The Elasticity of Demand for Petrol in Ireland

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This brief study attempts to estimate the price elasticity of demand for petrol in Ireland at the present time. The statistic is not without importance. Alcohol, tobacco and petrol are the three main sources of indirect tax revenues in this country. Estimates of the price elasticities of the first two are already available[1,2] so it seems worth making an effort to finish the task. Ignorance of price elasticities probably does little harm if we are prepared to let the price system work unhampered. But when we begin to interfere, to the extent that is normal in the case of such goods, it is wise to have some idea about the likely result of our actions.

There does not seem to be any alternative to the use of time series data. This problem is common to all investigations of price elasticity. It is virtually impossible to find adequate cross-section data and even when they are available they bring their own difficulties, notably the need to introduce the effects of variables which are difficult to quantify.[3]

The Model

Variations in the quantity of petrol over time will be caused by many factors other than price; indeed one would be surprised if price were the dominant influence. Thus it will not be possible to derive an accurate estimate of the price-quantity relationship without taking the other important variables into account. The first question to be decided is whether price and quantity are related in more than one way—that is whether we must use a model containing more than one equation or not.

The conventional model of a market is one in which the seller is trying to maximise profit or some other variable which depends on quantity sold and the buyer is trying to reach the highest level of satisfaction. In such a case price and quantity are linked by two equations (supply and demand) and since there will only be one value of each which will be consistent with the desires of both buyers and sellers then the values of these two variables will be determined within the system. However, this is scarcely a realistic representation of the market for petrol. About three quarters of the market price of petrol is excise duty and most price changes are due to changes in tax. Thus it does not seem reasonable to regard price as anything but a variable which is determined outside the system with little reference, if any, to the profitability of the industry. So changes in price lead to changes in quantity demanded and we can validly construct a single equation model with quantity as a dependent and price as one of a number of independent variables. To put the matter in a slightly more technical way, the supply curve is probably a horizontal straight line—the petrol companies take price as given and sell as much as they can at that price. Shifts in the curve then identify the demand curve.

There is another type of simultaneity which is simply ignored here. No attempt is made to see the demand for petrol as one of a complete set of demand relationships like those proposed by Stone, Houthakker and others.[4] The main reason for this is of course economy of effort, but in any case it is doubtful if one can hope for an accurate estimate of a particular elasticity in such a system. Difficulties of specification and estimation force one to ignore the entire supply side of the matter which must be relevant in a complete system.[5] For what it is worth, the model used here, with relative price, is very similar to a single equation out of the set proposed by Houthakker.[6]

Variables

Petrol does not (normally!) confer utility directly. The demand is a derived one depending on the demand for motor transport. To find the factors which affect the quantity of petrol demanded we must consider everything which might have an important influence on the demand for motor transport. Standard economic theory suggests that we consider the variables which might affect the position or slope of the budget plane and the form of the community indifference map.

Real income in the community would seem to be the first obvious consideration. Since there have been substantial changes in the level of real income and since the evidence suggests that the income elasticity of demand for motor transport is fairly high[7] it is reasonable to expect that income may exert a stronger influence than any other variable. The price of motor transport must be expected to have an effect on the demand. This price will be affected by the prices of vehicles and ancilliary items like tax, insurance and repairs and also by the price of fuel. Vehicle prices, tax and insurance are fixed costs in the sense that they do not vary with the use made of the vehicle. They must affect the decision to buy a vehicle and not interfere with the use made of it, so their influence will be allowed for if the stock of vehicles is included in the regression. Another reason for including this variable is given below. The cost of repairs is ignored because of practical difficulties of measurement. The price of fuel will affect both the number of vehicles bought and the use made of them. The elasticities presented below measure the response to a price change with the vehicle stock held constant and thus are, if anything, an understatement of the true situation. This point will be referred to again.

It is also possible that changes in technical efficiency could affect the price of motor transport. If a vehicle can be induced to go further on a gallon of petrol then each ton-mile or seat-mile costs less. I believe that this influence has not been sufficiently strong in the period to be worth including.

