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U.S. OIL DEMAND AND CONSERVATION

S. P. A. Brown and Keith R. Phillips*

Recent history has lent casual support to three popular theories about U.S. oil demand: U.S. oil consumption is very insensitive to changing oil prices; non-price conservation has reduced U.S. oil demand; and U.S. oil consumption falls more when oil prices rise than it rises when prices fall. Together these theories suggest that oil consumption could be held constant without much economic sacrifice. Our econometric evidence does not support these theories. We find that U.S. oil consumption is fairly responsive to changes in price over the long run, but with a considerable lag. The lag accounts for the data that seems to support the popular theories. Sharp oil price increases (or their equivalent) will be required to hold oil consumption constant during the 1990s.

I. INTRODUCTION

Recent growth of U.S. energy consumption has renewed concerns about energy security, the trade deficit, and the environment; reviving calls for energy conservation. Although the benefits and costs of energy conservation are controversial, some advocates have argued that extreme energy conservation--that is holding energy consumption constant as the economy grows--can be achieved without economic sacrifice. (For instance, see Chandler, Geller and Ledbetter, 1988.)

Perhaps energy conservation seems costless because recent history has lent casual support to the theory that U.S. oil consumption is very insensitive to oil prices. Oil prices increased sharply in late 1973 and 1974, but U.S. oil consumption rose from 1975 to 1979. From 1981 through 1985, both oil prices and U.S. oil consumption fell. Then, after oil prices plunged in 1986, U.S. oil consumption increased only slightly during the next few years.

The movements in consumption and oil prices since 1980 have also lent casual support to other, related theories about U.S. oil demand. One theory, which might be called "non-price conservation," is that changes in government policy and technology have reduced U.S. oil demand independently of the influence of price. Another theory is that U.S. oil consumption responds asymmetrically to changes in its price; it falls more when price rises than it rises when price falls (Sweeney, 1986). If correct, these theories would imply that extreme oil conservation can be achieved relatively painlessly.

Because substantial changes in the ratio of oil consumption to output require new capital investment, previous studies have found that oil consumption responds very slowly to price changes. (See Hogan, 1989; Gately and Rappoport, 1988; Huntington, 1986; and Brown and Phillips, 1984.) That slow response could create the illusion that U.S. oil consumption is very insensitive to changing oil prices, that non-price conservation has occurred, or that consumption responds asymmetrically to changes in price. If oil consumption is sensitive to price, but responds slowly, normal rates of economic growth will provide a strong impetus for increased oil consumption during the 1990s. Extreme oil conservation could prove quite costly.

II. ECONOMETRIC ANALYSIS

A. Estimation of the Basic Model

To investigate these competing explanations for the recent behavior of U.S. oil consumption, we constructed an econometric model of U.S. oil demand. Using quarterly data, we estimated U.S. oil consumption as a function of past and present real prices of crude oil, real gross national product, and the share of GNP in the industrial sector.[1] For purposes of estimation, we used natural logs of all variables. The available oil consumption data limited estimation to an interval from first quarter 1972 through first quarter 1988.

To account for the lags in price, but be parsimonious in estimating the model, we modeled the effects of price as a polynomial distributed lag. We used statistical tests to determine the appropriate number of lags and the degree of the polynomial. To allow for an erratic adjustment process, we allowed the polynomial to have a degree as high as 12. After finding 38 lags (9 1/2 years) of price optimal, our selection procedure selected a ninth-degree polynomial.[2]

The results of model estimation are shown in Table 1. As indicated by a high R^2 and significant F value, the model fits the data well. Furthermore, the restriction imposed on the coefficients by the ninth-degree polynomial cannot be rejected at the .05 percent level. (An F-statistic of .54 was calculated for the restriction while a hurdle value of 1.94 ($F_{29,23}$) was required for rejection.)

The coefficient on price and the combined coefficients on lagged prices are negative, as expected, and significant. We estimated the short-run (same-quarter) price elasticity of oil demand at -0.08 and the long-run (38 quarter) price elasticity of demand at -0.56. Our price elasticity estimates are generally consistent with previous studies. (See Hogan, 1989; Gately and Rappoport 1988; Huntington, 1986; Brown and Phillips, 1984; and Bohi 1981.)

Though oil consumption is fairly responsive to price over the long run, adjustment is quite slow. The slow adjustment created the appearance that U.S. oil consumption was insensitive to price during the 1970s and 1980s.

The coefficient on GNP is positive, as expected, and significant. Though we estimated the elasticity of demand with respect to real GNP at 1.13, the coefficient is not significantly different from one.

