OXFORD INSTITUTE FOR ENERGY STUDIES

The Irreversible Demand Effects of High Oil Prices: Motor Fuels in France, Germany and the UK

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ISBN 0 948061 53 7

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ABSTRACT

There is no doubt that the price shocks of the seventies have led to considerable reductions of oil demand. With the price collapse of 1985, the era of high oil prices abruptly came to an end, so that by the end of the decade real prices had returned to their pre-1974 levels. How did demand respond to the return to lower prices? Would lower prices totally reverse the demand reductions witnessed during the seventies and early eighties or have the price shocks triggered permanent changes in consumption patterns, so that demand would continue to be dampened, despite the price development? This paper addresses this question by examining the demand for motor fuels for road transport in France, Germany and the UK, using data from both before the first oil price shock and after the price collapse. As opposed to the majority of econometric studies of oil demand, the estimation is based on a demand function which allows for irreversible price effects, by distinguishing between the effects of rising and falling prices. The basic assumption to be tested is whether or not high oil prices have induced a technological change, which has irreversibly altered the demand function. In all cases, the evidence suggests that the price shocks have had permanent effects so that demand will not be totally reversible. Given a return to 1973 prices, the results indicate that long-run demand would be about 15 per cent lower than it would have been in absence of the price shocks.

1. INTRODUCTION

The majority of aggregate demand studies, whether concerned with energy or other goods, are based on the notion of a stable long-run demand function, which implies the existence of a unique equilibrium demand for any given relative price and income level. Given this static relationship, the effects of any price (or income) change will, by assumption, be totally negated as price (or income) returns to its initial level, so that demand is completely reversible. In some cases technical change may be introduced, which serves to change the equilibrium demand relationship over time, but it is generally assumed to be of an exogenous nature, unrelated to the actual price development. Although such technical progress surely exists, there is good reason to believe that prices, themselves, provide a motive force in the development of new technologies, so that some component of technical change is certainly price induced. Clearly, in the case of energy consumption - whether in industrial processes, transport or space heating - increasing efficiency has been attained over the past fifteen years chiefly in response to high energy prices. Since some of these energy-saving technologies will remain economically optimal despite falling prices, there is good reason to believe that the era of high energy prices will have a lasting, dampening effect on demand. If this is the case, reversible demand functions or specifications which only allow for exogenous technical change will not provide an adequate description of energy demand. Estimates of elasticities and forecasts based on such models could therefore be misleading.

It is the aim of this paper to investigate whether or not the price shocks of the seventies have elicited permanent changes in demand patterns, by analysing oil demand within the context of a model which allows for irreversible price effects. By including data for both before the first oil price shock and following the oil price collapse - when real prices had returned to their pre-1974 levels - we should be able to capture any change in the demand relationship. The empirical analysis concerns oil consumption for road transport, and includes three countries - France, Germany and the UK.

The models and methods employed in the analysis are presented in the following section and are described more fully in Dargay (1990) which also includes an application to sectoral energy demand in the UK. In Section 3, after a description of the data sources and a brief discussion of the development of motor fuel prices and demand, the empirical results are presented. The paper concludes with a comparison of the findings for the three countries, and looks at the implications of the results for future oil demand.

2. THE MODEL

2.1 Long-run Demand

In modelling aggregate oil consumption for road transport, we begin by assuming that long-run demand is determined by the following simple relationship:

$$E^{*} = \alpha + \beta P + \phi Y \tag{1}$$

where E^{*}, P and Y are the natural logarithms of the quantity of oil consumed for road transportation, the real price of motor fuels and real income. As specified above, long-run oil demand is uniquely determined by price and income. A price (or income) rise followed by an equivalent price (or income) fall will, in the long run, restore demand to its original level, so that it is perfectly reversible to changes in these variables. The notion of long-run irreversibility is incompatible with movements along a static demand curve, but instead presupposes some sort of shift or tilt in the demand curve itself. Since such movements occur over time, one demand curve predates another, and the long-run demand function itself will be dependent on time or previous events. Thus in order to test the hypothesis of irreversibility, the model must be extended to allow for some sort of intertemporal shift in the long-run demand curve.

A simple and often used method of allowing for such shifts is based on the notion of exogenous technical progress. Here, changes in technology - generally assumed to occur smoothly over time by including a time trend in long-run demand function - are responsible for movements in the long-run demand function. Although such technical change is unrelated to price or income movements, and has no effect on elasticities, its existence causes demand to be irreversible to changes in all other explanatory variables. If, for example, technical change is energy-saving, the same price and income at time $t + i$ would result in a lower demand than they would have done at time t.

Although it is important to take into account the existence of exogenous technical change, we are more concerned here with the possibility of irreversibility caused by price-induced improvements in technology or changes in behaviour which are of a permanent nature. For example, price rises may trigger the development of more energy-efficient technology which remains in use despite falling prices. Such shifts over time of the long-run demand function are thus the result of price changes, so that equilibrium demand is determined not only by a given price, but also by the previous price history. Although many different assumptions could be made and tested regarding price-induced irreversibility, two specifications are employed in the present study. Both are based on the assumption of asymmetric price responses, and involve generating new price variables that allow such irreversibility by inducing shifts in the long-run demand function.