There is some doubt as to which form of the price-variable is the most meaningful. If people are completely free of the money illusion then a uniform rise in all prices and income would leave their consumption-pattern unchanged. In such a case people would respond to relative price and some measure of this variable could be used unhesitatingly. However, there is no guarantee that people do, in fact, see through the "veil of money", especially in the case of petrol where the price changes receive a great deal of publicity. As evidence of this, most people believe that petrol has risen faster than the general level of prices in the last few years, but the variable P_r in Table 9 shows that the reverse is the case. For this reason all the regressions were calculated in pairs using both P_a (actual price) and P_r (relative price $= P_a \div$ Consumer Price Index).

The prices of other goods which have some special relationship with the commodity in question may have a significant influence. In the present case the list is not long but it would seem that motor transport and public transport fill approximately the same need so that some index of the price of public transport would seem to be worth including. Since actual prices because of their strong time trend caused serious problems of multicollinearity an index of relative price of public transport was used. The Consumer Price Index and the price of petrol were both used as deflators, the latter giving slightly better results.

Finally there are three factors which may affect the taste of the community for motor transport. The first is advertising. However it appears that advertising of both cars and petrol is of the competitive type and is aimed rather at changing market shares than at expanding the total market. If this is true then advertising is not important for the problem in hand. The second consideration is the stock of cars. This stock is not something that can change quickly. The level that exists at any moment is probably mainly determined by incomes of a large number of past periods. A community with a big stock of cars will probably demand a greater amount of motor transport at a given income level than a community with a small stock would. For this reason, in addition to the one mentioned above, it would appear necessary to include the stock of vehicles as a variable.

The final factor is the change from petrol to diesel as a fuel for commercial vehicles. It is reasonable to say that throughout the sample period virtually all private vehicles were petrol-driven. In the early 1950s there were many petrol-driven commercial vehicles but by 1969 virtually all used diesel fuel. So this change must have affected the demand for petrol. A study of the sample shows that from 1962 onward the ratio of diesel to petrol remained very stable at about ·25 to 1, so it may be calculated that the change to diesel for commercial use was more or less completed by that date. It is, however, necessary to introduce some sort of a correction for this process in the first half of the sample.

This correction may be achieved fairly simply in the following way. Define Q_c and Q_p as commercially—and privately—used petrol respectively. Q as $(Q_c + Q_p)$, Q_d as diesel used (all commercial) and R as a constant representing the amount of petrol for which one gallon of diesel can be substituted in normal road-haulage. Of these, Q and Q_d are the only variables that can be observed.

Assume that throughout the sample period the commercial demand for fuel is such that if it were all satisfied by diesel it would constitute ·25 times the private demand for petrol. This would be consistent with private and commercial demands both maintaining the same relationship with income.

Then Commercial fuel = ·25 x Private fuel

$$Q_d + \frac{1}{R}Q_c = \cdot 25\, Q_p$$

$$Q_d + \frac{1}{R}Q_c + \cdot 25 Q_c = \cdot 25 Q_p + \cdot 25 Q_c = \cdot 25 Q$$

$$Q_c\left(\frac{1}{R} + \cdot 25\right) = \cdot 25 Q - Q_d$$

$$Q_c = \frac{1}{\frac{1}{R} + \cdot 25}(\cdot 25 Q - Q_d) = R'(\cdot 25 Q - Q_d)$$

which expresses the unobserved Q_c as a function of R and the observed P and Q_d included. This may then be as an additive element in the demand equation thus

$$\begin{aligned} \text{Total petrol demand} &= \text{Private demand} + \text{Commercial Demand} \\ &= Q_p + Q_c \\ &= Q_p + R'(\cdot 25 Q - Q_d) \\ &= Q_p + R'D \text{ (say)} \end{aligned}$$

In short the variables deemed likely to affect the quantity of petrol demanded are income, price, the stock of private vehicles, the price of public transport and the "dieselisation factor".

