ECONOMIC RESEARCH REPORTS

THE CHANGING WORLD PETROLEUM MARKET: DEMAND IN THE INDUSTRIALIZED COUNTRIES

BY

Joyce Dargay
and
Dermot Gately

RR # 94-02 *February 1994*

C. V. STARR CENTER FOR APPLIED ECONOMICS

NEW YORK UNIVERSITY
FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF ECONOMICS
WASHINGTON SQUARE
NEW YORK, N.Y. 10003

The Changing World Petroleum Market: Demand in the Industrialized Countries

by
Joyce Dargay and Dermot Gately

January 1994

Abstract:

This paper surveys OECD energy and oil demand over the past three decades, analyzing the different paths of transportation oil, non-transportation oil, and non-oil energy -- both over time, and relative to income growth. We review both the OECD as a whole, and make regional comparisons within the OECD. We focus especially on the price-irreversibility of oil demand: why oil demand has not surged now that oil prices have returned to pre-1974 levels.

Among our conclusions are the following. There has been an asymmetric, smaller demand response to the price decreases of the 1980's than to the price increases of the 1970's. We expect a smaller demand response to future price increases than to those of the 1970's. The demand response to future income growth will be not substantially smaller than in the past. Finally, given the prospect of growing dependence on OPEC oil, in the event of a major disruption the lessened responsiveness of demand to price increases could cause dramatic price increases and serious macroeconomic effects.

Keywords: oil demand; price reversibility; asymmetry; hysteresis
Journal of Economic Literature classification number: Q41

send correspondence to:

Joyce Dargay	or	Dermot Gately
Transport Studies Unit		Economics Department
Oxford University		New York University
11 Bevington Road		269 Mercer St.
Oxford OX2 6NB U.K.		New York NY 10003 USA
Internet: Dargay@vax.ox.ac.uk		Internet: GatelyD@fasecon.econ.nyu.edu

The authors are grateful for research support from the C. V. Starr Center for Applied Economics of New York University, and from the Energy Information Administration of the U.S. Department of Energy. They are grateful to Wei Zheng for excellent research assistance. Of course, none of the above are responsible for any remaining errors.

1. Introduction

This paper surveys the changes in oil and energy consumption since 1960 within the industrialized countries (Organization for Economic Cooperation and Development: OECD). We focus especially upon the demand effects of the oil price shocks (in 1973-74 and 1979-80), as well as the apparent lack of effect of the oil price declines of the 1980's.

In this section we review a few controversial assertions from the past that have since been shown to be at least partly untrue, or to have been oddly transmuted by the events of the past decade.

"Prices won't matter for oil demand": a complete falsehood or just a half-truth?

In the mid-1970's, after the first oil price shock, we were told by demand elasticity pessimists that oil is a "necessity", and that consumers' responsiveness to price increases would be so small that the government must rely on non-price methods to reduce oil demand. But we now know that price increases *did* matter. Oil demand did fall, in response to price increases (and also in response to fuel-efficiency standards, energy-cost labeling, and mandated fuel-switching away from oil in electricity generation).

Yet the statement may be not a complete falsehood, but only a half-truth. Although the price-increases of the 1970's have had a demand-reducing effect, there seems to be little effect from the price declines of the 1980's. The reversal of the price increases has not reversed the demand reductions. Price increases may have mattered a great deal, but price decreases have not mattered as much.

"An oil ratchet process in the 1980's": price ratcheting up or demand ratcheting down?

In the early 1980's we were told that oil prices would ratchet up: price would increase when the demand for OPEC oil rose, but not decrease when the demand was sluggish. Of course, just the opposite happened, because demand for OPEC oil fell dramatically in the early 1980's.

Instead, now we may be witnessing a ratchet process of a different type. Instead of oil price ratcheting up, we see oil demand (at least for non-transportation purposes) ratcheting down. Price increases reduced demand, price cuts did not reverse the process, and price recoveries reduce demand again. Demand ratchets down, whenever price increases; but price cuts do not reverse the process.

"There is an addiction to low-priced oil and it's the demanders that are addicted":

another half-truth?

Some within OPEC had told us that their oil was too "noble" a fuel to be used merely for burning, or for generating electricity. They wanted it to be consumed only in high-value uses, for which there was no substitute fuel, such as in transportation.

But having ignored the adage that you shouldn't wish for something because you might actually get it, OPEC now has the worst of both worlds. Its two big price increases in the 1970's brought about a surge of energy conservation and fuel-switching, but these effects have not been reversed when oil prices collapsed in the mid-1980's.

Now OPEC's best hope for quick increases in oil demand may well be in its least noble use: big consumers with fuel-switching capabilities (such as electric power plants) may be induced to switch back to oil with long-term guarantees of low prices. However, as rapidly as this market for low-priced oil can expand, it can collapse just as quickly if price were to be increased: consumers with fuel-switching capability can quickly switch away from oil once again.

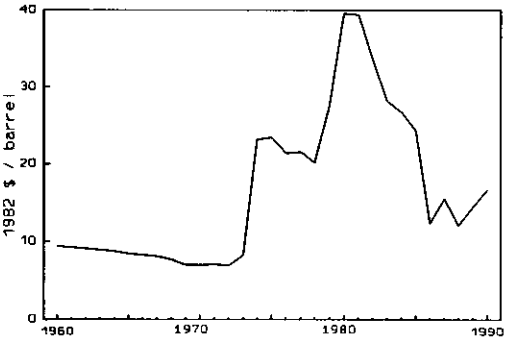
So this is the irony. OPEC can increase its revenue easily by selling more oil to the non-transportation market in low-priced, long-term contracts. But that market quickly evaporates if price is raised. So perhaps now the addiction to low-priced oil is not by consumers but rather by OPEC.

The outline of this paper is as follows. In Section 2, we review the past thirty years of energy and oil demand within the OECD, the different paths of transportation oil and non-transportation oil, both over time and in comparison with income (GDP) growth. We briefly review the fuel-shares for the non-transportation sectors: Residential and Commercial, Industrial, and Electricity Generation. First we discuss the OECD as a whole, then we compare regions within the OECD. In Section 3, we describe the question of whether oil demand is imperfectly price-reversible, and what the data and the econometric analysis show. In Section 4, we summarize the implications of our conclusions for the future growth of oil demand.

2. Oil and Energy Demand: The Past Thirty Years

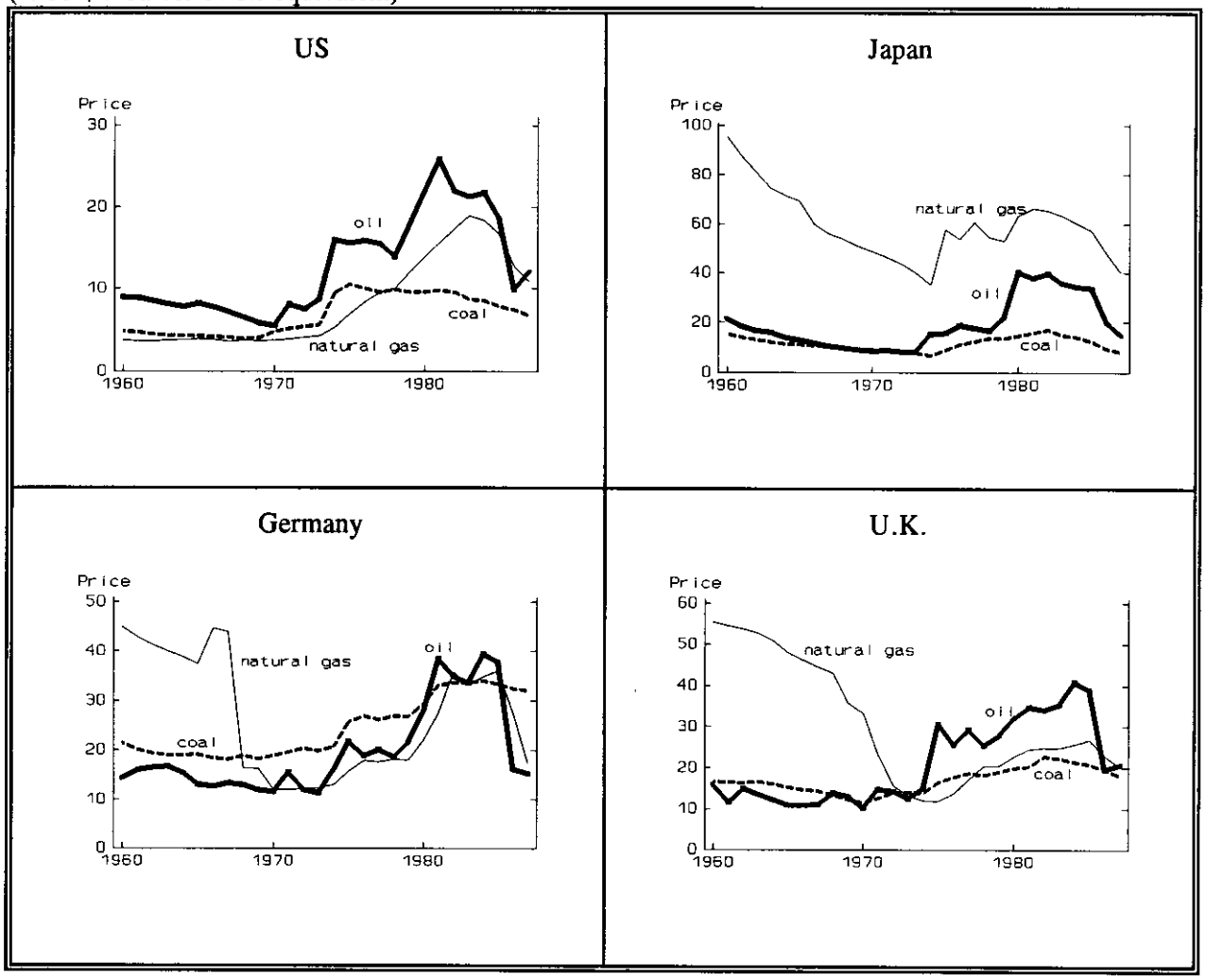
Because the effects of oil and other energy prices are central to this story, we begin by showing the path of world oil price (in real 1982 $) in Figure 1. We see the two oil price shocks, in 1973-74 and 1979-80, as well as the decline in oil prices in the early 1980's and the 1986 price collapse. By the late 1980's, the real price of crude oil had fallen below its 1974 level, but remained above its value in 1973.