The first specification is based on the jagged ratchet model proposed by Wolffram (1971) which distinguishes between the response to rising and falling prices. This is accomplished by decomposing the price variable into increasing and decreasing prices by generating two new variables, P+ and P-. The variable P+ is defined as the sum of all price rises from time s = 0 (the initial year of the data sample) to time s = t:[1]

$$P+(t) = \sum_{s=0}^{t} [(P(s) - P(s-1)] \text{ for } P(s) > P(s-1) \quad (2)$$

while P- is generated for falling prices in a similar fashion. From the construction of P+ and P- it is easily seen that

$$P+(t) + P-(t) = P(t) - P(0) \text{ for all t.} \quad (3)$$

By including P+ and P- in the demand function in the place of P, we have

$$E^* = \alpha_1 + \beta_1 P+ + \beta_2 P- + \phi Y. \quad (4)$$

Since only P+ changes as prices rise, the elasticity for rising prices is determined by the coefficient of P+. By the same reasoning, the elasticity for falling prices depends solely on the coefficient of P-. Because of the

[1] A derivation of this can be found in Houck (1977).

double-logarithmic specification used, both of these are independent of the price level and constant over time. Of course, the coefficients of both P+ and P- should be negative, and if the coefficient of P+ is greater (smaller) in absolute value than that of P- demand is more (less) elastic to rising than to falling prices. The case where demand is more elastic to price rises than to price falls can be visualized as a normal, reversible demand curve permanently shifting downwards as prices rise. The total effect of a price increase is thus the combined effect on demand of the movement along the initial curve, which is equal and opposite that caused by a price fall, plus the downward shift. Alternatively, we could imagine separate but identical demand curves each kinked at the current price so that demand is related to rising and falling prices in an asymmetric fashion. Either way, since the demand curve shifts as prices change, a price rise/fall followed by an equivalent price fall/rise will not restore demand to its initial level.

From the identity in (3) above, we see that if $\beta_1 = \beta_2$, the elasticities are identical for rising and falling prices and (4) reduces to the reversible specification (1). It can also easily be shown that including both P+ and P- in the demand equation is equivalent to including only P+ along with the actual price variable, P. The elasticity for rising prices is determined by the sum of the coefficients of the two price variables, while the effect of price falls is determined solely by the coefficient of the actual price variable. If the coefficient of P+ is not significantly different from zero, the elasticities for falling and rising prices will be identical so that demand will be reversible. If P+ is significant, however, the price effects will not be symmetric and demand will be irreversible. Again we would expect the coefficient of P+ to be negative, implying that demand is more elastic to price rises than to price falls.

An interesting feature of this model is that it implies that for any identical initial and final prices, the greater the price variability during the intervening period, the larger the decline in demand. This seems quite reasonable since price variability can be seen as a measure of uncertainty, and the more uncertain consumers are concerning oil prices, the more likely they will be to decrease their dependency on oil.

The second specification derives from the ratchet model of Traill, Colman and Young (1978), which assumes that only price rises above the previous maximum price have asymmetric effects. This specification is formulated by generating a new variable P_m, defined as the maximum previous price:[2]

$$P_m(0) = P(0)$$
$$P_m(t) = P(t) \text{ if } P(t) > P(t\text{-}i) \text{ for all } i = 1, ..., t$$
$$P_m(t) = P_m(t\text{-}1) \text{ otherwise.} \qquad (5)$$

The variable P_m is then included in the demand equation along with the actual price P.

By this definition, price rises above the previous maximum will cause a shift in the long-run demand curve, represented by the coefficient of P_m, which we would expect to be negative. In terms of price elasticities, if both P_m and P are significant, the price elasticity for a price fall will be determined simply by the coefficient of P. The relevant elasticity for price rises will be either the coefficient of P (if the price does not rise above its previous maximum) or the sum of the coefficients of P and P_m (if a new maximum is reached). If only P_m is significant, price decreases have no effect on demand, nor do price increases below the previous maximum, and the coefficient of P_m determines the price elasticity when prices rise above all previous levels. In both of these cases, demand is *not* reversible. However, if the coefficient of P_m is insignificant, all price changes have symmetric effects so the demand curve does not shift and demand will be reversible.

By including both P+ and P_m in the demand function along with P, we can distinguish between the effects of price rises both below and above the previous maximum as well as of falls. In this case, the long-run demand function in (1) becomes:

$$E^* = \alpha + \beta_P P + \beta_+ P+ + \beta_m P_m + \phi Y. \qquad (6)$$

[2] See Traill, Colman and Young (1978).

The elasticity pertaining to price falls is obtained from the coefficient of P, β_P, the elasticity for price rises below the previous maximum from β_P + β_+, and for price rises above the previous maximum from $\beta_P + \beta_+ + \beta_m$. If either β_m or β_+ equals zero, the model results in one of the above more simple irreversible specifications. Of course, if both β_m and β_+ equal zero we revert to the symmetric, reversible model.

