of the estimated coefficient. A ten percent increase in energy prices reduces the following year's real GDP by 1.3-1.4%, even when the large energy price increases in 1974 and 1979 are removed from this variable. The full set of coefficients for this specification is reported in the appendix.

Like its response to energy price changes, the output response to refined petroleum product prices (reported in the second row of Table 6) is not significantly asymmetric. In contrast, symmetry can be rejected in the output response to crude oil prices in the equation reported immediately below it. Output does not respond to crude oil price decreases, because the additional coefficient for crude price cuts is significantly positive and of equal magnitude to that for the original crude price variable. Symmetry, however, cannot be rejected when the 1986 oil price collapse experience is removed by a dummy variable for 1987.

AGGREGATE PRICES AND OUTPUT

In the standard aggregate supply and demand model, the aggregate price level could affect real output through the interactions between the markets for money and for final goods and services. A higher price level reduces the real money balances, pushing the interest rate higher. Investment and the demand for consumer durables fall, creating additional drag on output through the multiplier effect. In addition, consumer spending could contract as household wealth declines with falling assets (in real terms).

The preceding results indicate that energy price changes affect the aggregate price level contemporaneously (with a carryover to the following year) but do not significantly retard aggregate output until the following year. This pattern suggests a recursive formulation, where higher energy prices first raise the aggregate price level, which reduces aggregate output in the following year.

An OLS estimate of the change in output as a function of last year's consumer price change, current and last year's growth in money supply, and current year's change in government purchases indicates a significant effect of lagged consumer price on current output growth. A 10% increase in the consumer price level reduces aggregate output by 5.6% in the following year for the equation reported in row 1 of Table 7. In the equation immediately below, this response to the aggregate price is the same regardless of whether energy prices are rising or falling.

We considered, but found less appealing, specifications that included both the current and previous year's change in the aggregate consumer price level. Due to simultaneity between aggregate output and current consumer prices, the equation needs to be estimated with two-stage least-squares (2SLS) rather than OLS. In the first stage, the consumer price equation was estimated by including the exogenous variables determining aggregate supply and demand as instrumental variables. These variables included a constant, current and lagged energy prices, and lagged consumer prices in addition to the money supply and government purchases variables.

These results are shown in the last row of Table 7. The insignificant (and positive) coefficient for current consumer prices supports the recursive framework, where energy price changes are passed through to consumer prices relatively quickly, with aggregate prices depressing economic activity with a more delayed impact (during the second year).

CONCLUSIONS:

This analysis supports several conclusions that are important for understanding the short-run effects of oil price shocks on U.S. macroeconomic performance.

1. Crude oil price shocks are essentially energy price shocks. A significant portion of the asymmetry in the economy's response to crude oil price shocks occurs within the energy sector, and more precisely, within oil markets. Crude oil price increases are passed through to refined product prices more quickly than are price decreases.

2. Consumer prices appear to respond asymmetrically to energy price increases and decreases, but this result is critically dependent upon the 1986 experience. When the 1986 experience is excluded, symmetry cannot be rejected for sustained changes in energy prices lasting one year or more.

3. Aggregate output responds asymmetrically to crude oil price increases and decreases but symmetrically to petroleum product or energy price increases. Unless a researcher is particularly interested in the asymmetries within the energy system, future analysis should focus on the macroeconomic responses to petroleum product price or energy price changes, not crude oil price changes.

4. This asymmetry within the oil sector contributes importantly to the different economic responses to oil price increases and decreases. The response of real output to changes in

past aggregate price levels does not appear to depend upon whether energy prices are rising or falling.

5. The output responses to the large oil price shocks of the 1970s are similar to those for other oil price shocks in the post-World War II era. The link between real output and energy price changes is unaltered by arbitrarily removing the large oil price shocks from the sample.

6. Energy price shocks are supply shocks that cannot be explained within a framework emphasizing an aggregate production function for the nation. Although the supply shocks are initiated on the supply-side of the economy, there are important adjustments in aggregate demand. Monetary policies are imperfect tools for easing the adjustment to supply shocks because they do not address the original source of the shock itself--increasing production costs throughout the economy.

APPENDIX

Consumer price changes in the text are explained in terms of their lagged value, changes in energy prices, and the change in the level of the unemployment rate. Wage rate increases, and hence consumer price increases, should be less during periods of high unemployment, following a reduced-form specification (where wages are replaced by consumer prices) of an expectations-augmented Phillips curve. The preceding year's energy price change was insignificant in initial specifications.