Figure 1 International Price of Crude Oil 1960-90 (1982 $ / barrel)



We also show, in Figure 2, real prices for industrial use of coal, natural gas, and residual (heavy) fuel oil -- in several of the largest OECD countries. Again we see the effects of the oil price shocks, and the decline in oil prices in the mid-1980's. We also see important regional differences in the price of natural gas, reflecting its continued availability in the US, but its high price and delayed accessibility in many other countries.

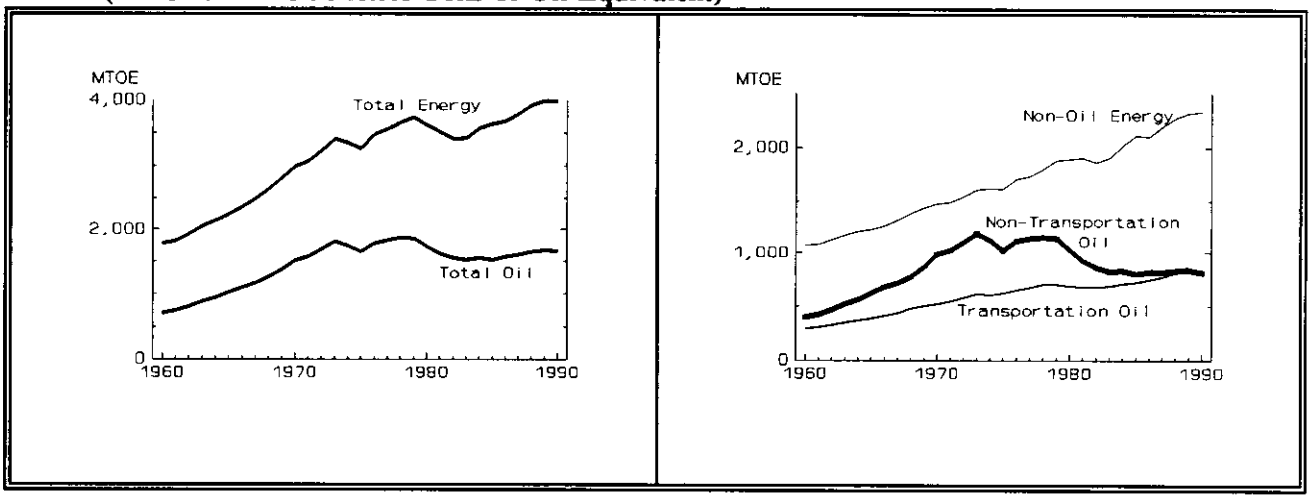
Figure 2. Real Fuel Prices in US, Japan, Germany, & U.K.: 1960-87
Industrial Use: Steam Coal, Natural Gas, & Residual (Heavy) Fuel Oil
(1980 $ / barrel of oil equivalent)



2.1 Total OECD: Energy and Oil Demand

The past three decades have witnessed considerable changes in energy and oil consumption patterns, both in the OECD and world wide. These were partially triggered by the changes in energy and oil prices described in the previous section. But other factors were also at work. One significant trend of the past decades has been the OECD's declining share of world energy and oil consumption. In the period 1960-73, the OECD consumed approximately 65 per cent of world commercial energy, and more than 72 per cent of oil. By 1992, these shares had declined to 52 and 58 per cent respectively. The greatest reductions occurred during the high price era of 1974 to 1985, but the declining share continues. This declining share of the OECD in world energy consumption is explained primarily by the following: lower rates of economic and population growth than in the rest of the world; lower energy-GDP elasticities, due to saturation levels of certain types of energy consumption; the relative shift of the industry-mix toward services within many OECD economies, and the growing industrialization of many previously agrarian developing countries; and a greater sensitivity to energy price rises than in the developing world. We can expect these trends to continue into the future.

Figure 3. Total OECD: Energy and Oil Demand, 1960-90
(MTOE: Million Metric Tons of Oil Equivalent)



The growth in energy demand slowed after the 1973-74 oil price shock, due both to conservation and to the slowing of income growth. Oil demand, which grew rapidly before 1973, flattened out after the first oil price shock, and then declined after the second oil price shock in 1979-80. Most of the variation in oil demand has been due to non-transportation uses of oil: the rapid growth prior to 1973 when oil replaced coal in the energy mix, and the rapid decline after 1979 when non-transportation oil was itself replaced by coal, natural gas, and nuclear power. Transportation oil demand grew more or less continually over the entire period, although the rate of growth slowed after the oil price shocks. This sectoral shift in oil use is significant. In 1960, slightly more than a half of oil demand was used for non-transportation purposes; by 1973 this share had approached two-thirds. The price increases reversed this pattern: now transportation accounts for over 50 per cent of oil demand.

It is also apparent that the variation in total energy demand after 1973 is primarily the effect of the variations in oil demand, especially non-transportation oil; non-oil energy consumption continued to increase with little deviation from its previous trend. Clearly, oil has been replaced by other energy forms: its share of primary energy consumption fell from 53 per cent in 1973 to 44 per cent by 1992. High oil prices have thus reduced the dominance of oil in the OECD's energy balance, and thus its oil dependence.

Figure 4. Total OECD: Energy & Oil Demand vs. GDP, 1960-90:
Energy & Oil (MTOE, log scale) vs. Real GDP (Million 1980 $, log scale)

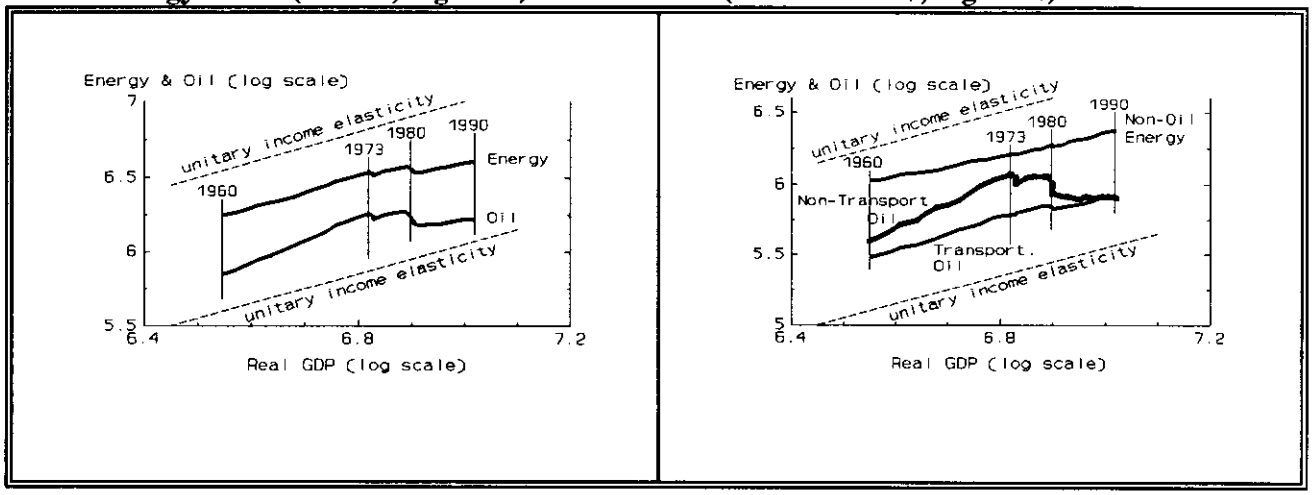
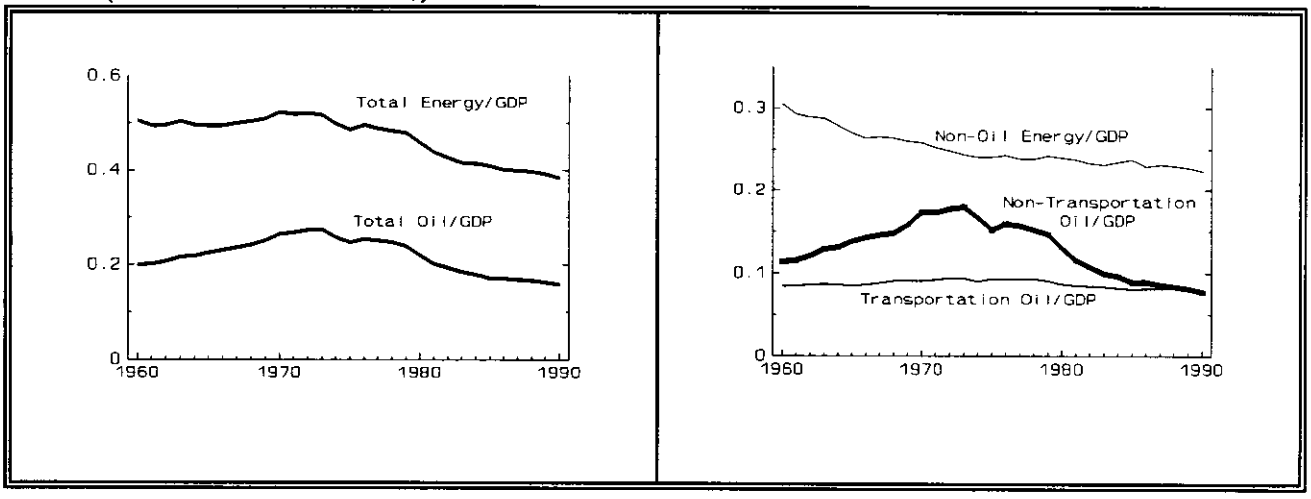