2.2 Dynamic Specification

The model above describes long-run demand relationships. Adjustment to long-run equilibrium is, however, certainly not instantaneous, so that some sort of dynamic adjustment mechanism must be included in the model specification if this is to be estimated on the basis of time-series data. For the present analysis an error-correction model is chosen, in which the dependent variable is given in differenced form so that the change in oil consumption is specified as a function of current and lagged changes in prices and income, the lagged levels of these variables and lagged changes and levels of energy consumption:

$$\Delta E_t = \alpha_L + \beta_{PL} P_{t-1} + \beta_{+L} P+_{t-1} + \beta_{mL} Pm_{t-1} + \phi_L Y_{t-1} + \Phi_L E_{t-1}$$

$$+ \sum_{i=0}^{n} [\beta_{Pi} \Delta P_{t-1} + \beta_{+i} \Delta P+_{t-1} + \beta_{mi} \Delta Pm_{t-1} + \phi_i \Delta Y_{t-1}]$$

$$+ \sum_{i=1}^{n} \Phi_j \Delta E_{t-i}. \qquad (7)$$

One advantage of this formulation is that the estimated coefficients are easy to interpret. The long-run solution is obtained from the coefficients of the level variables, for example, $\beta_P = \beta_{PL}/\Phi_L$, $\phi = \phi_L/\Phi_L$, etc. The short-run, or immediate impact of changes in the exogenous variables are given by the coefficients of the first differences, while the coefficients of the lagged differences define the lag structure.

Clearly, the model permits a more general dynamic structure than that imposed by the partial adjustment model often used in energy demand studies. This will be advantageous in the investigation of irreversibility. First, if the dynamics of the adjustment process are misspecified, the estimates based on the model may be biased, and we may mistake this misspecification for structural instability, and hence as an indication of irreversibility. A further advantage of a more general lag structure is that it permits the possibility of dynamic asymmetries and irreversibilities to be investigated. Since the intertemporal adjustment process is not constrained to be identical for all exogenous variables, the effects of price increases and decreases need not be distributed identically over time. The initial response of one or the other can be delayed, and the speed of adjustment to equilibrium can differ.

3. THE EMPIRICAL RESULTS

The irreversible error-correction model (7) was estimated for France, Germany and the UK using annual data covering the period 1960-88. Oil consumption is defined as the total amount of gasoline and diesel oil used for road transport, measured in metric tonnes, as reported in the OECD publication *Energy Statistics of the OECD Countries*. The real price of motor fuels is calculated as a divisia index of the prices of gasoline and diesel in local currencies, divided by the GDP deflator. Prices are inclusive of non-refundable taxes, and were obtained from the OECD publication *Energy Prices and Taxes* for the years 1978-88 and from the EEC publication *Energy Price Indices* (1982) for previous years. Real income is defined as real GDP, rather than private consumption, since the measure of oil consumption includes use by commercial as well as by private vehicles. Data on GDP and the GDP deflator were obtained from the IMF's *International Financial Statistics*.

In order to illustrate the differences and similarities amongst the three countries, the development of oil prices and consumption is presented in the following two figures. Figure 1 shows real price of oil used for road transport, constructed as described above, and presented in logarithmic form normalized so that the price in each country is set equal to 1 in 1960, the first year of the observation period. This obviously does not allow us to compare the relative prices between countries, but converting to a common currency would give a false conception of the actual price development on the domestic market. Price levels have, however, differed considerably in the countries over the entire period. In 1960, the price of gasoline was 50 per cent higher in France and 16 per cent higher in Germany than in the UK. By 1988, prices had converged markedly. The German price was 14 per cent lower and the French price 20 per cent above that in the UK.[3]

We see that until around 1972-73, the price of motor fuels declined in relation to other goods in all three countries, but far more dramatically and smoothly in France and Germany than in the UK, where falling real

[3] The prices are compared by converting the German and French prices to pounds using actual exchange rates.

prices were counteracted by increases in taxation. It is also apparent that the first oil price shock was rather different in the three countries. The upturn in prices from 1972-73 to 1974-75 meant a 43 per cent rise in real prices in the UK, but only 25 per cent in France and 20 per cent in Germany. A partial explanation for this is that prices were initially lower in the UK so that the impact of the world price rise was greater in percentage terms. Further, the strengthening of the deutschmark and the franc against the dollar reduced the impact in local currencies, while the weakening of the pound had the opposite effect.