Data

The following symbols are used from this point onward:

- Q : Quantity of petrol sold for road use
- Y : G.N.P. at constant (1958) prices
- P_a : Index of the actual price of petrol
- P_r : Index of the relative price of petrol: $P_a \div$ Consumer Price Index
- C : Number of cars registered in August of the year in question
- Q_d : Quantity of diesel sold for road use
- D : Dieselisation factor explained above; $(\cdot 25Q - Q_d)$
- P_t : Relative price of public transport: Price index $\div$ price of petrol
- d_1, d_2 ——, b_1, b_2 ——, k : constraints to be estimated
- u : Disturbance term

The series used and their sources are set out in Table 9; they are all annual data.

Mathematical Form

The form of the relationship between price and quantity is worth some thought. It is generally true that if one calculates a linear and a non-linear relationship the estimates of price elasticity at the means of the variables do not differ greatly. However policy decisions are rarely made at the means but more usually at extreme values of the variables and in such cases the two types of relationship may have very different implications.

Thus it seems wise not to exclude the possibility of non-linearities in the relationship. There are, of course, many types of non-linear function which could be used, but as long as the possibility of curvature is allowed for, the precise form of the function will scarcely affect the matter very much. It is probably unrealistic to expect the data to be sufficiently rich to show that, say, a log-linear form is more satisfactory than a quadratic.

On the whole, the log-linear form

$$\log Q = \log b_0 + b_1 \log Y + b_2 \log P + \text{——} \text{ or } Q = b_0 Y^{b_1} P^{b_2} \text{——}$$

has many advantages, not the least of which is ease of computation. Since the b's are free to take on values equal to less than or greater than unity the relationship between Q and the independent variables can be proportional, less than proportional or more than proportional. Thus there is a great deal of flexibility and the various independent variables may show themselves to be related to the dependent in different ways. Finally in the present case since the function may be written

$$\frac{Q}{Y^{b_1}} = b_0 P^{b_2}$$

it implies that basically the quantity is proportional to some power of income, the proportionality being modified by changes in price and the other variables. This appears to be a more reasonable approach than to assume, as one does in the case of a linear function, that the quantity demanded is composed of a number of independent parts one of which is determined by income, another by price and so on. The results of the linear regressions (Tables 7, 8) indicate that this belief is not altogether naive.

One minor fault of the log-linear function is that (if all the b's are positive) it is constrained through the origin. There does not appear to be any reason why this need be realistic so some improvement may be expected if the restriction is removed. To do this one sees the relationship as $Q = k + b_0 Y^{b_1} P^{b_2}$——. Estimation is most easily done by using the form $\log (Q-k) = \log b_0 + b_1 \log Y + b_2 \log P +$ ——, giving k a series of values and choosing the most satisfactory result. Since the object of the exercise is to find the best fit in the Q.P plane the t- value of the coefficient of P seems to be the most sensible criterion; however as one would expect, there is a close correspondence between the behaviour of this statistic and that of the other t- values and the overall goodness-of-fit.

In summary, then, the functional form

$$\log (Q-k) = \log b_0 + b_1 \log Y + b_2 \log P + b_3 \log C + b_4 \log D + b_5 \log P_t + \log u$$

Two series of regressions were calculated; one using $P = P_a$ (actual price) and one using $P=P_r$ (relative price), each being tried in combination with a series of values for k ranging from -70 to $+100$. The criterion for selecting the best outcome in each case is the t-value of b_2. Strictly speaking D should appear as an additive element in a linear rather than a log-linear regression. Its use here represents an approximation.

The Results

The basic results are presented in Tables 1 and 2 below which are, I hope, self-explanatory. The figures in brackets are t- values of the coefficients. Using the t- value of the coefficient of P as the criterion the most acceptable regression is that using (Q−60) in the case of P_a and (Q−35) in the case of P_r. The t-values reach a peak in these cases and decline continuously on either side. The other statistics (the t- values of Y, C, D and P_t and the multiple correlation coefficient) tend to confirm this conclusion.