Figure 5. Total OECD: Energy/GDP & Oil/GDP ratios, 1960-90
(MTOE / Million 1980 $)



The reduction in the growth of energy and oil consumption after 1973 was not solely the result of price increases. Also important was the slowdown in economic growth. The rapid, pre-1973 GDP growth of 5 per cent annually period was halved during the post-1973 period. Figure 4 shows this slowdown. Because the logarithmic scales measure percentage changes rather than the usual absolute changes, it can be seen that there was much greater percentage growth in income from 1960-73 than from the longer period 1973-90: the horizontal distance between 1960 and 1973 GDP values is considerably larger than between 1973 and 1990 GDP values.

Also shown in Figure 4 are diagonal, dashed lines which indicate unitary income elasticity (ignoring price effects): energy demand growth parallel to these lines shows the same percentage growth in energy as in income. Thus we see that, prior to 1973, energy demand grew about as fast

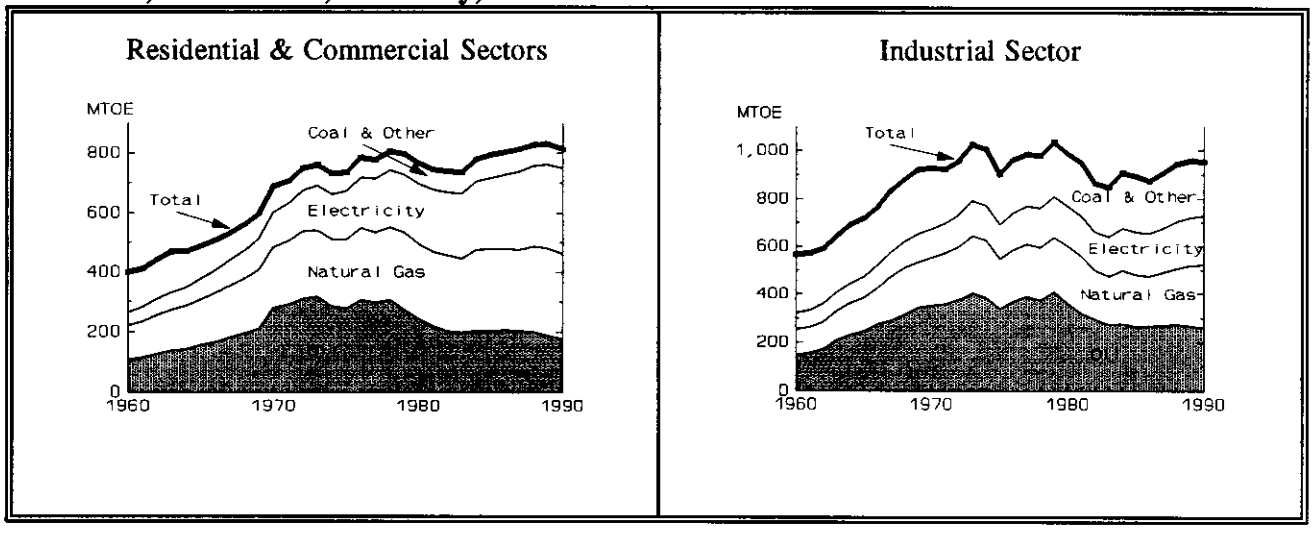
as income, while oil demand grew even faster than income, primarily because of the rapid growth of oil for non-transportation purposes (such as electricity generation). Transportation oil grew about as fast as GDP, both before and after 1973. Non-transportation oil grew faster than GDP until 1973, declined sharply in the early 1980's, and has been flat since then despite the oil price collapse.

Figure 5 provides a different view of this relationship between energy (or oil) and income: the familiar ratios energy/GDP and oil/GDP. The same differences before and after 1973 are evident. The energy/GDP ratio was fairly constant until 1973, implying an income elasticity near unity. Oil demand, on the other hand, rose more rapidly than income; the oil/GDP ratio increased. This was due to the faster growth of non-transportation oil; transportation oil increased at the same rate as GDP.

The picture changed substantially after 1973. Following the first oil price shock in 1973-74, both the energy/GDP and oil/GDP ratios began to fall in a similar fashion. Following the second oil price shock of 1979-80, however, the oil/GDP ratio fell far more drastically with sharp declines in non-transportation oil. The shift *toward* oil that was evident up until the mid-1970's was dramatically reversed; there was then a dramatic switch *away* from non-transportation oil.

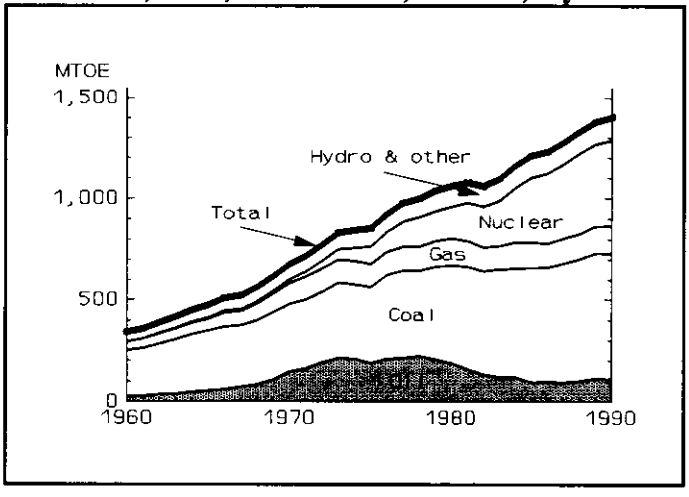
Clearly, the changing relationship between energy and oil consumption and GDP was largely the result of the rising energy prices of the 1970's. However, with the price collapse of 1986, real oil prices have returned to pre-1974 levels. If conventional demand theory were assumed, this price fall should reverse the effects of the price increases, leading to an increase in oil consumption and in the oil/GDP ratio. The evidence, however, speaks against this. From the graphs, we see that although both total energy and oil consumption had begun to rise by the mid-1980's, GDP increased more rapidly, so that the decline in the energy/GDP and oil/GDP ratios continued. Although the decline in the energy/GDP ratio can partially be explained by factors which began prior to 1973 -- the relative decline of industry and the growth of services, efficiency improvements in energy transformation, approaching of saturation levels for some household energy use -- the continued fall in the oil/GDP ratio seems to be a clear indication that oil demand has not responded to the price reductions to the same extent as it did to the rising prices of the previous decade. Oil demand has ratcheted down. This "irreversibility" is particularly apparent in the case of non-transportation oil.

Figure 6. Total OECD: Sectoral Use of Energy, 1960-90: Oil, Natural Gas, Electricity, Coal & Other



Unlike transportation where there are virtually no substitutes for oil, in non-transportation uses of oil there are substitutes available, and there has been an absolute decline in oil consumption. This is the result of both energy conservation and fuel-switching away from oil. The sectoral fuel-shares are shown in Figures 6 and 7: for the Residential and Commercial Sectors, for Industry, and for Electricity Generation. In both the Residential and Commercial sectors and in the Industrial sector, the switch has been away from oil to natural gas and to electricity. In electricity generation, which itself has become much less oil-intensive than in the past, oil has been replaced by the expansion of nuclear power and a return to coal.

Figure 7. Total OECD: Fuels Used in Electricity Generation, 1960-90 Oil, Coal, Natural Gas, Nuclear, Hydro & Other



2.2 Regional Differences within the OECD:

US, OECD Europe, Japan, Other OECD (Canada, Australia, New Zealand)

Although there are important regional differences within the OECD, let us first note the similarities across regions. Non-oil energy demand has continued to grow for the past three decades, spurred by income growth, and after 1973 by fuel-switching induced by the oil price increases. Transportation oil demand has also grown consistently over the past three decades, albeit at a slower rate since 1973 because of slower GDP growth and higher oil prices.

The growth of non-transportation oil demand, which surged until 1973, was stopped abruptly by the 1973-74 oil price shock. After the second price shock in 1979-80, non-transportation oil demand declined sharply. The collapse of oil prices in the 1980's stemmed the demand decline, but did not reverse it: demand has remained relatively flat.