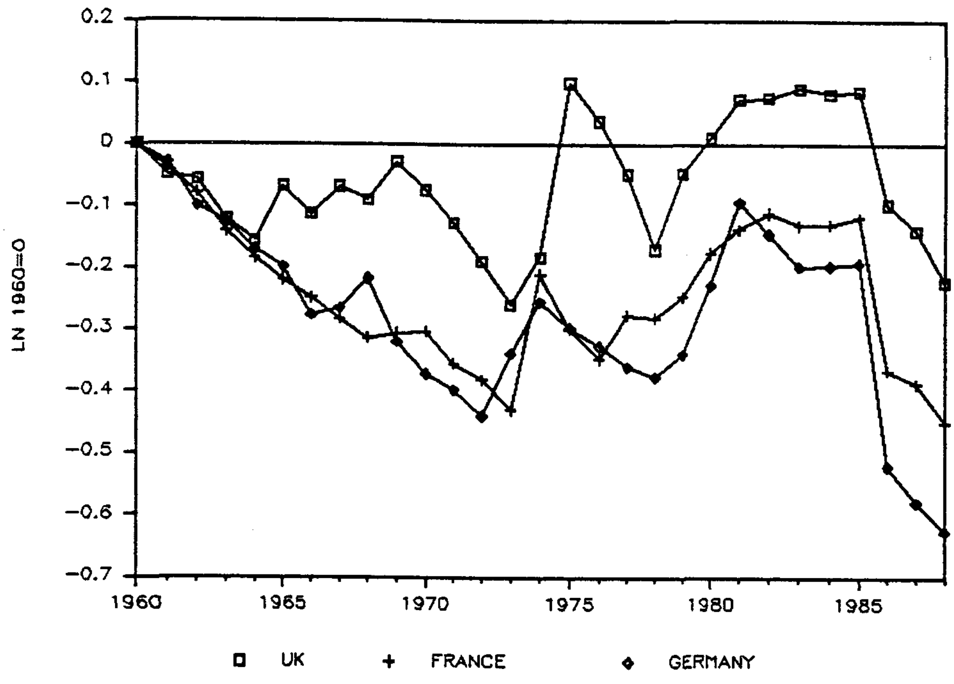

Figure 1: Logarithmic Index of Real Oil Prices for Road Transport (1960 = 0). 1960-88.

The second oil price shock had an obvious impact on prices in Germany and the UK, both experiencing a real price increase of about 30 per cent between 1978-81. In France, the higher initial prices, price regulation and increasing taxation in the latter part of the seventies brought about a steady rise from the mid-seventies onwards, so that the effect of world oil price increases was mitigated. It is also apparent that the 1985 collapse in world oil prices did not lead immediately to lower domestic prices in any of the countries. The reason for this is mainly the strengthening of the dollar against European currencies in this year, but increases in taxation in all three countries also played an important role. As world prices continued to fall in 1986, improvements in exchange rates accentuated the decline in local currencies. Relatively stable world oil prices and little changes in taxation kept nominal prices pretty constant for the next few years, while real prices continued to fall.

It is clear that real prices have varied considerably over the entire period. The variation was greatest in Germany and smallest in the UK, due to the substantial decline in prices in the former. Price shocks, however, were more substantial in the UK. Taking only years showing price increases, the average per cent change was 3 per cent in the UK, as compared to about 2 per cent in France and Germany. Also, we see that without exception motor fuel prices were far lower in real terms in 1988 than they were in 1960 - by 20 per cent in the UK, 36 per cent in France and 47 per cent in Germany. Since, with the exception of years of the Suez crisis, real prices declined in the fifties as well, fuel for road transport is now cheaper than it has been for the past forty years. Interestingly, the diagramme makes it quite clear that despite the oil price shocks of the seventies, real prices in France and Germany were never higher than they were in the early sixties. Even at their maximum, prices were 10 per cent below that of 1960. Only in the UK did real prices ever rise above that of 1960, and at their maximum by only about 10 per cent. It is apparent, as well, that by 1988 real prices had nearly returned to - and in Germany had fallen well below - what they were prior to the first oil price shock.

As mentioned above, the oil prices described here are an aggregate index of the prices of motor gasoline and diesel, weighted by the relative shares of the fuels consumed. Since diesel has become a more significant share in all countries, and since the price of diesel has been relatively lower, the decline in prices also reflects the changing composition of motor fuels. However, the observations made in the previous paragraph hold in large even for each fuel individually. In all countries, the price increases on diesel followed those on gasoline quite closely, although they were somewhat milder in the UK. By the late eighties, the real prices of both fuels were lower than they had been in 1960.

Total consumption of oil for road transport in the three countries per unit real GDP is shown in Figure 2. The ratios are given in logarithmic form, normalized with 1960 equal to zero in each country. Since GDP is measured in national currencies, the diagramme does not give an indication of the relative intensities of oil consumption in the three countries. Converting GDP to constant dollars, however, we find that the oil-GDP ratio was about 13 per cent lower in France and 23 per cent lower in Germany than in the UK in 1960, whereas by 1988 it was 11 per cent lower in France and only 8 per cent lower in Germany.

