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ENVIRONMENTAL INFORMATION AND THE DEMAND FOR SUPER UNLEADED PETROL IN THE UNITED KINGDOM

Roger Fouquet

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Department of Economics
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Enquiries:

Director of SEEC and Editor of SEEDS: David Hawdon
email: D.Hawdon@surrey.ac.uk

Secretary: Isobel Hildyard *email: I.Hildyard@surrey.ac.uk*

SEEC, Economics Dept, University of Surrey, Guildford GU2 5XH, UK.
Telephone: +44 (0)1483 259379 Fax: +44 (0)1483 303775

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ABSTRACT

This paper tests and supports the hypothesis that information provided by the media about the environmental effects of benzene had a significant impact on the demand for super unleaded petrol in the United Kingdom between 1991 and 1995, explaining in part the large drop in demand at the end of 1994. The study uses a data set, including two specially created series measuring the provision of information about lead and benzene, and the cointegration approach to estimate the relationship between demand and its potential determinants. It finds that the additional provision of information about benzene significantly reduces the demand for super unleaded. Although of an exploratory and speculative nature, the study suggests that consumers do not always free-ride from taking account of negative externalities associated with their actions and that policy-makers might use the provison of information as a complement to or substitute for other policies internalising negative externalities.

KEYWORDS:

Super unleaded petrol, Energy demand, Information, Environmental policy

ENVIRONMENTAL INFORMATION AND THE DEMAND FOR SUPER UNLEADED PETROL IN THE UNITED KINGDOM[1]

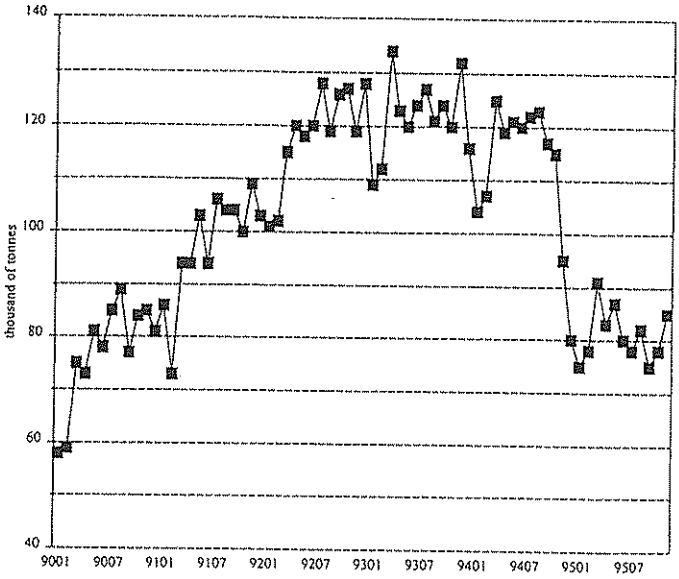
1. INTRODUCTION

The recent dramatic drop in super unleaded fuel consumption in the United Kingdom (see Figure 1) has been attributed to 'adverse publicity' (Semple 1995) about its high levels of benzene which is associated with child leukaemia (Department of the Environment 1994). If consumption did decline as a result of adverse publicity, it indicates the potential for policy-makers to use the provision of environmental information as a means of influencing behaviour and as a substitute or complement to other policies encouraging individuals to internalise negative externalities (Kennedy et al 1995)

This paper tests whether information about the environmental risks from super unleaded fuel combustion had a significant impact on the fuel's consumption in the United Kingdom and discusses policy implications related to environmental information. The paper models individual demand for super unleaded petrol as part of a decision making process in a household production function (Eltony 1993) and estimates the relationships between individual demand and its determinants using the cointegration approach (Dargay 1992, Bentzen 1994, Eltony and Al-Mutari 1995). It extends earlier work by taking explicit account of drivers' beliefs about environmental risks through the creation of data sets on the provision of lead and benzene information. The next section discusses the evidence on the relationship between information provision and consumer behaviour when opportunities to free-ride exist.

[1] This paper is based on Chapter V of my Ph.D. thesis, 'Information for Energy-Related Environmental Policy: The Role of Disaggregated Dynamic Energy Demand Modelling', University of Surrey, Guildford 1997

Figure 1. Demand for UK Super Unleaded Petrol 1990-1995



Source: Data acquired directly from the Division of Statistics, Department of Trade and Industry

The following three sections present the model designed to assess the impact, the data used and the method of estimation. The sixth section reviews the results. The final section discusses policy implications of the results.