In the first row of Table A-1, this same equation is estimated by relaxing the constraint that the current and lagged unemployment rates have equal coefficients of the opposite signs, i.e., the two unemployment variables replace the change in the unemployment rate. The previous specification implies that changes in wages (and hence prices) respond to changes in the unemployment rate (as in the "wage curve") rather than to the level of the unemployment rate (as in the expectations-augmented Phillips curve). The F-statistic associated with imposing the single constraint on an unconstrained specification involving 39 degrees of freedom is $F(1,39) = 0.95$, which lies below the critical value of 4.08. Hence, we do not reject the null hypothesis of a constrained equation and use the previous specification (with the change in unemployment rates) in the remaining equations. Its adoption does not affect our results on the effects of energy price changes.

The symmetry results of Table 5 hold for other measures of consumer prices as well (Table A-1). Equations explaining the consumer price index for urban areas as the dependent variable, with and without the additional 1986 energy price variable, are shown in the second and third rows. As in the text, the energy price declines have been separated into those for 1986 and all others. These results are followed by equations explaining this same CPI index excluding energy. Symmetry cannot be rejected for either variable, once 1986 is excluded. This table also reports equations with energy prices weighted by energy expenditures.

Table A-2 contains estimates exploring different specifications of output growth as a function of current and lagged change in energy prices, money supply, and government purchases. The estimated coefficients are insignificant for lagged values of money supply, government purchases, and output (row 1). In addition, the coefficient for current energy price changes is insignificant (row 2), while the preceding year's change causes a significant reduction in output growth.

Given the t-statistic (1.34) on the coefficient for energy price decreases, a symmetric output response to energy prices cannot be rejected. Moreover, the effect of the previous year's energy price change on aggregate output remains unaltered regardless of whether the 1970 experiences with the large oil price shocks are removed by inclusion of a separate lagged energy price change variable for 1974 and 1979. For example, the equation shown in row 4 includes a separate energy price change variable for 1974 in explaining output growth in 1975. As was done in the text, the basic energy price change variable shown in the second column of coefficients equals zero for this year, thereby excluding this effect. A ten percent increase in energy prices reduces the following year's real GDP by 1.3-1.4%

in all equations. reported in rows 3-6 of Table 7. The last equation shows estimates when energy price changes are weighted by energy-expenditures shares.

A two-stage least-squares estimate of a consumer price changes, corresponding to the output change equation reported in Table 7 is shown in Table A-3. The same set of instrumental variables (associated with aggregate supply and demand functions) is used. Controlling for simultaneity between consumer price and output changes does not alter the estimated impacts of fuel prices and lagged consumer prices very much, compared to the OLS specification.

NOTES

[1] Augmented Dickey-Fuller (1979) tests indicate that the key variables are stationary when expressed as first differences. In addition, weighted least-squares were also estimated to adjust for possible heteroscedastic errors associated with very large energy price changes. Please see footnote 4 later in the text for some comments on these results.

[2] This specification was implemented as the first difference in the logarithm of each variable.

[3] Since the variables are the first difference in logarithms, the coefficient indicates how much the dependent variable changes for a one percent change in the independent variable.

[4] Although I have consistently checked for the influence of large energy price changes on the results, the 1986 observation suggested that perhaps the system experienced heteroscedastic errors associated with large energy price changes. To counter this effect, a weighted least-squares approach was applied to the equations, where the error's variance was assumed to be a function of the squared energy price change variable. This approach increased the efficiency of the coefficients' estimates but the results were similar to those reported here. For example, reading across the second row of Table 5, the estimated coefficients (with Table 5's estimates in parentheses) were .014 (.011) for the constant term, .127 (.139), -.076 (-.037), -.110 (-.132), -.005 (-.005), and .541 (.552) for the independent variables, and.867 (.848) for the explanatory power (adjusted R-squared).

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Table 1: Oil and Energy Price Increases and Decreases During 1949-93

	Positive	Negative
Years		
Crude Oil	25	14
Petroleum Products	27	19
All Energy	27	15
Mean Change (as a fraction of the base year's level)		
Crude Oil	.129	-.102
Petroleum Products	.141	-.086
All Energy	.095	-.040
Standard Deviation		
Crude Oil	.141	.150
Petroleum Products	.146	.122
All Energy	.106	.066

Notes: Periods with no changes are excluded.