Figure 8. Regional Demands: Transportation Oil, Non-Transportation Oil, and Non-Oil Energy

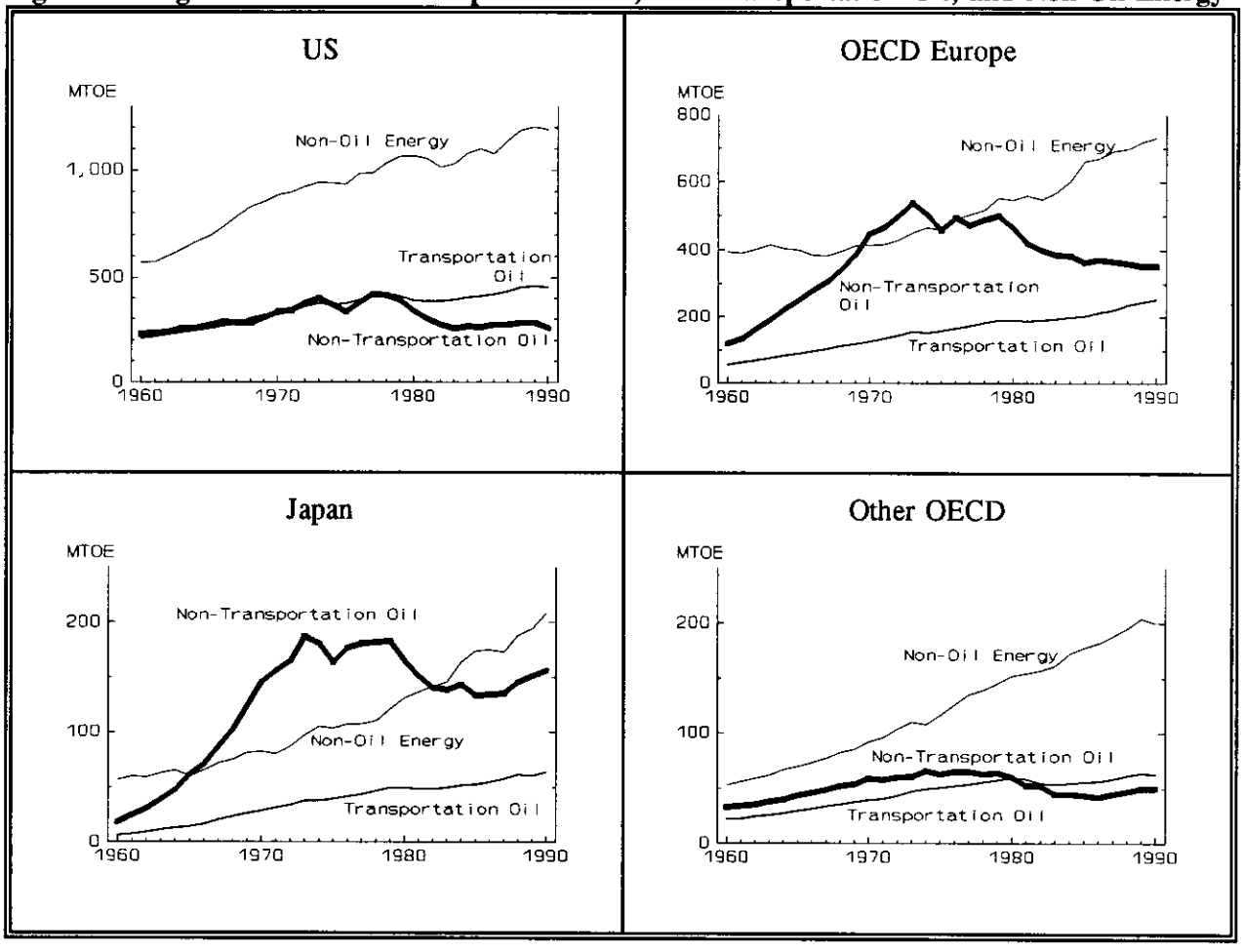
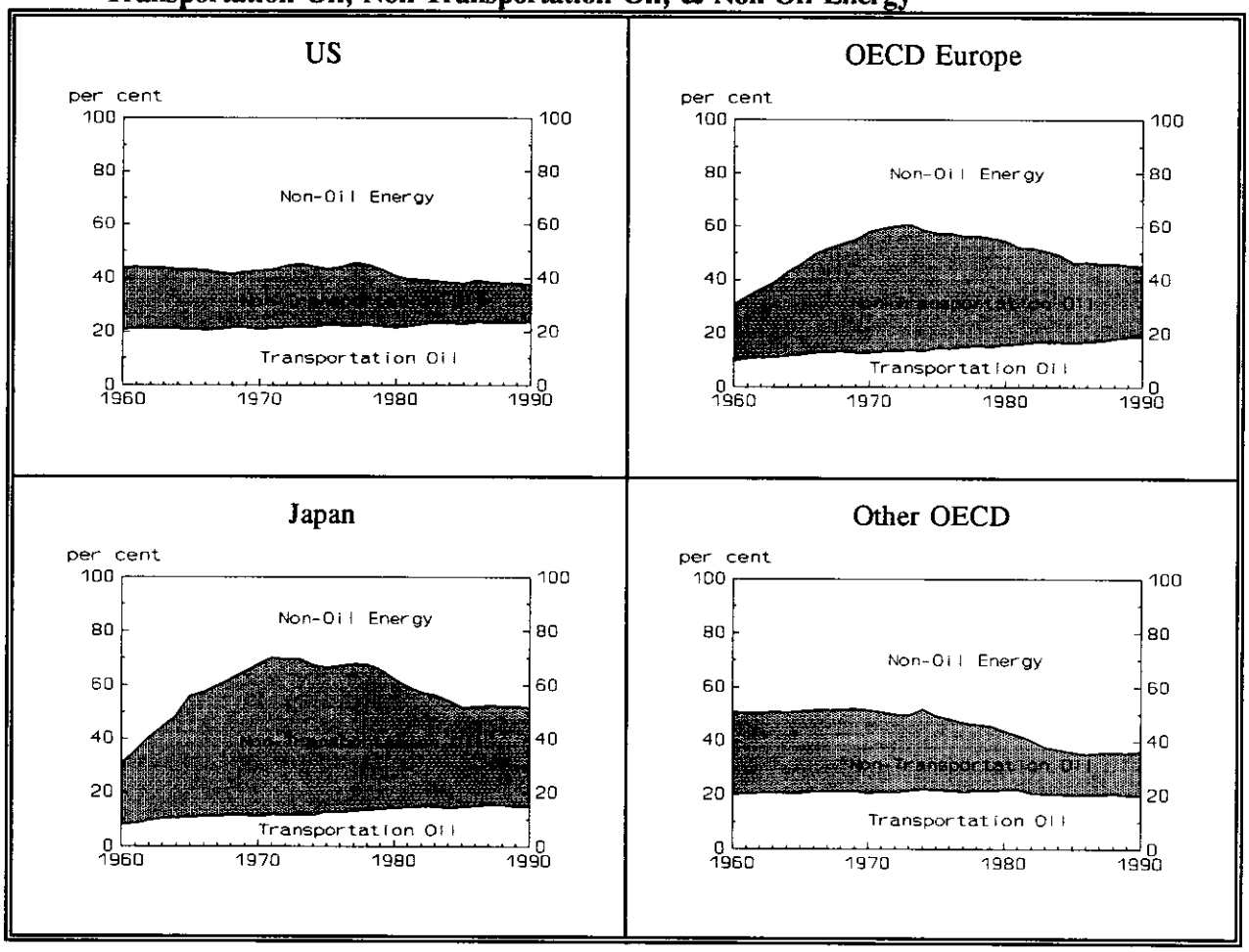


Figure 9. Regional Energy Shares:
Transportation Oil, Non-Transportation Oil, & Non-Oil Energy

