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Recent history has lent casual support to theories that U.S. oil consumption is very insensitive to changing oil prices, that non-price conservation has reduced U.S. oil demand, and that U.S. oil consumption falls more when price rises than it rises when price falls. We find that econometric evidence does not support any of these theories. U.S. oil consumption is fairly responsive to changes in price over the long run, but it requires nearly a decade to adjust fully. That slow response accounts for the evidence that seems to support the other theories. These findings suggest that lower oil prices will stimulate U.S. oil consumption considerably.

I. INTRODUCTION

Despite much scientific evidence to the contrary, recent history has lent casual support to the theory that U.S. oil consumption is very insensitive to oil prices.[1] 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. If correct, these theories would imply that lower oil prices will not stimulate U.S. oil consumption very much, if at all.

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.[2] 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 with a considerable lag, lower oil prices should stimulate U.S. oil consumption considerably.

We constructed an econometric model of U.S. oil demand to investigate these competing explanations for the recent behavior of U.S. oil consumption. Our approach is similar to that of Gately and Rappoport (1988). Like them, we model the effect of changes in price on U.S. oil consumption as a polynomial distributed lag and examine the possibility of consumption responding asymmetrically to rising and falling oil prices. Unlike them, we use quarterly data and optimize the lag structure of the price variable, substantially reducing autocorrelation in the residuals. Our principal contribution, however, is that we test statistically for evidence that asymmetry and non-price conservation have affected U.S. oil demand.

II. ECONOMETRIC ANALYSIS

Estimation of the Basic Model

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.[3] 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.[4]

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 -.08 and the long-run (38 quarter) price elasticity of demand at -.56. Chart 1 shows how consumption adjusts to a 10 percent change in price over 38 quarters. Though oil consumption is fairly responsive to price over the long run, adjustment is quite slow. Our estimate of the response of oil consumption to changes in its price is generally consistent with previous studies.[5]

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.[6]

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.[7] If an important omitted variable can be characterized as a function of time, its omission leads to both autocorrelation and heteroscedasticity of the error terms.[8]

Non-price conservation is not supported by the evidence. Although the Durbin-Watson statistic was inconclusive at 1.69, a t-test that the parameter for first-order autocorrelation was equal to zero could not be rejected. Similarly, a test for heteroscedasticity failed to reject the hypothesis that the error terms of the regression are homoscedastic.[9]

In short, price and the other variables are able to explain the time trends found in the consumption data. Once the proper lags and degree of polynomial for price have been determined, no time-dependent component of consumption is left to be explained as non-price conservation.

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.[10]

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.

III. U.S. OIL DEMAND, 1972 TO 2000

We constructed several variables with our model to see how slow adjustment might have created the appearance that U.S. oil consumption is very insensitive to changes in the price of oil, has been reduced by non-price conservation, or responds asymmetrically to rising and falling prices. For each quarter over which the model was estimated, we calculated long-run oil consumption, short-run oil consumption, and the growth in oil consumption that can be attributed to the non-price factors that we included in the model.[11] We also use the constructed variables to assess the direction that U.S. oil demand will take in the 1990s.

In periods where long-run consumption is less than short-run consumption, price exerts downward pressure on oil consumption, and consumption should grow more slowly than is implied by non-price factors. Conversely, in periods where long-run consumption exceeds short-run consumption, price exerts upward pressure on oil consumption, and consumption should grow faster than is implied by non-price factors.

U.S. Oil Demand, 1972 to 1973

Prior to third quarter 1973, real oil prices generally fell or were constant (Chart 2a). From 1972 to 1973, long-run consumption exceeded short-run consumption (Chart 2b). Consequently, U.S. oil consumption generally grew faster than was implied by non-price factors (Chart 2c).

U.S. Oil Demand, 1973 to 1985

From third quarter 1973 through the end of 1985, long-run consumption was less than short-run consumption. Two episodes of rapidly rising oil prices (one from late 1973 through 1974 and another from 1979 to early 1981) sharply reduced long-run oil consumption. Short-run oil consumption remained considerably higher. Consequently, over the period as a whole, consumption generally grew more slowly than was implied by non-price factors.