The coefficient on industrial production as a share of GNP is not significantly different from zero. We were somewhat surprised to find this variable was not significant in explaining oil consumption. We had expected, other things being equal, greater industrial production would be associated with greater oil consumption. A closer examination of the data revealed that the series had little variation during the estimation period, as well as little effect on consumption. This is evident in the standardized regression coefficient for the variable, which is -.01. The standardized regression coefficients for real GNP and price are 2.03 and -3.63, respectively.[3]

B. Testing for Non-price Conservation

Because it is frequently thought to be the result of technological drift, non-price conservation is commonly modeled as a function of time. In our model, therefore, the effects of non-price conservation would be evident as the omission of a time-dependent variable.[4] If an important omitted variable can be characterized as a function of time, its omission can lead to heteroscedasticity of the error terms. (See Maddala, 1988, pp. 208-9.)

Non-price conservation is not supported by the evidence. A test for heteroscedasticity failed to reject the hypothesis that the error terms of the regression are homoscedastic. (For a discussion of this test, see Maddala, pp. 162-3.) In short, price and the other variables are able to explain the time trends found in the consumption data. Lagged adjustment to past price increases--rather than non-price conservation--explains why both the price of oil and U.S. oil consumption fell during the early 1980s.

C. Testing for Asymmetry

Asymmetry would be evident as instability in the estimated coefficients across periods of rising and falling oil prices. Instability is indicated if the estimated coefficients change across selected sub-periods for which the model was estimated.

During the period we studied, the price of oil generally rose through second quarter 1981, and then generally declined. Nevertheless, the period cannot be divided at second quarter 1981 to test for instability. Given the long lags found in estimation over the full period, the early years in the second sub-period would reflect the influence of rising, as well as falling prices. In fact, as of fourth quarter 1985, prices remained above the levels posted prior to third quarter 1979. During the first 3 quarters of 1986, however, prices dropped sharply. Since then, real prices have remained below post 1974-levels.

If consumption responds differently to rising prices than to falling prices, a model fit to data for the period prior to 1986 would be unstable in the following period. Given the 9 observations in the second sub-period, estimation of coefficients for the second period is not possible. Instead, we used a predictive test of stability developed by G. C. Chow for use when the number of regressors in the second period is greater than the number of observations. (For a discussion of this test, see Maddala, pp. 130-7.)

Using the test developed by Chow, we failed to reject that the model estimates are stable across periods of rising and falling oil prices. Out-of-sample forecasts of U.S. oil consumption from first quarter 1986 through first quarter 1988, made with coefficients estimated with data prior to 1986, are not significantly different at the 5-percent level from the actual consumption figures recorded for those quarters. (The calculated F-statistic was .20 against a hurdle value of 1.64 ($F_{65,43}$) required to reject stability.)

Therefore, we find no evidence that U.S. oil consumption responds asymmetrically to rising and falling oil prices. Slow adjustment--not asymmetry--explains why U.S. oil consumption increased only moderately in the two years following the 1986 plunge in oil prices.

III. HOW COSTLY CONSERVATION?

Our econometric findings suggest that meaningful oil conservation is likely to prove costly in the 1990s. Oil conservation in the 1970s and 1980s was the result of sharp increases in the price of oil. As has been evident in the past few years, current oil prices are stimulating and will stimulate renewed growth in U.S. oil consumption. Sharp price increases (or their equivalent) will required to hold U.S. oil consumption constant during the 1990s. The market is unlikely to generate such increases.

A. Past Oil Demand and Conservation

From third quarter 1973 through the end of 1985, U.S. oil consumption generally grew more slowly than was implied by non-price factors. In-sample simulations based on our econometric model revealed that two episodes of rapidly rising oil prices--one from late 1973 through 1974 and another from 1979 to early 1981--combined with slow adjustment to exert downward pressure on oil consumption throughout the period. Even though real oil prices declined after 1981, lagged adjustment to past oil price increases continued to put downward pressure on U.S. oil consumption.

The 1986 plunge in oil prices removed that pressure. Since first quarter 1986, oil prices have exerted upward pressure on U.S. oil consumption. Our simulations suggest that as of 1988, an oil price of less than $26.63 per barrel would put upward pressure on the oil-consumption-to-GNP ratio over the next ten years. (All prices cited are the composite refiner acquisition cost for crude oil in 1988 dollars per barrel.)

B. Future Oil Demand and Conservation

Given reasonable assumptions about U.S. economic growth, out-of-sample simulations based on our econometric model indicate that either oil consumption or prices will rise sharply during the 1990s.[5] For a constant price of $25 per barrel and economic growth of 2.5 percent annually, we estimate that U.S. oil consumption would be nearly 40 percent higher in 2000 than it was 1988. With economic growth of 3.0 percent annually, U.S. oil consumption would be nearly 50 percent higher in 2000 than it was in 1988.