In an equation of this type the elasticity is not given precisely by the regression coefficient. Defining price elasticity of demand as $\frac{P \, . \, dQ}{Q \quad dP}$ it is easily shown that it can be reduced to $b_2\left(1-\frac{k}{Q}\right)$ using the definitions of k and b_2 in the equation above. In the present case the elasticity will be less than b_2 (−1·1146 for P_a and −·9854 for P_r at the 1969 value of Q. The Durbin-Watson statistic is 2·37 for the P_a equation and 2·31 for the P_r equation, both of which indicate absence of autocorrelation with 95 per cent probability.

The following conclusions are suggested by the results

(*a*) (Q−k) as a dependent variable and gives better results than Q.

(*b*) The absolute value of the price elasticity of demand for petrol is not appreciably below unity.

(*c*) The elasticity with respect to absolute price is not very much different from the elasticity with respect to relative price,

(*d*) Absolute price is as "good" an explanatory variable as relative price. There is no appreciable difference in their t-values or in the contribution which they make to overall goodness of fit,

(*e*) The coefficient of P_t (relative price of public transport) has a negative sign. This would imply that public transport is complementary to the demand for petrol. I can think of no reason why this should be so. The variable ($P_{ta}^c \div CPI$) also has a negative coefficient as also has the actual price in some cases.

Points (*b*) and (*c*) require some further investigation. There is of course no reason why they should not be valid—for example both measures of price might be equally unsatisfactory approximations to the true variable to which consumers respond. However there is a peculiarity in the sample which suggests a reason for these results. There were two years (1957, 1960) in which exceptionally big changes in price took place. These are very much greater than all the other changes and so must be dominant in the regression. Further, since the changes in P_a and P_r in these years were very much the same it is inevitable that their regression coefficients should be similar.

It is worth removing the influence of these two changes. This is done by using only the ten observations from 1960 to 1969. The variable D is dropped from the regression because it has been virtually reduced to zero by 1960. The results shown in Tables 3 and 4, are reasonable. The elasticity with regard to P_a is very much lower than with regard to P_r.

The coefficients of P_a and P_r seem to be fairly stable. As long as the variable C is retained, the dropping of the other two makes very little difference (Tables 5, 6). If C is dropped the confidence intervals become very wide. Finally, in Tables 7 and 8, the results of simple linear regressions are shown. The logarithmic form is vastly superior.

It is worth recalling that the elasticities measured here represent the effect of price changes with stocks of vehicles held constant. Since an increase in the price of petrol may be expected to reduce the stock of vehicles the total elasticity when this effect is allowed for is likely to be greater.

Conclusion

The main conclusion suggested by the evidence is that the price elasticity of demand at the present time (and particularly the elasticity with regard to relative price) can scarcely be much less than unity. This relatively big elasticity may well be due to the abnormal publicity which is given to changes in petrol prices—changes which are proportionally rather small. It would seem that it is quite useless to raise the rate of tax on petrol if the purpose is to gather more revenue, for the resulting decrease in quantity will be at least big enough to prevent income from rising. It is true, of course, that in the past increases in tax have been accompanied by increases in revenue, but these increases have been caused by changes in other factors, notably by increases in income. Revenue would have been about the same—possibly even higher—if the tax rate were not changed.

If it were desired to decrease the quantity of petrol used, higher tax rates would be quite effective; but such a policy has never been announced and it seems unlikely to have been contemplated. In the circumstances, the industry can validly claim that it is being treated rather badly. On the assumption that the elasticity is about unity, higher rates of duty bring no benefit to the exchequer but they do reduce the quantity of petrol sold. So, if the profit per unit is roughly constant, the industry must be worse off. In logic, when tax rates are raised the industry ought to be allowed to raise its margins by an equal proportion so as to maintain its position. Or are we simply trying to improve the environment by discouraging oil companies?