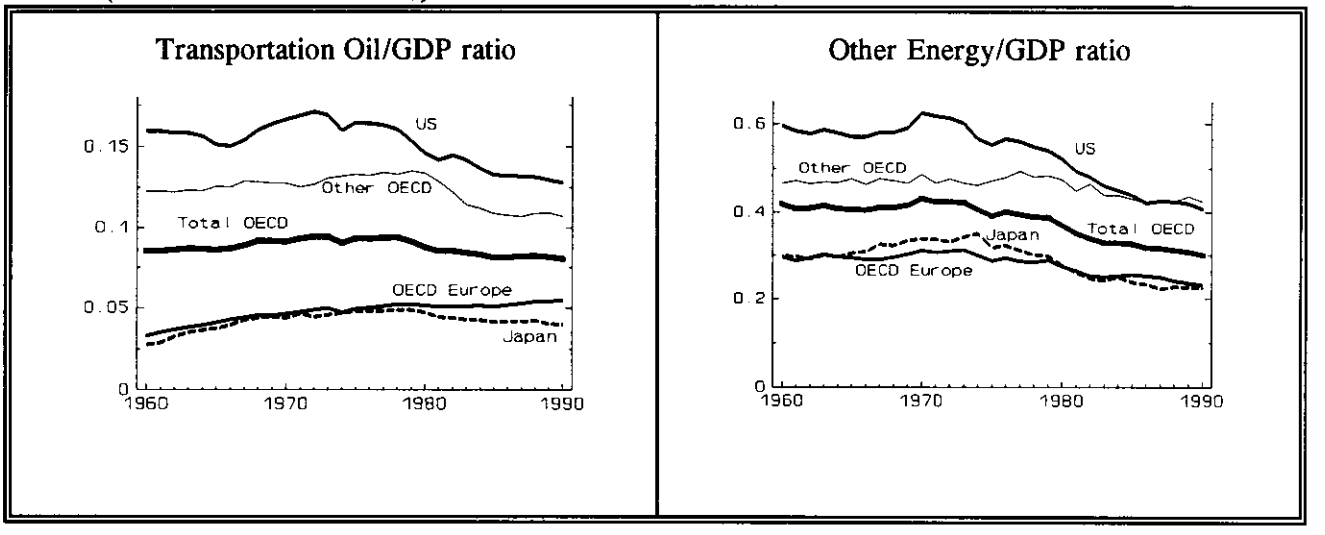


Yet there are important regional differences, primarily between Europe and Japan on the one hand, and the US and Other OECD on the other. In the 1960-73 period, Europe and Japan shifted very rapidly toward oil for non-transportation uses, away from coal. Oil's share of energy in those two regions, which had been about 30% in 1960, rose so rapidly that it had doubled by 1973 in Europe, and more than doubled in Japan. In contrast, oil's share in the US and Other OECD had remained fairly constant over this period, at about 45-50%. Much of this difference is explained by greater accessibility to natural gas in the US and Other OECD, than in Europe and Japan. In the 1960's, natural gas comprised one-third of US energy consumption, and 15 per cent in the Other OECD. But the share of natural gas was less than 2 per cent in Europe and Japan; other than coal, there were few substitutes for oil in these two regions.

Likewise, just as Europe and Japan had shifted most rapidly *toward* non-transportation oil prior to 1973, their shift *away* from non-transportation oil after the price increases was also more rapid than in the US and Other OECD. Europe and Japan reversed about half of their pre-1973 shift

toward oil, so that oil now constitutes about half of their energy demand. They were able to do this by increasing the share of nuclear power in electricity generation (shown below), and shifting toward natural gas for other non-transportation uses. In Europe, the availability of natural gas was increased by discoveries in the North Sea, the building of pipelines, and the importation of natural gas into the continent from North Africa and the Soviet Union. In Japan, natural gas had to be imported by tanker in liquified form (which is more costly). Yet despite Europe and Japan's shift away from non-transportation oil, its share of total energy in those two regions remains double or triple that in the US and Other OECD.

Figure 10. Ratios of Transportation Oil to GDP and Other Energy (Non-Oil Energy + Non-Transportation Oil) to GDP (MTOE / Million 1980 $)



Also varying across regions are the ratios of transportation oil to GDP, and other energy to GDP (other energy = non-oil energy + non-transportation oil); see Figure 10.

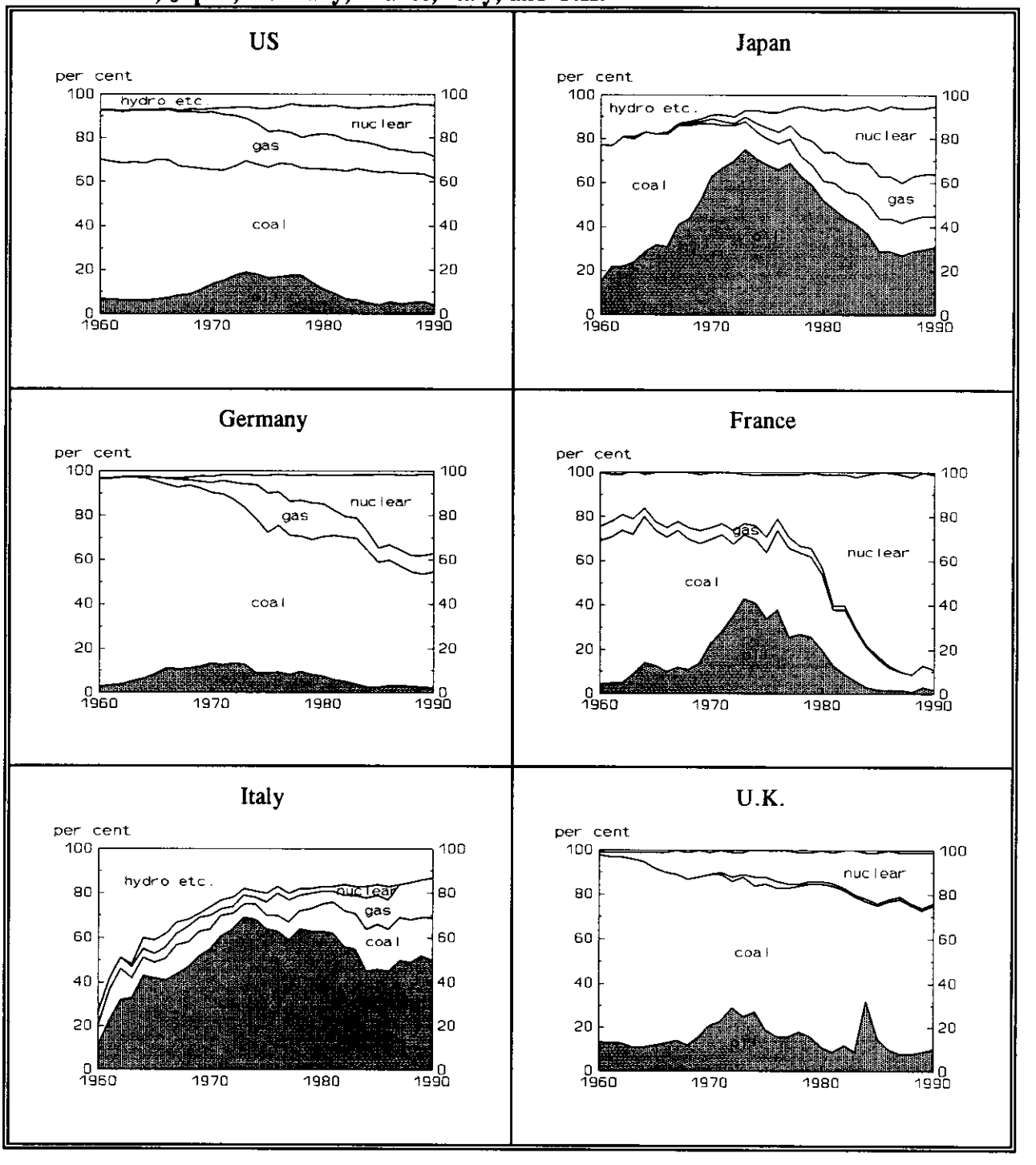
As noted earlier, the ratio of transportation oil to GDP has been relatively flat over the past three decades, declining slightly in the 1978-80 period. The US and Other OECD, whose ratios had been roughly triple those of Europe and Japan, have reduced the ratios significantly in the past decade -- to a level that is now about double that in Europe and Japan. Europe's ratio has actually risen over this period, while Japan's rose until the oil price increases and then fell somewhat.

The ratio of other energy to GDP, which is a rough measure of conservation in non-transportation sectors, has fallen consistently in all regions since the oil price increases. Again, Europe and Japan have lower ratios than do the US and Other OECD, but the greatest reductions since 1973 have been made by the US.

Comparing these ratios is a simple way of measuring improvements in energy conservation, but it only skims the surface of the regional differences within the OECD with respect to fuel-switching. In this regard, perhaps the easiest comparisons between countries can be made by viewing the fuel-shares within electricity generation. We do this in Figure 11 on the next page, for the six largest countries. As can be seen, there are huge differences across countries in these fuel-shares. Japan and Italy, for example, have historically been reliant on oil-fueled electricity, although that dependence has been reduced substantially in the past decade. The other four (US, Germany, France, and U.K.) had been more reliant on coal-fired power in the 1960's, and shifted toward oil prior to 1973, but since then have shifted back to coal and/or to nuclear power. France, in particular, has

moved away from oil almost completely, as its nuclear program has expanded dramatically. But despite the collapse of oil prices in the mid-1980's there has been no significant shift back to oil; the UK spike in 1984-85 was caused by their coal strike.

Figure 11. Fuel Shares in Electric Power: Oil, Coal, Natural Gas, Nuclear, Hydro etc. for US, Japan, Germany, France, Italy, and U.K.