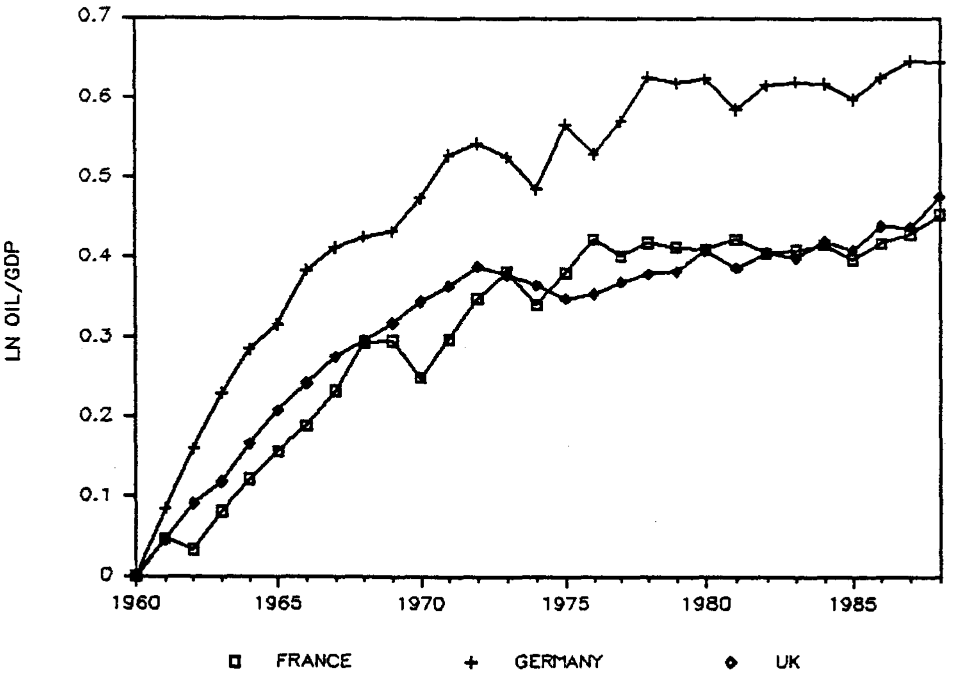

Figure 2: Ratio of Oil Consumption for Road Transport to Real GDP. Logarithmic Index (1960=0). 1960-88.

The convergence of the oil-GDP ratios is apparent from the figure, where we see that the rate of growth in Germany far exceeded that in the other two countries. For all countries, the growth rate was highest for the period up till 1972, slightly over 3 per cent per annum in France and the UK and 4.6 per cent in Germany. During the rest of the period growth slowed down substantially, on average to less than 0.7 per cent per annum.

It could be mentioned that the relative importance of diesel differs markedly in the three countries. Diesel's share has grown continuously in France, from 24 per cent in 1960 to 43 per cent in 1988. The pattern is rather different in Germany, where the share of diesel fell until the mid-seventies, to rise afterwards. By 1988, diesel made up about 34 per cent of total consumption. In the UK diesel's share remained more or less constant at about 25 per cent until the early eighties, and increased to 30 per cent of total consumption by 1988. However, as the consumption figures include both private and commercial transport, without detailed information about the vehicle stocks it is impossible to clarify the extent to which these differences and changes have to do with the relative importance of cars versus commercial vehicles and the penetration of diesel in each user category.

The price variables P+ and P_m were constructed as shown in equations (2) and (5). However, as seen in Figure 1, real prices in France and Germany never rose above that of 1960, so that P_m as defined in (5) is a constant, and would thus be unable to explain any irreversibilities. P_m was therefore redefined for these countries with the price in 1973 as a base, so that $P_m(t)$ was set equal to the price in 1973 for all years up to and including 1973, and as in (5) for t greater than 1973. By this definition, the effects of price increases above the previous maximum after 1973 are allowed to have different effects on demand than other price increases/decreases, and thus give rise to irreversibilities. Finally, a dummy variable, D_{74}, equal to 1 in 1974 and 0 otherwise was included in the model to capture the effects of rationing and shortages during the first oil crisis.

As a starting-point for the estimation, lags of two years were included on all differenced variables, limiting n = 2 in equation (7). Although this restricts the dynamic structure, it does permit some flexibility, particularly since the adjustment process is not constrained to be the same for all explanatory variables. From this general irreversible dynamic specification, the model was sequentially simplified by omitting those lagged variables that have a statistically insignificant influence. Since the test for irreversibility entails determining whether or not P+ and P_m provide any explanatory power over and above that embraced by the actual price variable P, all insignificant P+ and P_m variables were deleted, while the levels of the actual price variables and their first differences were not, irrespective of their statistical significance.

In order to determine the final dynamic specification, this process is repeated until further deletions are rejected on the basis of statistical tests. F-tests for the restrictions imposed and the Lagrange multiplier (LM) test for autocorrelation of the residuals are reported in the tables. Further, the functional form of the model is tested by including the square of the fitted dependent variable as a regressor (the RESET $\hat{E}^2$test) and the existence of exogenous technical change by including a time trend (the RESET-t test). Finally, to insure that the estimated parameters of the model are constant over time, so that no unexplained structural change is evident, the stability of the estimated equations over the observation period was analysed by recursive estimation techniques and the appropriate Chow-tests.[4] The Chow tests for parameter constancy of the models after the price collapse of 1986 are reported as well as F-tests for a structural break coincident with the first oil price shock of 1974.

The resulting models, along with the estimated coefficients and t-values for the three countries are shown in Table 1. In all cases, we find that the lagged levels of oil demand, income and at least one price variable are statistically significant as are many of the differenced variables. All estimated parameters are of the expected sign and define a plausible dynamic structure. Also, since the lagged level of P+ is significant for France and Germany and that of P_m for the UK, reversibility is rejected on statistical grounds. Further, the level of the actual price variable has a significant influence only for France, suggesting price falls have no long-term effect on demand in Germany and the UK. Additionally, as P_m is the only significant price level variable for the UK, only price rises above the previous maximum appear to have any effect on demand in this country.

[4] All estimations and statistical tests were carried out using the program package PC-GIVE. The reference manual, Hendry (1989), can be consulted for the statistical formulation of the tests used and further references concerning these.

Looking further down the table, we see from the low standard errors, σ, and the high R^2, that the models explain the data rather well. Further, the LM tests give no indication of residual correlation and the RESET tests for adding $\hat{E}^2$ or t do not suggest functional misspecification nor the significance of a time trend. Also, we see that the implied parameter restrictions on the general model are not rejected on the basis of the F-tests. In all cases, recursive estimation gives no indication of parameter instability over the observation period. Particularly, from the Chow tests for the 1986-88 period, the estimated parameters are equally valid for the years following the price collapse, so that the insignificant effect of price increases holds even for this period. Finally, including a shift variable for the post-74 period is also rejected for France and Germany. This was not done for the UK, since the P_m variable itself produces an equivalent shift as prices only rose above previous maximum levels in 1975.