Table 2: Estimated Coefficients for Refined Product Price Change Equations, 1949-93
(T-statistics appear in parentheses)

	Constant	Change in: Crude Price [t]	Change in: Crude Price [t-1]	Decrease in Crude Price [t]	Decrease in Crude Price [t-1]	Increase in Crude Price [t]	Increase in Crude Price [t-1]		
1	0.015	0.932	-0.103					Adj R^2=	0.738
	(1.11)	(11.2)	(-1.26)					D-W=	1.861
2	0.019	1.194	-0.367	-0.497	0.590			Adj R^2=	0.788
	(1.21)	(10.3)	(-3.31)	(-2.56)	(3.02)			D-W=	1.909
3	0.019			0.697	0.223	1.194	-0.367	Adj R^2=	0.788
	(1.21)			(5.29)	(1.65)	(10.3)	(-3.31)	D-W=	1.909

All variables are first differences in logarithms.

Table 3: Estimated Coefficients for Wholesale Energy Price Change Equations, 1949-93
(T-statistics appear in parentheses)

	Constant	Change in Product Price		Decrease in Product Price		Increase in Product Price			
		[t]	[t-1]	[t]	[t-1]	[t]	[t-1]		
1	8.80E-03	0.541	0.177					Adj R^2=	0.927
	(1.90)	(20.9)	(6.97)					D-W=	1.531
2	-1.84E-03	0.573	0.207	-0.104	-0.113			Adj R^2=	0.933
	(-0.296)	(15.3)	(5.66)	(-1.47)	(-1.65)			D-W=	1.508
3	-1.84E-03			0.469	0.094	0.573	0.207	Adj R^2=	0.933
	(-0.296)			(9.37)	(1.90)	(15.3)	(5.66)	D-W=	1.508

All variables are first differences in logarithms.

Table 4: Effect of a Sustained 10% Change in Oil Prices

Assumption	1st-Year Change	2nd-Year Change	Total Impact on 2nd-Year Level
Change in Product Price for a 10% Change in Crude Price:			
Symmetry*	9.3%	-1.0%	8.2%
Asymmetry:			
price increase	11.9%	-3.7%	7.8%
price decrease	-7.0%	-2.2%	-9.3%
Change in Energy Price for a 10% Change in Product Price:			
Symmetry**	5.4%	1.8%	7.3%
Asymmetry:			
price increase	5.7%	2.1%	7.9%
price decrease	-4.7%	-0.9%	-5.6%

* Symmetry is rejected at 95% significance level.
** Symmetry is **not** rejected at 95% significance level.

Table 5: Estimated Coefficients for Consumer Price Change Equations, 1949-93
(T-statistics appear in parentheses)

	Constant	Change in Energy Price	Decrease in Energy Price*	1986 Energy Price Decrease	Change in Unemployment	Consumer Price[t-1]	Nonoil Import Price		
1	0.010	0.144	-0.130		-0.005	0.547		Adj R^2=	0.849
	(3.54)	(7.81)	(-3.04)		(-3.94)	(7.46)		Durbin's H=	-0.686
2	0.011	0.139	-0.037	-0.132	-0.005	0.552		Adj R^2=	0.848
	(3.64)	(7.16)	(-0.323)	(-3.08)	(-3.58)	(7.49)		Durbin's H=	-0.700
3	0.009	0.080	-0.040		-0.004	0.580	0.121	Adj R^2=	0.893
	(3.58)	(3.67)	(-0.948)		(-3.08)	(9.35)	(4.20)	Durbin's H=	0.224

All variables are first differences in logarithms, except for the unemployment rate, which is the first difference in levels.
* Energy price declines for all years, except for the second equation, when they measure price declines in all years except 1986.

Table 6. Estimated Coefficients for Output Growth Equations With Oil Prices, 1949-93
(T-statistics appear in parentheses)

	Constant	Change in Energy Price [t-1]	Decrease in Energy Price [t-1]	Change in Money	Change in Govt	1986 Decrease in Energy Price [t-1]		
	with Energy Price:							
1	0.011	-0.130	0.099	0.326	0.207		Adj R2=	0.510
	(1.64)	(-4.60)	(1.34)	(4.02)	(4.58)		D-W=	2.055
	with Product Price:							
2	0.010	-0.084	0.034	0.295	0.223		Adj R2=	0.536
	(1.58)	(-4.25)	(0.868)	(3.76)	(5.07)		D-W=	2.033
	with Crude Price:							
3	0.016	-0.110	0.122	0.265	0.190		Adj R2=	0.545
	(2.50)	(-5.26)	(3.26)	(3.41)	(4.34)		D-W=	2.136
4	0.016	-0.110	0.122	0.264	0.190	0.122	Adj R2=	0.533
	(2.35)	(-5.07)	(1.58)	(3.34)	(4.24)	(3.20)	D-W=	2.136