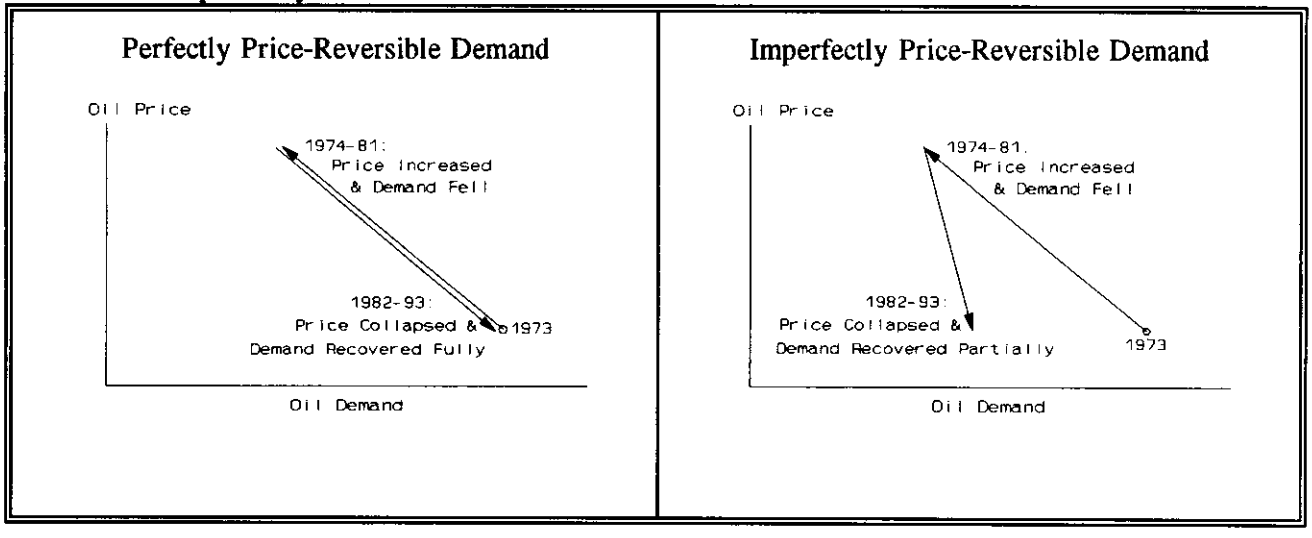
3. Imperfectly Price-Reversible Oil Demand

(or Why Demand Won't Surge Now That Price Has Collapsed)

The most important issue in oil demand analysis since the 1986 oil price collapse has been whether the demand reductions achieved in the early 1980's would be reversed by the price collapse. That is, do we believe that oil demand is perfectly price-reversible, or only imperfectly price-reversible -- such that some or all of the demand reductions would remain after prices fell. A similar question asks whether the demand response is symmetric or asymmetric with respect to price increases and price decreases. Yet another way of phrasing this question is to ask whether there is hysteresis in the oil demand relationship: now that the cause of the demand reduction (i.e. high prices) has been removed, do we expect its effect to remain?

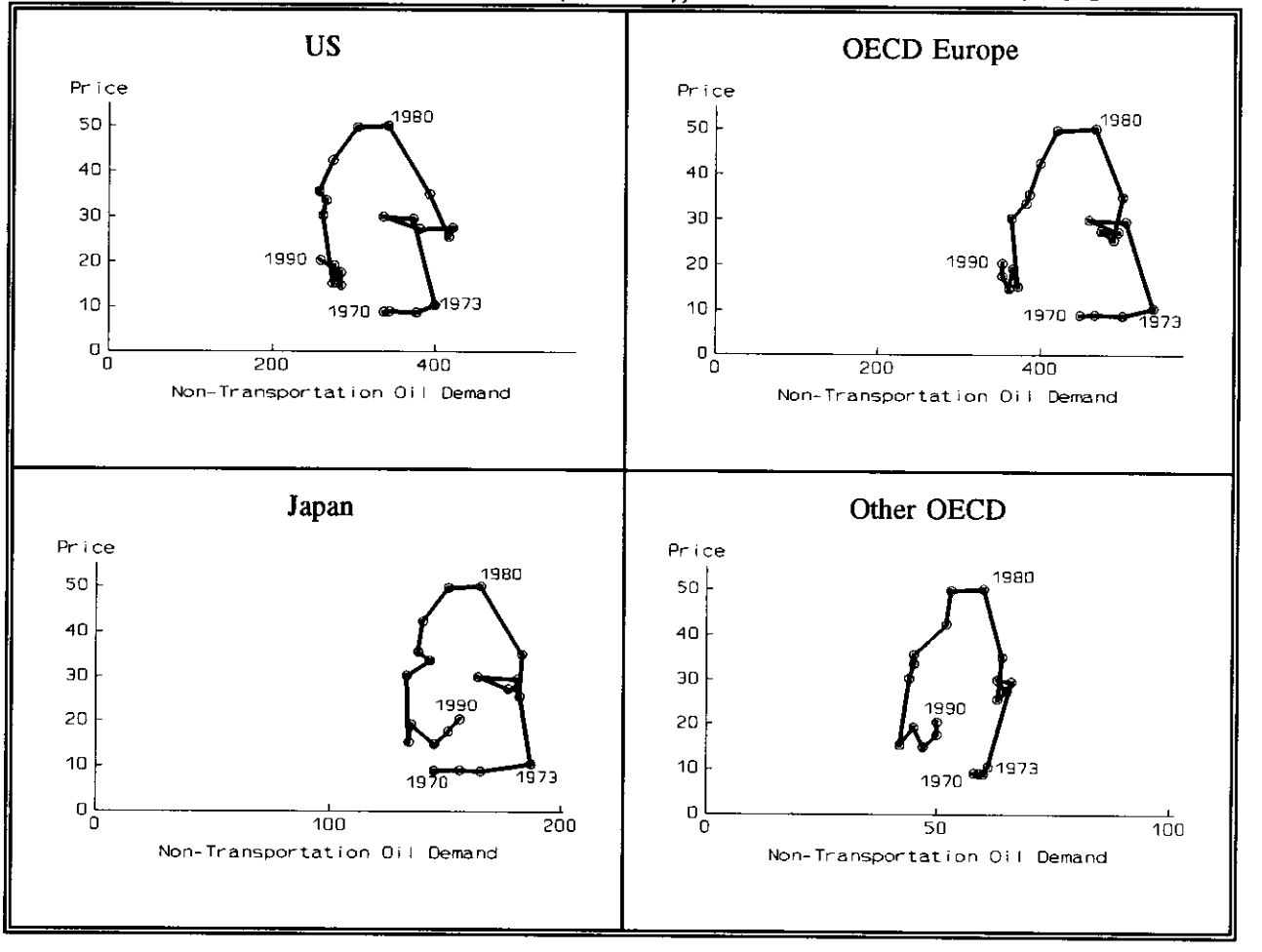
The following illustrations depict these two cases, in greatly simplified form. If we were to make the conventional assumption that demand were perfectly price-reversible, then the demand reductions following price increases of the 1974-81 period would be fully reversed by the price reductions of the 1982-93 period. On the other hand, if demand were only imperfectly price-reversible, then demand would only partially recover when the price increases of the 1970's were reversed in the 1980's.

Figure 12. Simple Illustrations of Perfectly Price-Reversible Demand and Imperfectly Price-Reversible Demand



Even with a lagged or delayed adjustment to the price changes, the reversal of the demand reductions ought to be evident in the data, which is what we show on the following pages. In Figure 13 we show the actual 1970-90 time-paths of price vs. non-transportation oil demand. Then in Figure 14 we graph price vs. the ratio of transportation oil demand to GDP (in order to correct for the effect of income growth on transportation oil demand[1]).

Figure 13: Price vs. Non-Transportation Oil Demand, 1970-90;
Real International Crude Oil Price (1985 $/b); Demand in Million Metric Tons