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TABLES

Tables 1—6 present the coefficients in regressions of the form:

$$\log (Q-k)=\log (b_0+b_1, \log Y+b_2 \log P+b_3 \log C+b_4 \log D+b_5 \log P_T$$

TABLE 1: (Price = P_A)

(Q−k)	Constant	Y	P	C	D	P_T	R
		2·6329	−3·3679	3·5137	·0634	−1·7912	
Q−70	−3·1485	(2·25)	(−4·74)	(5·74)	(0·65)	(−2·17)	·9955
		2·6805	−2·2622	2·3852	·0605	−1·0687	
Q−65	−4·6537	(4·98)	(−6·96)	(8·49)	(1·35)	(−2·82)	·9986
		2·5415	−1·6913	1·8308	·0649	−·7011	
*Q−60	−4·8690	(6·88)	(−7·57)	(9·48)	(2·11)	(−2·69)	·9991
		2·3878	−1·3351	1·4892	·0683	−·4810	
Q−55	−4·7898	(7·06)	(−6·53)	(8·43)	(2·43)	(2·02)	
		2·2407	−1·0900	1·2546	·0700	−·3348	
Q−50	−4·5984	(6·67)	(−5·37)	(7·15)	(2·51)	(−1·42)	·9988
		1·3749	−·3018	·4587	·0591	·0617	
Q	−2·4643	(4·96)	(−1·80)	(3·17)	(2·56)	(·32)	·9969

TABLE 2: (Price = P_R)

(Q−k)	Constant	Y	P	C	D	P_T	R
		2·3199	−2·0249	1·0361	−·0214	−·8804	
(Q−60)	−1·4991	(3·77)	(−3·69)	(4·01)	(−0·46)	(−1·58)	·9974
(Q−55)							
		2·2330	−1·6264	0·7559	·0162	−·7497	
(Q−50)	−1·5877	(6·85)	(−5·59)	(5·52)	(·65)	(−2·55)	·9988
		2·1497	−1·4743	·6700	·0261	−·6863	
(Q−45)	−1·5495	(7·99)	(−6·14)	(5·93)	(1·28)	(−2·82)	·9990
		2·0662	−1·3465	·6013	·0330	−·6307	
(Q−40)	−1·4885	(8·73)	(−6·37)	(6·05)	(1·83)	(−2·95)	·9991
		1·9801	−1·2373	·5470	·0376	−·5800	
*(Q−35)	−1·4086	(9·12)	(−6·38)	(5·99)	(2·28)	(−2·96)	·99914
		1·8988	−1·1418	·5016	·0409	−·5343	
(Q−30)	−1·3268	(9·23)	(6·22)	(5·81)	(2·62)	(−2·88)	·99911
		1·5077	−·7717	·3341	·0459	−·3523	
Q	−·7924	(8·58)	(−4·92)	(4·53)	(3·44)	(−2·22)	·9987

TABLE 3: (Price = P_A)

(Q–k)	Constant	Y	P	C	D	P_T	R
		1·6407	−1·3382	2·4465	—	−·4279	
(Q–70)	−5·1668	(1·65)	(−2·10)	(8·57)		(−·75)	·9988

TABLE 4: (Price = P_R)

(Q–k)	Constant	Y	P	C	D	P_T	R
		1·6070	−2·4221	1·8770	—	−1·1003	
(Q–70)	−0·2974	(1·67)	(−2·18)	(5·47)		(−1·60)	·9989

TABLE 5: (Price = P_A)

(Q–k)	Constant	Y	P	C	D	P_T	R
		2·0003	−1·1761	1·5457			
(Q–60)	−5·1420	(5·80)	(−8·62)	(8·50)			·9984
		4·2780	−·5804		−·1093		
(Q–60)	−9·3322	(10·68)	(−2·26)		(−1·76)		·9913
		4·8648	−·4702			−·1839	
(Q–60)	−10·9302	(5·50)	(−0·85)			(−0·27)	·9893

TABLE 6: (Price = P_R)