Much higher oil prices (or their equivalent) would be required to hold U.S. oil consumption at its 1988 level. With economic growth of 2.5 percent annually, a price of $45 per barrel would be required to hold oil U.S. oil consumption constant at its 1988 level of about 17 million barrels per day. With economic growth of 3.0 percent annually, a price of $50 per barrel would be required.

Holding U.S. oil consumption at its 1988 level will be costly unless the market generates about a doubling of real world oil prices by 2000. Prices that high appear unlikely. Participants in Energy Modeling Forum 11 recently forecast oil prices for 2000 in a range from $15 to $35 per barrel (See Huntington, 1989). Forecasts made with demand assumptions that correspond to our econometric findings range from $28 to $35 per barrel.

C. Achieving Oil Conservation

Though holding U.S. oil consumption at its 1988 level will require a domestic price that is about $15 to $20 per barrel higher than is forecast for

2000, the required tax would be greater because U.S. conservation efforts would depress world oil prices. If non-tax methods are used to further oil conservation, the opportunity costs of conservation are likely to be higher than the tax. Although engineering studies can suggest ways to reduce energy use, Brown (1982) has shown that past attempts to legislate specific conservation technologies were inefficient. The marginal cost per unit of energy saved varied considerably across the legislated technologies. And, the legislation ignored some low-cost methods of conservation.

IV. SUMMARY

Estimating the long-run price elasticity of oil demand at -0.56, we find U.S. oil consumption is fairly responsive to changes in price, but it requires nearly a decade to adjust fully. We find no evidence that non-price conservation has shifted U.S. oil demand inward or that consumption responds asymmetrically to changes in price. The slow adjustment in demand has created the appearance that U.S. oil consumption is insensitive to changes in price, that non-price conservation has occurred, and that consumption responds asymmetrically to changes in price.

Our findings imply that if effective oil conservation policies are not implemented, low oil prices and normal economic growth can be expected to stimulate strong growth in U.S. oil consumption during the 1990s. Sharp price increases (or their equivalent) will be required to hold oil consumption constant. That suggests that meaningful oil conservation will be costly.

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Table 1
Regression Results
for U.S. Oil Consumption

	Independent Variables (in natural logs)				
	Intercept	Real Oil Price in period t	Real Oil Price in periods t-1 to t-38	Real GNP	Industrial Production as share of GNP
Coefficient	2.01	-.08	-.48	1.13	-.23
t-statistic	2.62	-5.64	70.22*	11.81	-1.73
Level of significance	.01	.01	.01	.01	.09
Standardized Coefficient		-.48	-3.10	2.03	-.09

Summary Statistics

Overall F-Value	Adj R^2	Durbin-Watson	F-Value for Polynomial
77.86	.93	1.69	.54

* The value reported for the lags of oil price is an F-statistic.

FOOTNOTES

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1. Monthly oil consumption data for the United States were obtained from the U.S. Central Intelligence Agency. The data were transformed to quarterly values of average barrels per day and then seasonally adjusted with the X11 procedure contained in the Statistical Analysis System (SAS).

A quarterly series of real oil prices was constructed by taking quarterly averages of the monthly producer price index for crude oil available from U.S. Department of Labor and deflating it with the fixed-weight GNP deflator available from U.S. Department of Commerce. The price series is not seasonally adjusted.

The real GNP series was obtained from the U.S. Department of Commerce. The real GNP series is seasonally adjusted by the source.

A quarterly series of the share of GNP accounted for by industrial production was obtained by taking quarterly averages of the monthly U.S. industrial production index available from the Board of Governors of the Federal Reserve System and dividing it by real GNP. The industrial production series is seasonally adjusted by the source.

2. We determined the number of lags by selecting the number that

maximized the adjusted R^2 without any polynomial restrictions. We selected the degree of the polynomial by starting at 12. If the highest degree of the polynomial was found insignificant at the 5-percent level, we dropped it in the subsequent estimation. We continued this procedure until reaching a degree that was significant. For a more detailed description of these procedures, see Maddala, 1988, pp. 354-61.

3. The standardized regression coefficient of a variable is computed by multiplying the variable's standard deviation by its regression coefficient, and then dividing that product by the standard deviation of the dependent variable.

4. Though frequently modeled as a function of time, if it occurs, non-price conservation need not be correlated with time. In our model, the effects of non-price conservation might be evident either as instability in model estimates or an omitted variable that is a function of time. Because we rule-out instability in the estimated coefficients below, only the omission of a time-dependent variable need be considered here.

5. For the purposes of out-of-sample simulation, we assumed no change in the industrial-production-to-GNP ratio and a GNP elasticity of oil demand equal to unity.

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