From 1975 to 1979, however, U.S. oil consumption grew, creating the impression that U.S. oil consumption is insensitive to oil prices. Our estimates indicate, however, that less than 40-percent of the adjustment to the 1973-74 price spike was completed by early 1979. Economic expansion pushed consumption upward from 1975 to 1979. Higher oil prices moderated that growth somewhat. Over the four-year period, consumption grew less than non-price factors would have suggested.

U.S. oil consumption began to decline in 1979. For a brief two-year period, consumption declined while the price of oil rose.

The price of oil began slipping with consumption in early 1981, lending credence to theories that oil consumption is insensitive to price or has been reduced by non-price conservation. To the contrary, past increases in price continued to exert downward pressure on consumption--even as price fell. Until first quarter 1986, long-run consumption remained below short-run consumption. Short-run demand continued to shift inward, even as slipping oil prices and economic growth were stimulating long-run consumption.

U.S. Oil Demand, 1986 to 1988

The 1986 plunge in the price of oil increased long-run oil consumption sharply. For the first time since 1973, long-run consumption exceeded short-run consumption. Though it had declined since 1981, the price of oil exerted upward pressure on consumption only after its 1986 plunge. Consumption began to rise in first quarter 1986, but over the next two years, it increased only moderately. This has provided casual support for views that U.S. oil consumption is insensitive to oil prices, has been reduced by non-price conservation, or responds asymmetrically to rising and falling oil prices.

According to our estimates, however, less than 30 percent of the adjustment to the lower price was complete by first quarter 1988. Nonetheless, since second quarter 1986, growth in consumption generally has been greater than that implied by non-price factors. The strong growth in U.S. oil consumption that has been evident since first quarter 1988 further indicates that consumption is responding to lower oil prices.

U.S. Oil Demand, 1988 to 2000

In first quarter 1988, the price of crude oil was $15.47 per barrel and U.S. oil consumption was 17 million barrels per day. (This price and all prices cited hereafter are the composite refiner acquisition cost for crude oil in 1988 dollars per barrel.) At $15.47 per barrel, long-run consumption (at 23 million barrels per day) exceeded short-run consumption (at 17 million barrels per day) by a considerable margin. We estimate that a price of $26.63 per barrel would have been required in first quarter 1988 to equalize long-run and short-run consumption (at about 17 million barrels per day). Therefore, at prices below $26.63 per barrel, U.S. oil consumption can be expected to grow faster than that implied by GNP and industrial growth. Given normal economic expansion, that suggests U.S. oil consumption will be much higher by the year 2000, unless its growth is choked off by a much higher oil price or the emergence of a new energy source.

IV. SUMMARY AND IMPLICATIONS

Over the long run, U.S. oil consumption is fairly responsive to changes in price (We estimate the long-run price elasticity of U.S. oil demand is -0.56.), but it requires nearly a decade to adjust fully. For some observers, slow adjustment in demand may have created the appearance that U.S. oil consumption is insensitive to changes in price, that non-price conservation has occurred, or that consumption responds asymmetrically to changes in price.

Our econometric evidence does not support the contention that oil conservation has shifted U.S. oil demand inward independently of changes in the price of oil. From late 1973 through the end of 1985, higher oil prices held the growth in U.S. oil consumption below that implied by GNP and industrial growth. Lagged adjustment to past price increases--not non-price conservation--explains why both the price of oil and U.S. oil consumption fell from 1981 to 1985.

Nor does our econometric evidence support the contention that consumption is less responsive to falling oil prices than to rising oil prices. Slow adjustment--not asymmetry--explains the only moderate increase in U.S. consumption in the two years following the 1986 plunge in oil prices. Further increases in consumption are to be expected.

In fact, our analysis indicates that, even in the absence of economic growth, current (first quarter 1988) U.S. oil consumption is too low to be sustained at a price below $26.63 per barrel over the long run. Consequently, during the 1990s, short-run demand can be expected to rise. Adjustment will be slow. But together with an expanding economy, that rise can be expected to contribute to strong growth in U.S. oil consumption during the 1990s.

If our analysis of U.S. oil demand is indicative of the world situation, much higher world oil consumption or prices are to be expected in the 1990s.[12]

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NOTES

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1. See Bohi (1981) for a review of the scientific evidence.