Table 1. Oil Demand For Road Transport: Irreversible Models. All Models in differenced form, with ΔE as dependent variable. Estimation period 1962-88.

	FRANCE		GERMANY		UK	
k	0.38	(1.29)[1]	-0.99	(1.77)	0.40	(3.52)
E(t-1)	-0.49	(2.40)	-0.49	(4.39)	-0.23	(3.52)
Y(t-1)	0.63	(3.75)	0.84	(3.81)	0.34	(2.68)
P(t-1)	-0.22	(4.23)	-0.01	(0.22)	-0.02	(0.84)
Pm(t-1)					-0.32	(2.42)
P+(t-1)	-0.17	(3.17)	-0.21	(3.26)		
ΔY			0.64	(3.12)	0.66	(5.63)
ΔP	-0.08	(1.76)	-0.01	(0.14)	-0.06	(1.74)
ΔPm					-0.50	(2.64)
ΔP+			-0.40	(3.16)		
ΔE(t-1)	-0.41	(2.40)	-0.24	(2.01)	-0.58	(3.99)
ΔY(t-1)					0.87	(4.43)
ΔP(t-1)	0.07	(1.14)				
ΔPm(t-1)						
ΔP+(t-1)	-0.26	(2.78)				
D74	-0.08	(4.47)	-0.07	(3.92)	-0.09	(6.34)

	FRANCE	GERMANY	UK
R^2	0.94	0.91	0.95
DW	1.93	2.11	2.06
σ	0.0111	0.0153	0.0085
RSS	0.00209	0.00402	0.00116
LM	1.60 F(3,14)[2]	0.55 F(3,14)	0.27 F(3,13)
RESET E^2	1.12 F(1,16)	0.01 F(1,16)	1.30 F(1,15)
RESET t	1.45 F(1,16)	0.34 F(1,16)	0.63 F(1,15)

F-test for parameter restrictions from:

	FRANCE	GERMANY	UK
general model	1.89 F(6,11)	0.35 F(6,11)	0.40 F(5,11)

Tests for parameter constancy:

	FRANCE	GERMANY	UK
Chow 1986-88	1.03 F(3,14)	0.13 F(3,14)	0.32 F(3,13)
Shift 74	0.01 F(1,16)	0.23 F(1,16)	

Elasticity	sr	lr	sr	lr	sr	lr
Price fall	-0.08	-0.45	(-0.01)	(-0.02)[3]	-0.06	(-0.10)
rise	-0.08	-0.80	-0.41	-0.44	-0.06	(-0.10)
Pm	-0.08	-0.80	-0.41	-0.44	-0.56	-1.50
Income	0	1.29	0.64	1.71	0.66	1.49

Notes: 1. t-values.
2. Distribution and degrees of freedom for test statistics. * and ** denote that test statistics are significant at the 95% and 99% confidence levels respectively.
3. Elasticities in parentheses are based on parameters which are not significantly different from zero at the 10% error level.

The resulting price and income elasticities are shown at the bottom of the table. For France we find that consumers initially respond in the same proportion to all price changes, but rather weakly, as the short-run elasticity of -0.08 contests. In the long-run, however, the response is far greater, and significantly different for rising and falling prices. On the basis of the long-run price elasticities of -0.80 for price rises and -0.45 for price falls, a bit over 40 per cent of the long-run effect of price increases is irreversible. In Germany it appears that oil demand has been far less sensitive to price changes. Price falls have apparently had no effect on demand in any time perspective. There is, however, a significant response to price rises with an elasticity of about -0.4 in both the short and long run, so that adjustment is extremely rapid. Since demand does not react to falling prices, the entirety of the effect of price rises is irreversible. In the UK, prices appear to have had the smallest effect on demand, with only price rises above the previous maximum producing a considerable response. However, as mentioned above, since real prices only rose above that of 1960 in 1975, and thereafter never above that of 1975, the effect of the P_m variable is to shift the long-run demand curve downwards for the subsequent period. The elasticity estimates for this variable can therefore not be compared with those for the price rise variables for the other two countries.

Regarding the income elasticities, we find that they are greater than unity in the long run for all countries. Demand appears to be most sensitive to income in Germany and least so in France. The initial response is considerably lower, implying that consumers do not fully react immediately to changes in income. In France, there appears to be no significant reaction until the following year.

The dynamic adjustment of demand to price and income changes also differs somewhat among countries. For France and Germany we find median lags of between one and three years for the price and income variables, while 95 per cent of the total response is completed well within ten years. For the UK, adjustment is considerably slower: although the median lags are about the same, it takes around fifteen years to complete 95 per cent of the long-run reaction.

As additional support for the validity of the irreversible models, these are compared with a reversible specification. Beginning with the same general model as before, first all P+ and P_m variables are deleted. The F-statistics for the implied restrictions with F(6,11) are 5.91, 1.98 and 1.29 for France, Germany and the UK, respectively. On this basis, the reversible model can be rejected with 99 per cent confidence for France, but not for Germany or the UK. Continuing the simplification procedure, results in the reversible models presented in Table 2. Even these models fit the data rather well, and there is no evidence of residual autocorrelation. However, the RESET tests cannot reject including $\hat{E}^2$ for France, and the significance of a time trend is indicated for all countries. As discussed earlier, this in itself would lead to irreversibility.