Table 7: Estimated Coefficients for Output Growth Equations With Consumer Prices, 1949-93
(T-statistics appear in parentheses)

	Constant	Consumer Prices [t-1]	Consumer Prices(-)* [t-1]	Money [t]	Money [t-1]	Govt [t]	Consumer Prices [t]		
1	0.021	-0.560		0.328	0.077	0.212		Adj R2=	0.541
	(2.86)	(-5.19)		(3.34)	(0.803)	(4.83)		D-W=	1.943
2	0.019	-0.554	0.158	0.333	0.062	0.214		Adj R2=	0.542
	(2.68)	(-5.13)	(1.03)	(3.38)	(0.635)	(4.89)		D-W=	1.903
Two-stage least squares:									
3	0.020	-0.723		0.348	0.033	0.207	0.219	Adj R2=	0.557
	(2.86)	(-3.60)		(3.52)	(0.310)	(4.76)	(0.961)	D-W=	1.928

All variables are in first differences in logarithms.
* Consumer prices when energy prices decline

Table A-1: Estimated Coefficients for Additional Consumer Price Change Equations, 1949-93
(T-statistics appear in parentheses)

	Constant	Change in Energy Price [t]	Decrease in Energy Price* [t]	Unemploy Rate [t]	Unemploy Rate [t-1]	Change in Unemploy	Consumer Price [t-1]	1986 Energy Price Decline [t]		
1	5.54E-03	0.149	-0.127	-4.28E-03	5.43E-03		0.497		Adj R^2=	0.849
	(0.970)	(7.82)	(-2.97)	(-2.66)	(4.06)		(5.57)		Durbin's H=	-0.286
CPI, urban:										
2	0.013	0.201	-0.150			-0.005	0.413		Adj R^2	0.744
	(3.19)	(6.65)	(-2.13)			(-2.01)	(4.35)		Durbin's H=	-0.257
3	0.014	0.194	-0.023			-0.004	0.421	-0.152	Adj R^2=	0.741
	(3.24)	(6.04)	(-0.119)			(-1.78)	(4.38)	(-2.15)	Durbin's H=	-0.248
CPI, except energy(1959-1993)										
4	0.023	0.108	-0.136	-0.003	0.000		0.779		Adj R^2=	0.891
	(3.28)	(6.38)	(-3.46)	(-1.45)	(-0.176)		(9.12)		Durbin's H=	0.466
5	0.023	0.110	-0.197	-0.003	0.000		0.782	-0.136	Adj R^2=	0.888
	(3.27)	(6.26)	(-1.47)	(-1.45)	(-0.240)		(9.01)	(-3.42)	Durbin's H=	0.226
6	0.011	0.110				-5.00E-03	0.612		Adj R^2=	0.818
	(3.37)	(6.84)				(-3.47)	(7.98)		Durbin's H=	-0.088
Energy-share-weighted fuel price:										
7	0.013	1.59E-04	-1.50E-04			-4.82E-03	0.537		Adj R^2=	0.758
	(3.30)	(4.98)	(-2.93)			(-2.89)	(5.30)		Durbin's H=	1.001

Oil-share-weighted oil price:							
8	1.09E-02	1.75E-04	-1.63E-04	-4.96E-03	0.592	Adj R^2=	0.768
	(2.99)	(5.06)	(-3.07)	(-3.04)	(6.30)	Durbin's H=	0.650
Energy-share-weighted fuel price (1970-93):							
9	2.43E-02	1.33E-02	-1.11E-02	-9.39E-04	0.349	Adj R^2=	0.922
	(5.76)	(10.1)	(-3.97)	(-0.752)	(4.31)	Durbin's H=	1.340

All variables except the unemployment rate are in first differences in logarithms,
Energy price declines for all years, except for Equations #3 and #5, when they measure price declines in all years except 1986.

Note: Energy-share-weighted energy price changes use these weights:
Physical energy per constant $GDP times the fuel & power price index in Eq. 6; and
Physical oil & gas per constant $GDP times the petroleum product price index in Eq.7; and
Energy end-use expenditures per $GDP (available, 1970-93) in Eq. 8.