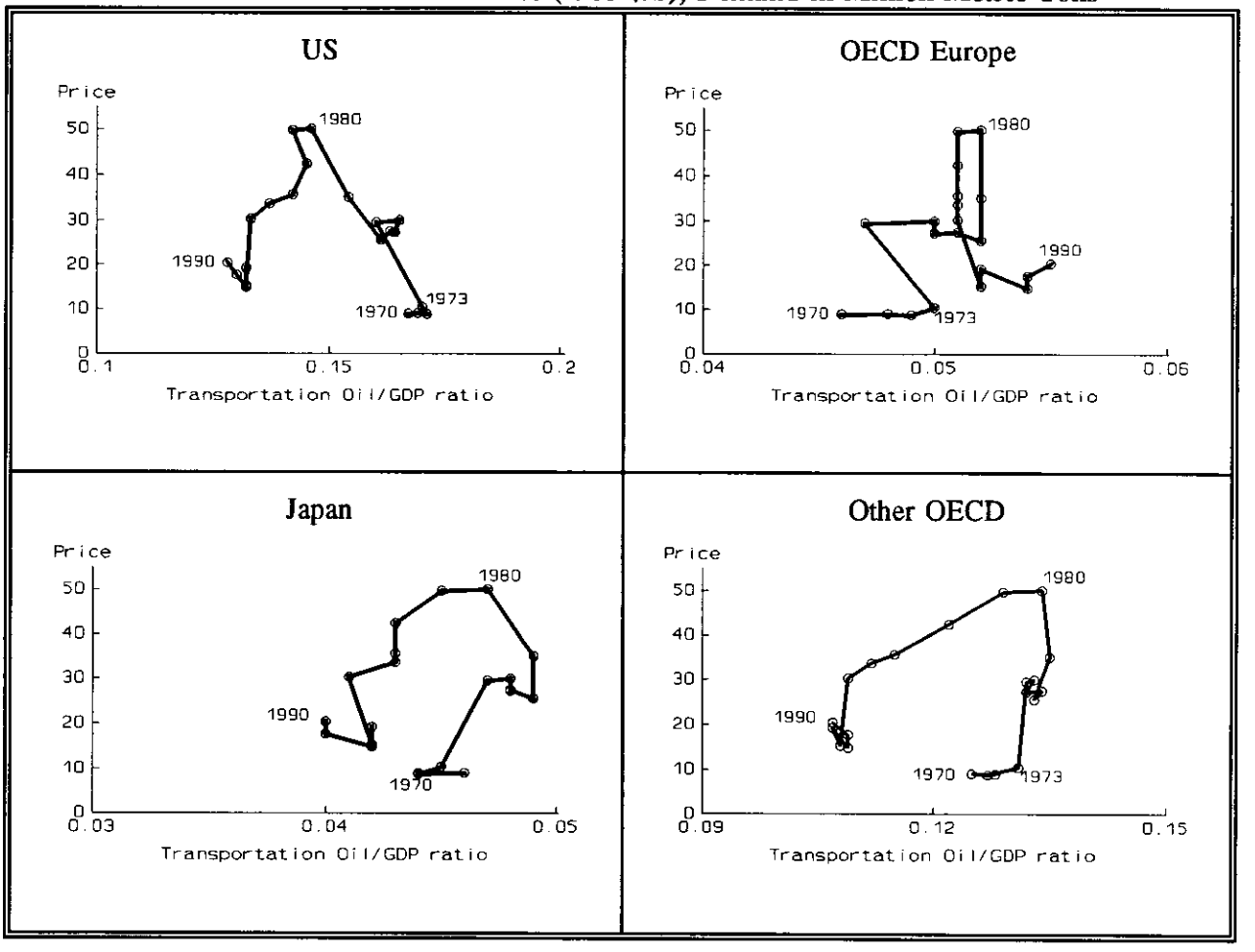


[1] For non-transportation oil, the demand reductions caused by the price increases are so great that they overwhelm the demand-increasing effect of income growth. For this reason, we graph the absolute levels of non-transportation oil demand. In contrast, transportation oil demand has continued to grow over time, so we graph not the absolute demand levels, but the ratio of transportation oil to GDP.

In both cases, we graph the world price of crude oil, for reasons of simplicity, rather than each region's real product prices (which are used in the econometric work).

Although the actual historical data for non-transportation oil in Figure 13 are not as neat as the simplified diagrams in Figure 12 -- due to lagged adjustment and changes in income and other factors -- there is clear evidence of imperfect price-reversibility: an inverted-V or inverted-U shape describing the period 1973-90. The price increases, in 1973-74 and again in 1979-81, caused non-transportation oil demand reductions that were barely reversed at all when price falls during the mid-1980's. There is little evidence of demand increasing after the 1986 price collapse: only in Japan during 1987-90, and perhaps also in the Other OECD.

Figure 14: Price vs. Transportation Oil/GDP ratio, 1970-90;
Real International Crude Oil Price (1985 $/b); Demand in Million Metric Tons



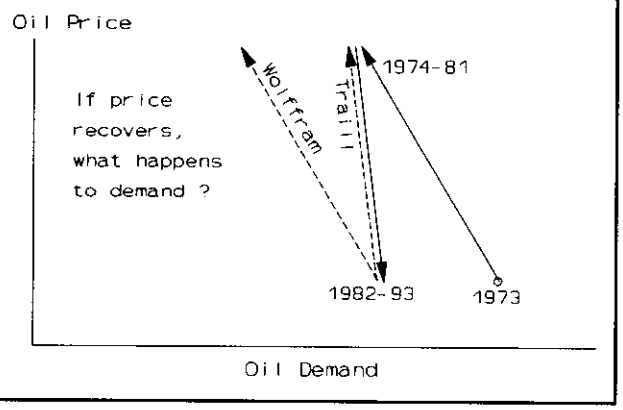
Likewise for transportation oil in Figure 14, we see evidence of imperfect price-reversibility in all cases, except perhaps OECD Europe. The inverted-V or inverted-U shapes -- for the US, Japan, and Other OECD -- show the post-price-increase reductions in the demand/GDP ratio not being reversed by the price declines of the 1980's. Only in OECD Europe has the ratio increased over the past two decades.

What would cause such irreversibilities to exist? Among the most important causes are the following. One is the irreversibility of the technical knowledge that was created after the oil price increases: it was not lost or abandoned when oil prices collapsed. For examples, consider the improvements in vehicle design (better aerodynamics and lighter, stronger materials), and the increased awareness and use of energy conservation techniques. A second factor was the non-reversal of government policies that had been enacted to reduce oil use, but which were not abandoned when oil prices fell in the 1980's. Among these would be mandated energy-cost labeling and energy-efficiency standards for appliances and vehicles. A third factor causing oil demand reductions not to be reversed is the long-lasting nature of the investments made when prices had risen. Attic insulation was not un-installed when heating oil prices fell, and nuclear power plants (with their high fixed costs and low marginal costs) were not abandoned.

From the graphical evidence it does appear that the demand response to price cuts in the 1980's will not reverse the demand reductions caused by the price increases of the 1970's. However, there is another important question, concerning the effect on demand of future price recoveries (i.e. price increases which do not exceed the historic maximum levels of the early 1980's). Will the demand response to a future price recovery be as great as it was to the price increases of the 1970's? Or will a price recovery only reverse the small demand increase caused by the price cuts? Or will it be somewhere in between?

These possibilities are depicted in the Figure 15. The greatest demand reduction from a price recovery, equal to that for the price increases of the 1970's, is labelled "Wolffram"[2]. It assumes that all price increases have the same effect -- both increases in the maximum historical price and (sub-maximum) price recoveries. The smallest demand reduction from a price recovery is labelled "Traill"; it merely reverses the small,

Figure 15 Effect on Demand of a Price Recovery



[2] Wolffram (1971) first proposed a price-decomposition method for measuring separately the effects (upon agricultural supply) of price increases and price decreases. He wanted to allow for the possibility that the effects need not be symmetric. But he also assumed, in effect, that the response to all types of price increases would be the same, both to increases in the maximum historical price and to subsequent (sub-maximum) price recoveries.

partial reversal of the 1980's demand increase[3]. It assumes the response to a price recovery is equal to the (small) response to a price cut. The third alternative would lie somewhere in between: demand responds more strongly to price rises than to price falls, but not quite as much to price recoveries as to increases in the maximum historical price.

Recent attempts to investigate the "irreversibility" issue have been based on econometric models which distinguish between the response to the different types of price changes described above. By using price-decomposition techniques, the hypothesis of equal response can be tested statistically.

These techniques are described in greater detail elsewhere; for examples, see Dargay(1992a), Gately(1992) or Dargay-Gately(1993). The basic approach is as follows. We decompose the price P_t into three component series, each of which is monotonic: maximum historical price $P_{max,t}$ (positive and non-decreasing), the cumulating series of price cuts $P_{cut,t}$ (non-positive and non-increasing), and the cumulating series of price recoveries $P_{rec,t}$ (non-negative and non-decreasing):

(1) $P_t = P_{max,t} + P_{cut,t} + P_{rec,t}$

(1a) $P_{max,t} \equiv \max (P_0,\ldots,P_t)$

(1b) $P_{cut,t} \equiv \Sigma^t_{i=0} \min \{0, (P_{max,i-1}-P_{i-1})-(P_{max,i}-P_i)\}$

(1c) $P_{rec,t} \equiv \Sigma^t_{i=0} \max \{0, (P_{max,i-1}-P_{i-1})-(P_{max,i}-P_i)\}$

Figure 16 Decomposing Price into 3 Series

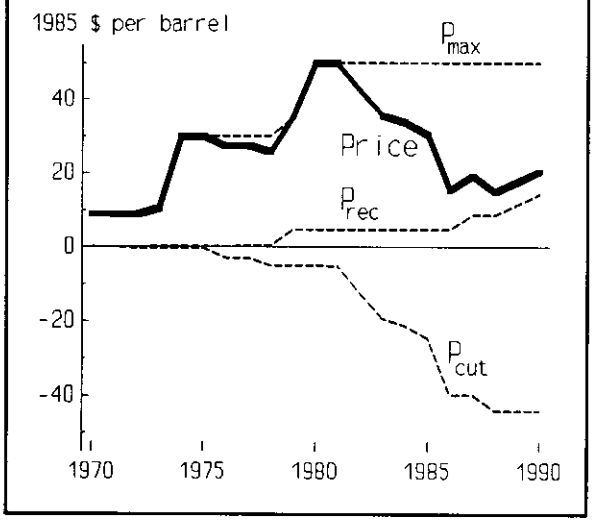


Figure 16 shows the real price of crude oil, together with its three-way decomposition. We see the jump in P_{max} in 1973-74 and 1979-80; it is always positive and non-decreasing. The cumulating series of price cuts, P_{cut}, is negative and non-increasing; it shows the dramatic price declines of the 1980's. Also shown is the cumulating series of price recoveries, P_{rec}, which is positive and non-decreasing; but such price increases have been relatively few, and small.

With this price decomposition, we can then examine two alternative demand specifications: one in which demand is assumed to be perfectly price-reversible, and one which allows for imperfect price-reversibility. Examples of two such models that could be estimated are as follows:

[3] Traill *et al.* (1978) proposed an alternative to Wolffram's specification which assumed, in effect, that the response to price recoveries would be equal to the response to price decreases.