Confirming the F-tests reported above for the deletion of all P+ and P_m variables from the general specification, we see that the restrictions imposed by the final models are only rejected in the case of France. As the final reversible models are nested within the reversible models in Table 2, these could be compared with each other. The F-tests reject the restrictions implied by the reversible models at the 5 per cent level for all three countries. Finally, there is some indication of parameter instability in all of the models. As is shown in the table, parameter constancy is rejected for the 1986-88 period for France and Germany, and a structural break in 1974 is indicated for the UK. On the basis of this instability and the other statistical tests discussed above, the reversible models are clearly inferior to the irreversible specifications in Table 1. The evidence thus strongly favours the hypothesis of an irreversible oil demand function.

Table 2. Oil Demand For Road Transport: Reversible Models. All Models in differenced form, with ΔE as dependent variable. Estimation period 1962-88.

	FRANCE		GERMANY		UK	
k	0.88	(10.53)[1]	0.59	(2.42)	0.57	(6.49)
E(t-1)	-0.23	(2.06)	-0.24	(2.11)	-0.10	(2.07)
Y(t-1)	0.22	(1.50)	0.26	(1.40)	0.07	(0.90)
P(t-1)	-0.22	(5.29)	-0.08	(2.07)	-0.11	(3.66)
ΔY			0.31	(1.29)	0.61	(4.57)
ΔP	-0.17	(3.01)	-0.14	(2.49)	-0.11	(3.66)
ΔE(t-1)					-0.41	(2.79)
ΔY(t-1)					0.93	(4.17)
ΔP(t-1)						
D74	-0.05	(2.28)	-0.07	(2.99)	-0.08	(5.03)

	FRANCE	GERMANY	UK
R^2	0.87	0.82	0.93
DW	2.09	2.14	1.81
σ	0.0147	0.0202	0.0098
RSS	0.00452	0.00815	0.00173
LM	0.18 F(3,18)[2]	0.32 F(3,17)	0.78 F(3,15)
RESET E^2	8.27 F(1,20)**	3.02 F(1,19)	0.77 F(1,17)
RESET t	4.47 F(1,20)*	4.75 F(1,19)*	4.75 F(1,17)*

F-test for parameter restrictions from:

	FRANCE	GERMANY	UK
general model	3.72 F(10,11)*	1.72 F(9,11)	1.20 F(7,11)
irreversible	4.94 F(4,17)**	5.47 F(3.16)**	3.93 F(2,16)*

Tests for parameter constancy:

	FRANCE	GERMANY	UK
Chow 1986-88	3.94 F(3,14)*	3.58 F(3,17)*	1.08 F(3,15)
Shift 74	2.89 F(1,20)	0.40 F(1,19)	5.80 F(1,17)*

Elasticity	sr	lr	sr	lr	sr	lr
Price	-0.17	-0.96	-0.14	-0.33	-0.11	(-0.40)[3]
Income	0	(1.00)	(0.31)	(1.08)	0.61	(0.70)

Notes: 1. t-values.
2. Distribution and degrees of freedom for test statistics. * and ** denote that test statistics are significant at the 95% and 99% confidence levels respectively.
3. Elasticities in parentheses are based on parameters which are not significantly different from zero at the 10% error level.

As a final test of the validity of the irreversible models, predictions for 1989 were compared with actual oil demand. The forecast errors were found to be 0.2, 1.4 and 2.3 per cent for France, Germany and the UK, respectively. For the reversible models the comparable figures are 2.0, 1.7 and 3.0. The irreversible model clearly has better predictive power for all countries, and is particularly good in the case of France.

Finally, by simulating the irreversible models in Table 2, we could determine the combined long-run effects of all price changes since 1974, and thus arrive at a measure of the irreversible demand reduction implied by the estimates. To do this, long-run demand is calculated for the actual price and income development up until 1988 and compared to what it would have been had prices remained at their 1973 levels. For France, the price rises of the seventies have led to the greatest reduction in long-run demand, 26 per cent, but part of this has been (or will be) recaptured by subsequent price falls and particularly by the price collapse of 1986. However, long-run demand is still 14 per cent lower than it would have been had prices never risen, despite the fact that prices by 1988 had already returned to what they were in 1973.

For Germany, although the long-term effects of the price rises have been much smaller than in France, only 15 per cent, since demand does not respond to falling prices, the total reduction is permanent and long-run demand is 15 per cent lower than it would have in the absence of the price increases. Although prices in 1988 were lower than in 1973, the additional decline is irrelevant, since according to the model demand is unresponsive to falling prices.

The estimates for the UK, indicate that the post 1973 price increases have led to a long-run decline in demand of 18 per cent, while the price falls during the period have increased demand by 4 per cent. Although real prices were slightly higher in 1988 than in 1973, the estimates indicate that a return to 1973 prices will only add about 0.4 per cent to this. Long-run demand is thus 13.6 per cent lower than it would have been had prices remained what they were in 1973.