Table A-2. Estimated Coefficients for Output Growth Equations With Energy Prices, 1949-93
(T-statistics appear in parentheses)

	Constant	Change in Energy Price [t-1]	Money [t]	Govt [t]	Decrease in Energy Price [t-1]	Yearly Change in Energy Price [t-1]	Money [t-1]	Govt [t-1]	Output [t-1]	Energy Price [t]		
1	0.012	-0.126	0.341	0.244			-0.034	-0.031	-0.092	0.019	Adj R^2=	0.468
	(1.56)	(-4.12)	(2.58)	(4.06)			(-0.222)	(-0.492)	(-0.490)	(0.620)	Durbin's H=	-0.089
2	7.74E-03	-0.117	0.327	0.212						0.014	Adj R^2=	0.491
	(1.19)	(-4.21)	(3.94)	(4.58)						0.515	D-W=	2.054
3	0.011	-0.130	0.326	0.207	0.099						Adj R^2=	0.510
	(1.64)	(-4.60)	(4.02)	(4.58)	(1.34)						D-W=	2.055
4	0.011	-0.140	0.324	0.206	0.112	-0.117 (1974)					Adj R^2=	0.500
	(1.67)	(-3.87)	(3.96)	(4.53)	(1.40)	(-2.89)					D-W=	2.053
5	0.011	-0.129	0.323	0.206	0.098	-0.141 (1979)					Adj R^2=	0.498
	(1.62)	(-4.28)	(3.89)	(4.51)	(1.29)	(-1.87)					D-W=	2.049
6	0.011	-0.140	0.323	0.206	0.111	-0.117 (1974; 1979 not shown)					Adj R^2=	0.487
	(1.65)	(-3.49)	(3.85)	(4.46)	(1.34)	(2.85)					D-W=	2.052
7	6.35E-03	-0.112	0.329	0.213	-0.335	-0.119 (1986)					Adj R^2=	0.571
	(1.02)	(-4.09)	(4.34)	(5.03)	(-1.85)	(-1.71)					D-W=	1.926
	Energy-expenditure-weighted fuel price change:											
8	0.011	-9.93E-05	0.311	0.210			-0.042				Adj R^2=	0.435
	(1.45)	(-3.67)	(2.78)	(4.28)			(-0.388)				D-W=	1.864

All variables (except for dummy variables) are in first differences in logarithms.

Table A-3. Estimated Coefficients for Consumer Price Change Equations With Output Growth, 1949-93
(T-statistics appear in parentheses)

	Constant	Output [t]	Energy Prices [t]	Energy Prices [t-1]	Consumer Prices [t-1]		
Two-Stage LS:							
1	-6.71E-04	0.229	0.121	-0.038	0.746	Adj R^2=	0.810
	(-0.113)	(2.15)	(7.17)	(-1.65)	(7.10)	D-W=	1.863
Ordinary LS:							
2	1.47E-03	0.180	0.121	-0.041	0.733	Adj R^2=	0.812
	(0.302)	(2.44)	(7.20)	(-1.82)	(7.15)	D-W=	1.916

All variables are in first differences in logarithms.

Figure 1. Trade Wealth Effects, Selected Years, 1973-90

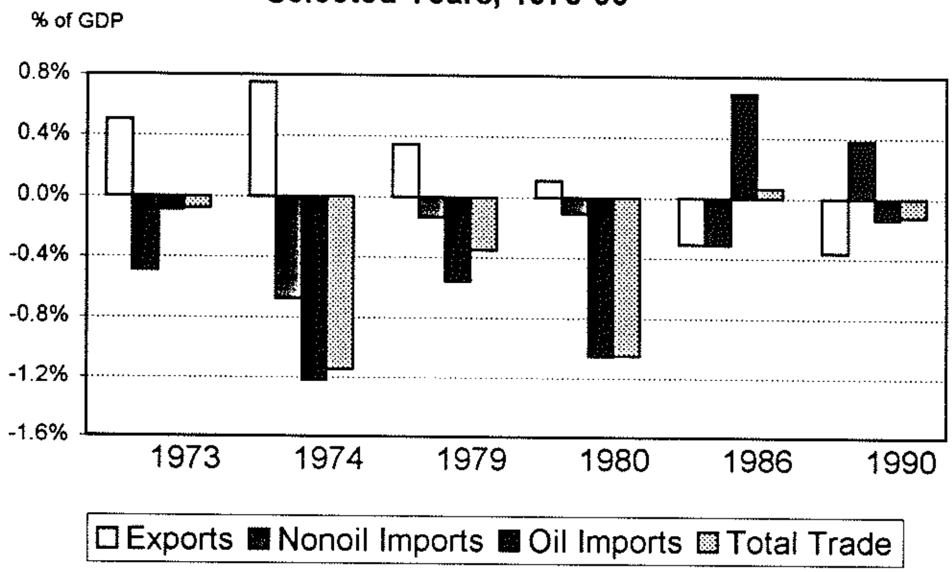

Figure 2. Percent Change in GDP for a 1 Percent Increase in Energy Prices Excluding Major Shocks