2. See Hogan (1989), Gately and Rappoport (1988), Huntington (1986), Brown and Phillips (1984).

3. Monthly oil consumption data for the United States was 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.

4. 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.

5. See Hogan (1989), Gately and Rappoport (1988), Huntington (1986), Brown and Phillips (1984), and Bohi (1981).

6. 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.

7. 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.

8. See Maddala (1988), pp. 208-9.

9. For a discussion of this test, see Maddala, pp 162-3.

10. For a discussion of this test, see Maddala, pp. 130-7.

11. For any quarter, long-run consumption is the consumption that is consistent over the long run with the price, GNP and industrial-production-to-GNP ratio that prevailed during the quarter. Short-run consumption is the fitted value of consumption from the estimated equation.

12. For further analysis of this issue, see Brown and Phillips (1989).

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.

Chart 1
Estimated Increase in U.S. Oil Consumption
Resulting from a 10-Percent Decrease in Price

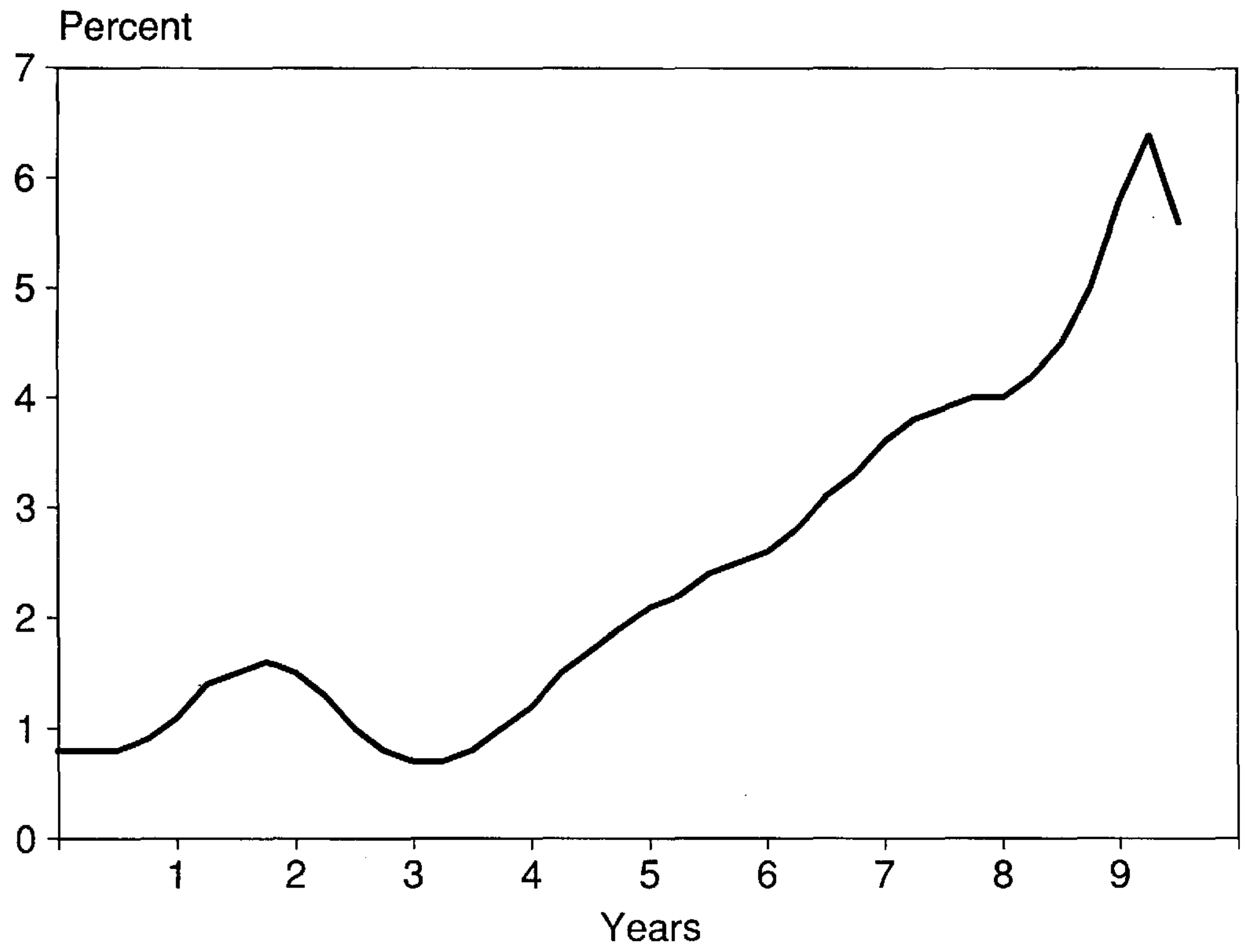


Chart 2a
Real Oil Price

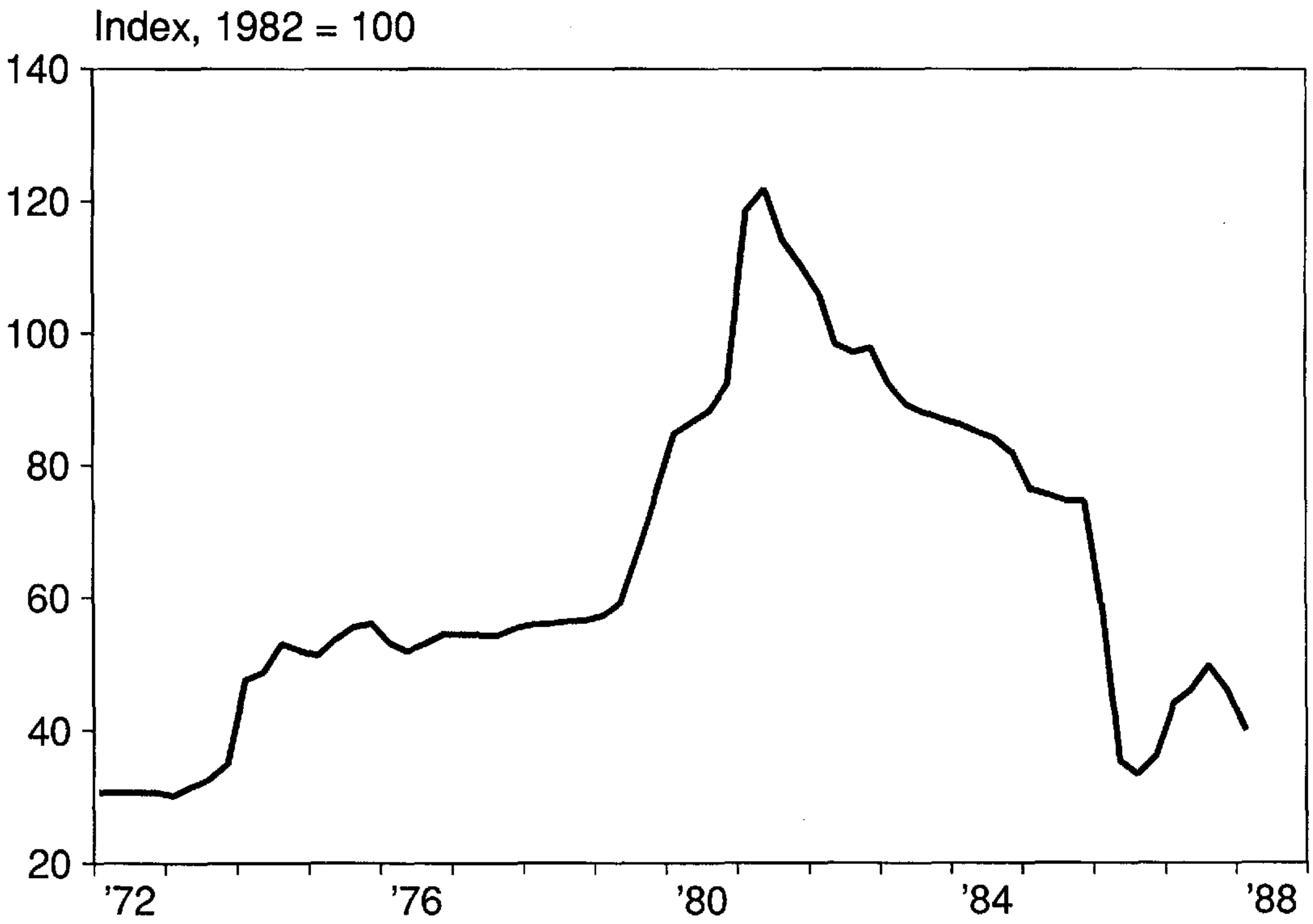


Chart 2b
Long-Run and Short-Run Oil Consumption

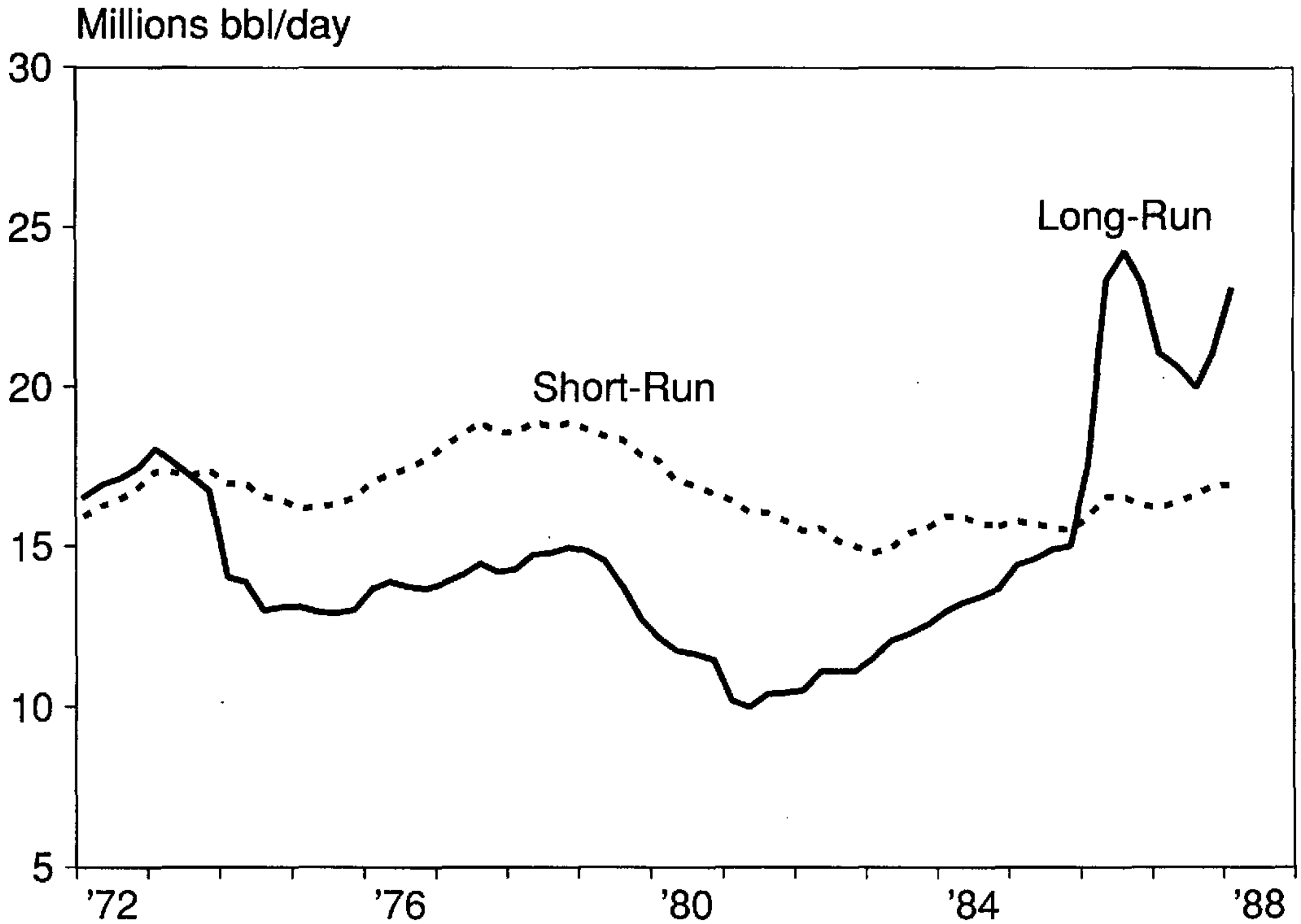
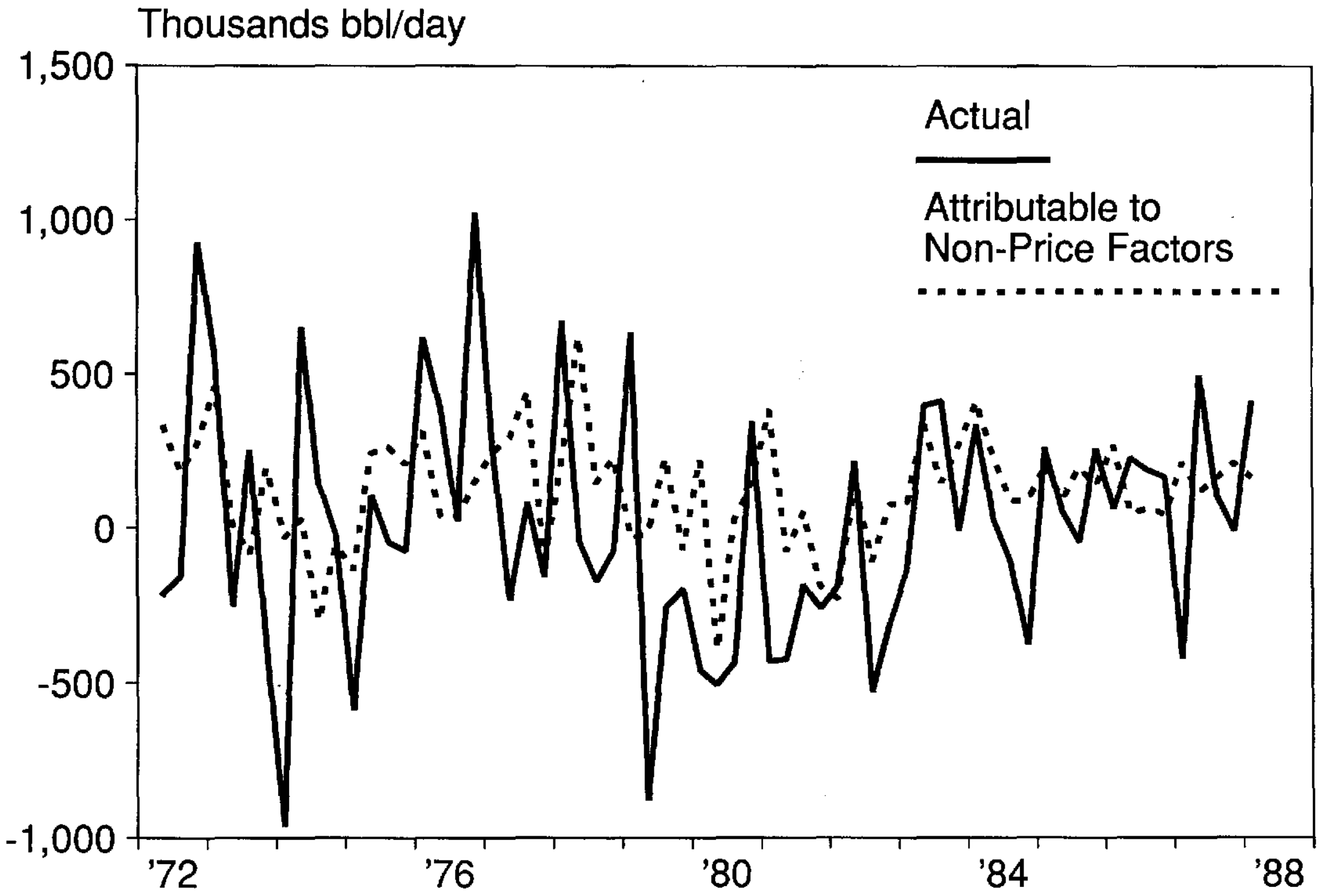


Chart 2c
Growth in U.S. Oil Consumption



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