4. CONCLUSIONS

To summarize the results obtained concerning the reversibility of demand for motor fuels, we find that for all three countries, an irreversible model explains the data better than the reversible and is generally preferred on the basis of the statistical tests employed. In all instances, the evidence suggests that the price rises of the seventies have had a permanent dampening effect on demand so that a return to lower prices will not restore the demand relationships prevailing in the early seventies.

Despite the differences in the development of real prices depicted in Figure 1, the models for all three countries agree quite well about the permanent long-term effects of the price increases. The evidence suggests that had not the price rises of the seventies and early eighties occurred, long-run demand would have been 15 per cent higher in Germany, 14 per cent higher in France and 13.6 per cent higher in the UK. The explanation for this in terms of price response, however, differs somewhat for the individual countries. In Germany, price rises are met by a relatively small long-run price elasticity of -0.44, but since demand does not react to price falls, the entirety of the response to price rises is irreversible. The reaction to price increases is far greater in France, with an elasticity of -0.8, but demand also responds with an elasticity of -0.45 to price falls so that only 40 per cent of the long-term effect of the price rises is irreversible. In the UK, the permanent decrease in demand is explained in terms of a structural break in the long-run demand curve stemming from the price shock of the mid-seventies. Since all other price rises/falls have had negligible effects, the demand savings resulting from the initial price shock are nearly totally irreversible.

The time required for demand to respond to the price increases differs also in the three countries. The median lags are one year for France and Germany and three years for the UK, while the time required for complete adjustment (95 per cent) is seven years for France, five years for Germany and fifteen years for the UK. Adjustment to the price increases of the seventies and eighties is thus more or less complete in France and

Germany, but will carry on for another few years in the UK, with about 10 per cent of the total reaction as yet incomplete.

The estimated income elasticities also vary amongst the countries, but in all cases the elasticity is greater than unity. It is lowest in France (1.3), highest in Germany (1.7) and half way between in the UK (1.5). The initial reaction is similar in Germany and the UK, with about 40 per cent of the total response occurring within one year. In France, on the other hand, there is no response at all in the first year, but 40 per cent of the total after two years. Although the intertemporal adjustment pattern differs somewhat for the individual countries, 95 per cent of the total adjustment to income changes is complete in ten years or less in all cases.

Comparing these results for the irreversible models with those implied by reversible specifications also shows some similarities between countries. In all instances, the income elasticity is significantly lower in the reversible specification. For both France and Germany the reversible model results in a long-run elasticity of around 1.0, while that for the UK is 0.7. In all cases, however, the long-run elasticity is rather poorly determined. Regarding the price elasticities, the reversible model for Germany gives a value much greater than that obtained from the irreversible model for price falls and slightly smaller than that obtained for price rises. For the UK the elasticity is greater than that for price falls and rises below the previous maximum, but smaller than that for rises above the previous maximum. For France, the results are totally different - the elasticity obtained from the reversible model is larger than both that for price falls and price rises in the irreversible model.

The results summarized above for the three countries and the similarities and differences amongst them raise some interesting questions concerning the mechanism of the price response and the explanation for the irreversible demand reduction. It would seem that as both the number of vehicles in use as well as distances driven have increased in all countries, the reduction in consumption is primarily explained by improvements in vehicle fuel efficiency - the 14 to 15 per cent irreversible decline captured by the models. Although part of the response to high prices may have been a switch to cars with smaller engine capacity - and thus fuel consumption -

this tendency seems to have been reversed as prices fell, so the permanent effects are probably only marginal. The improvements in fuel efficiency already attained, however, are of a permanent nature, even though low oil prices may curtail any further development in this direction. The costs of research efforts have been paid and with environmental issues currently on the agenda, it would be unfeasible to return to less fuel-efficient engines.

Finally, it is interesting to look at the implications of our results for future oil demand. The relatively large income elasticities indicate that the demand for motor fuels will continue to rise more rapidly than income in all three countries. However, as the model assumes a constant elasticity, any changes in this would not be captured. From the price elasticities, we find that falling prices will result in substantial increases in demand only in France. Price rises, on the other hand would be met with a rapid response in Germany, and a slower, but greater response in France. The relative insensitivity of demand to price changes in the UK indicates that a considerable price rise would be necessary for demand to fall. However, as the results suggest that the decline in demand witnessed following the oil price shocks of the seventies can chiefly be explained by technological improvements, the response to further price increases may not be the same. Limits to fuel efficiency may necessitate changes in behaviour or transportation patterns for demand to react as strongly as before to increasing prices.

REFERENCES

Dargay, J. M. (1990), *Have Low Oil Prices Reversed the Decline in Energy Demand?: A Case Study for the UK*, Oxford Institute for Energy Studies, Working Paper EE9, April.

Hendry, D. (1989), *PC-GIVE: An Interactive Econometric Modelling System*, Institute of Economics and Statistics, Oxford University.

Houck, J. P. (1977), "An approach to specifying and estimating nonreversible functions", *American Journal of Agricultural Economics*, vol. 59, pp. 570-72.

Traill, B., D. Colman and T. Young (1978), "Estimating irreversible supply functions", *American Journal of Agricultural Economics*, vol. 60, August, pp. 528-31.

Wolffram, R. (1971), "Positivistic measures of aggregate supply elasticities: some new approaches - some critical notes", *American Journal of Agricultural Economics*, vol. 53, pp. 356-9.

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