(1.1) Perfectly Price-Reversible:

$$\log D_{it} = \alpha_i + \gamma \log GDP_{it} + \beta \log P_{it} + \phi \log D_{it-1}$$

(1.2) Imperfectly Price-Reversible:

$$\log D_{it} = \alpha_i + \gamma \log GDP_{it} + \beta_m \log P_{max,it} + \beta_c \log P_{cut,it} + \beta_r \log P_{rec,it} + \phi \log D_{it-1}.$$

We then use standard statistical tests to reject (or not reject) various hypotheses. For example, using equation (1.2), we could test the hypothesis that demand is perfectly price-reversible by using a Wald test of restrictions on the coefficients: $\beta_m = \beta_c = \beta_r$.

Some of the results relating to oil demand are shown in the following table. In all of the cases reported, the imperfectly price-reversible models are preferred on statistical grounds over the traditional, perfectly price-reversible models. An important point to note is that estimates of both price and income elasticities based on the imperfectly price-reversible models are more stable than those based on traditional models. In the latter, not only do price elasticities generally decline when post-1986 data (with moderate income growth and very low prices but only modest demand growth) is included in the data sample, but income elasticities fall substantially and sometimes even become negative.

Table 1. Elasticity Estimates from Imperfectly Price-Reversible Demand Specifications

Oil Product[a]	Region	long-run demand elasticities				Reference
		Income	changes in price			
			Increases in P_{max}	Price Cuts P_{cut}	Price Recoveries P_{rec}	
Total Oil	OECD	1.75	-.77	-.14	-.44	Gately(1993b)
Total Non-Transportation Oil	OECD	1.88	-.94	.0[b]	-.71	Dargay-Gately(1993)
	US	1.46	-.77	-.23	-.77 (Wolffram)	Gately(1993a)
	Japan	1.48	-.76	.0[b]	-.76 (Wolffram)	Gately(1993a)
Non-Transport'n Distillates	OECD	.14	-.97	-.13	-.03	Dargay-Gately(1993)
Residual (Heavy) Fuel Oil	OECD	.0[b]	-1.45	-.8	-1.58	Dargay-Gately(1993)
Total Transportation Oil	US	.70	-.21	-.04	-.21 (Wolffram)	Gately(1993a)
Gasoline (per driver)	US	.79	-1.08	-.46	-1.08 (Wolffram)	Gately(1992)
Road Transportation Oil	France	1.29	-0.80	-0.45	-0.80 (Wolffram)	Dargay(1992a)
	Germany	1.71	-0.44	-0.02	-0.44 (Wolffram)	Dargay(1992a)
	U.K.	1.49	-1.50	-0.10	-0.10 (Traill)	Dargay(1992a)

Notes:

a. The pattern of lagged adjustment to price changes differs between the models. Those for non-transportation oil assume a Koyck-lag scheme (lagged dependent variable). For gasoline and transportation oil, a polynomial distributed lag on past prices was used, an autoregressive distributed lag for road transportation oil.

b. The coefficient had the wrong sign but was not statistically significant.

4. Conclusions

We reach several important conclusions from our work on the imperfect price-reversibility of oil demand:

1. There has been an asymmetric, smaller demand response to the price decreases of the 1980's than to the price increases of the 1970's.
2. We expect a smaller demand response to future price increases than in the past.
3. The demand response to future income growth will be not substantially smaller than in the past.
4. Given the prospect of growing dependence on OPEC oil, in the event of a major disruption the lessened responsiveness of demand to price increases could cause dramatic price increases and serious macroeconomic effects.

4.1 Historical Asymmetry of Oil Demand Response to Price Increases and Decreases

The oil demand reductions that resulted from the oil price increases of the 1970's were far greater than the oil demand increases in response to the oil price declines of the 1980's. Oil demand has not increased much -- and will not -- in response to the oil price cuts of the 1980's. Perhaps only 1/4 of the demand reductions will be reversed.

If oil demand projections had been done in the mid-1980's, and one had (wrongly) assumed that oil demand were perfectly price-reversible, the result would have been to greatly overestimate the modest demand growth which actually occurred after the 1986 price collapse. As we had observed in Gately(1992, p. 199):

> "... consider the oil demand projections of some prominent models participating in the recent world oil study of Stanford University's Energy Modeling Forum (1991). The effect of demand being perfectly price-reversible is that world oil demand would surge in the 1990's if the low prices of the late 1980's were to be maintained. Estimates of the price-reversibility effect alone, ignoring other factors such as income growth, are that world oil demand by the year 2000 would exceed 1988 levels by 8 to 21 million barrels/day (MBD). To put this in perspective, total OPEC production in 1988 was only 21 MBD. Thus if demand is perfectly price-reversible and if oil prices remain low, then by the year 2000 (even without the effects of income growth) we shall need at least another Saudi Arabia, and maybe even another OPEC to satisfy world oil demand."

4.2 Oil Demand Response to Future Price Changes

For future price cuts we expect a consistently small response, but for oil price recoveries (i.e. modest price increases) we expect a smaller response in the future than we have had in the past. The easiest oil demand conservation and fuel-switching away from oil has already been done. Since it has not been *un-done* by the price cuts of the 1980's, it cannot be *re-done* if price were to recover in the

1990's. Additional conservation and fuel-switching would be required for demand to fall. For example, once the US has doubled the fuel-efficiency of its vehicle fleet (and that doubling has not been reversed), it is harder to double it again in response to a price recovery. Similarly, once oil has been replaced as a fuel for electricity generation (a process not reversed), that same oil cannot be replaced a second time. Oil demand has thus become less responsive to price increases, so that the possibilities of further reducing oil consumption in response to higher oil prices is much less today than it was in the 1970's.

A corollary to the above observation is that the recent (1993) price reductions, caused by OPEC's inability to restrict production, will have relatively little effect in stimulating demand: the demand elasticity to price cuts is very low, especially in the short run.

However, there is an important exception to this point. If OPEC is able to recapture some of the non-transportation oil markets that it lost to fuel-switching -- by long-term contracts at attractive prices -- then oil consumption could increase dramatically. Such an increase, however, would be highly conditional on low prices, and could be easily reversed if price were to rise again.

4.3 Oil Demand Response to Future Income Growth

The effect of income growth on oil demand has not been reduced substantially over the previous decades -- despite underestimates of this income effect when using recent data, which would be due to wrongly specifying demand as being perfectly price-reversible. As was shown in Gately (1993b) and in Dargay-Gately (1993), if demand were wrongly assumed to be perfectly price-reversible, then the inclusion of post-1986 data -- with moderate income growth and very low prices -- causes the estimate of income elasticity to be reduced, and sometimes to become negative! With the imperfectly price-reversible specification, however, no such error is caused: the estimated income elasticity is relatively unaffected by the inclusion of the post-1986 data.

4.4 Future Oil Demand Vulnerability

The good news for the OECD is that the oil price collapse won't bring about a quick return to high oil consumption. However, with growing income pushing up oil demand -- especially outside the OECD -- and with flat or declining non-OPEC supply, the world faces a growing dependence on OPEC oil, especially after the turn of the century. In the event of an OPEC supply disruption, either intentional or accidental, a reduced demand responsiveness to price increases could well drive price up higher and faster than in the 1970's, with comparably negative effects on the world economy.

References

Dargay, Joyce, (1990), "Have Low Oil Prices Reversed the Decline in Energy Demand? A Case Study for the UK", Oxford Institute for Energy Studies, April 1990.

-----, (1992a), "The Irreversible Effects of High Oil Prices: Empirical Evidence for the Demand for Motor Fuels in France, Germany, and the UK", in D. Hawdon, ed., *Energy Demand: Evidence and Expectations*, Academic Press, London, pp. 165-82.

-----, (1992b), "Are Price and Income Elasticities of Demand Constant?: The UK Experience", Oxford Institute for Energy Studies, EE16.

-----, and Dermot Gately, "The Imperfect Price-Reversibility of Non-Transportation Oil Demand in the OECD", December 1993, New York University: C. V. Starr Center for Applied Economics

Gately, Dermot, "Imperfect Price-Reversibility of Oil Demand: Asymmetric Responses of US Gasoline Consumption to Price Increases and Declines", *The Energy Journal*, Vol. 13, No. 4, 1992, pp. 179-207.

-----, (1993a) "Oil Demand in the US and Japan: Why the demand reductions caused by the price increases of the 1970's won't be reversed by the price declines of the 1980's", *Japan and the World Economy*, Vol. 5, No. 4, 1993.

-----, (1993b) "The Imperfect Price-Reversibility of World Oil Demand", *The Energy Journal*, Vol. 14, No. 4, 1993.

Griffin, James M., *Energy Consumption in the OECD: 1980-2000*, Ballinger Publishing Co., Cambridge MA, 1979.

Hogan, William W., "Patterns of Energy Use", in John C. Sawhill and Richard Cotton, eds., *Energy Conservation*, The Brookings Institution, Washington, DC, 1986.

-----, "OECD Oil Demand Dynamics: Trends and Asymmetries", *The Energy Journal*, Vol. 14, No. 1, 1993, pp. 125-157.

Pindyck, Robert, *The Structure of World Energy Demand*, MIT Press, Cambridge, Mass., 1979

-----, "Irreversibility, Uncertainty, and Investment", *Journal of Economic Literature*, 29:3, September 1991, pp. 1110-1148.

Traill, Bruce, David Colman, and Trevor Young, "Estimating Irreversible Supply Functions", *American Journal of Agricultural Economics*, August 1978, pp. 528-531.

Wolffram, Rudolf, "Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches - Some Critical Notes", *American Journal of Agricultural Economics*, 53, 1971, pp. 356-359.