(Q–k)	Constant	Y	P	C	D	P_T	R
		1·7078	−·8037	·5445			
(Q–40)	−2·6880	(6·88)	(−7·88)	(5·10)			·9983
		2·7460	−·5996		−·0363		
(Q–40)	−4·8037	(14·33)	(−·364)		(−1·16)		·9954
		3·3220	−1·2389			−·7748	
(Q–40)	−3·6122	(15·52)	(−3·01)			(−1·91)	·9960

(Tables 7 and 8 show the coefficients obtained in regression of the form:
$Q = b_0 + by_1 + b_2 P + b_3 C + b_4 D + b_5 P_T$).

TABLE 7: (Price = P_A)

Constant	Y	P_A	C	D	P_T	R
−76·18	·1597	−·0030	·2487	2·0165	·0500	·9985
	(4·71)	(−·03)	(4·63)	(5·36)	(·33)	

TABLE 8: (Price = P_R)

Constant	Y	P_R	C	D	P_T	R
−41·54	·1810	−·2238	·2280	1·8078	−·1487	·9988
	(5·73)	(−1·63)	(4·87)	(4·99)	(−·95)	

TABLE 9: *Data*

YR	*Q*	*Y*	*PA*	*CPI*	*PR*	*C*	*QD*	*D*	*PTA*	*PT*
1953	75·7	598	100·0	100·0	100	109	6·6	11·6	100·0	100·0
1954	79·5	604	100·0	100·1	99·9	118	7·0	12·2	100·0	100·0
1955	83·7	616	100·0	102·7	97·4	128	8·0	12·1	102·0	102·0
1956	81·7	608	101·3	107·1	94·6	136	9·1	12·1	114·0	112·5
1957	76·4	612	133·6	111·5	119·8	135	10·9	9·3	114·0	85·3
1958	77·5	601	134·2	116·5	115·2	143	11·0	7·8	117·8	87·8
1959	81·4	627	134·9	116·5	115·8	154	13·1	6·5	119·3	88·4
1960	84·0	659	153·3	117·0	131·0	170	15·3	5·3	129·5	84·5
1961	90·6	692	155·3	120·2	129·2	186	17·6	3·5	129·5	83·4
1962	95·3	714	158·6	125·3	126·6	207	21·9	1·3	143·3	90·4
1963	104·2	744	159·2	128·4	124·0	229	24·5	0	143·3	90·0
1964	113·7	771	165·7	137·0	120·9	225	—	0	156·4	94·4
1965	124·3	793	174·3	143·9	121·1	281	—	0	160·6	92·1
1966	131·4	804	183·5	148·2	123·8	296	—	0	170·1	92·7
1967	140·6	848	187·5	152·9	122·6	314	—	0	179·6	95·8
1968	155·9	915	194·7	160·1	121·6	337	—	0	199·6	102·5
1969	171·9	953	201·3	172·0	117·0	354	—	0	227·4	113·0

Information and Sources:

- Q : Quantity of petrol sold. Unit 1 million gallons. *Source:* Reports of Revenue Commissioners 1953–1969.
- Y : Gross National Product at constant (1958) prices. Unit £1 million. *Source:* National Income and Expenditure 1969 (C.S.O.), Tables A_4 and B_6.
- P_A : Index of the National average price of petrol. Supplied by the C.S.O.

CPI : Consumer Price Index. *Source:* Statistical Abstracts 1953–1969, Section XII, Reworked to base 1953.
P_R : Index of relative price of petrol. $P_A \div C.P.I.$
C : Number of private cars registered in August of each year. Unit one thousand. *Source:* Statistical Abstracts, 1953–1969. Section XI.
QD : Quantity of diesel sold for road use. Unit 1 million gallons. *Source:* Reports of Revenue Commissioners 1953–69.
D : Artificial variable ($\cdot 25Q - QD$).
PTA : Index of the price of public transport, from figures supplied by the C.S.O.
PT : Relative price of public transport. $PTA \div P_A$.

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