2. INFORMATION, CONSUMER BEHAVIOUR AND FREE-RIDERS

Externalities associated with transportation are becoming an increasing concern for policy-makers (Royal Commission on the Environment 1994, Newbery 1995, Johansen et al 1995). Uncertainty about transport users' impact on the environment - as a result of the complex and gradual nature of this impact - might be a partial explanation for negligent behaviour. It has been proposed, therefore, that better provision of environmental information and education would encourage the public to act in a less environmentally damaging manner (Pearce et al 1989).

For information to influence behaviour, three factors must occur: first, information must change drivers' beliefs about the attributes of the petrol and, in particular, the benzene content and its damaging effects on the environment and health; second, drivers must be willing to pay to reduce these environmental and health attributes of goods; and, third, drivers must decline to free-ride when the opportunity to do so exists. In the past, economists have suggested that, even under improved or full information and with a willingness to pay for less damage to the environment, individuals would not have a propensity to take full account of their actions upon the environment because they are presented with incentives to free-ride (Buchanan 1968).

The literature on advertising indicates that information does alter individual beliefs (see, for example, Chern et al 1995). Evidence from experiments and hedonic pricing methods suggests that individuals are willing to pay for some environmental improvements (eg Cummings et al 1986 or Cropper

and Oates 1992). Research using contingent valuation methods to examine changes in willingness to pay for environmental attributes as a result of additional information (Bergstrom et al 1989, Whitehead and Blomquist 1991, Hanley and Spash 1993, Ajzen and Brown 1996) implicitly looks at both how information alters beliefs and how new beliefs increases willingness to pay. Most of these studies indicate that information does, under certain circumstances, change willingness to pay values for environmental services.

There is considerable evidence to show that there is an association between information and behaviour. For example, Berndt et al (1995), Chern et al (1995) and Hu et al (1995) and (Burton and Young 1996) demonstrate significant effects of advertising in the media on health beliefs and consumer behaviour.

What differentiates consumer decisions in the context of information about health risks, say, and information about environmental risks is the impact of an individual's influence on the level of risk. An individual can, in certain circumstances, alter her behaviour to reduce health risk; and, therefore, the personal benefits to risk reduction are considerable. The effect of one individual's actions upon the environment, however, will usually be negligible; it requires action from numerous individuals to reduce environmental risk. As a result, the private costs of altering behaviour are, therefore, likely to outweigh the negligible private benefits of acting in an environmentally friendly manner; thus, the individual will free-ride.

Research into the free-rider problem has found that even when opportunities to do so exist, individuals do not always free-ride and suggests that

this may be the result of a combination of confusion, such as not being aware of available opportunities, and altruism on the part of individuals (Andreoni 1995). It has been claimed that there are cases where new information about the environmental impact of goods, services and other activities has been considered the cause of changes in consumption patterns, such as the responsiveness of British drivers to requests to avoid using cars on days of very poor air quality (Department of the Environment 1994). The only empirical research I have found on the influence of environmental information on behaviour is related to the sensitivity of US stock prices to news about firms' toxic releases (Hamilton 1995). There appear to be few if any studies examining the influence of environmental information on consumer behaviour. The model described below sets out to investigate the responsiveness of UK drivers to environmental information about super unleaded petrol.

3. MODEL OF THE DEMAND FOR SUPER UNLEADED PETROL

Aggregate Demand

Aggregate Demand for a road fuel, such as super unleaded petrol (ADSUL), can be represented by the identity average fuel consumption per vehicle (DSUL) multiplied by the vehicle stock that uses the fuel (S); that is

(1) $ADSUL = DSUL \cdot S.$

Individual Utility Maximisation

The individual demand for super unleaded petrol can be seen as part of a household production process where members of the household combine technology and goods to generate utility. As Lancaster (1966) suggested, utility

is a consequence of the bundles of attributes or characteristics present within goods consumed. In the case of a driver contemplating using super unleaded fuel, the attributes that form the goods and, thus, determine utility include the power to move the car, M, possibly the environmental impact of combusting lead, L, and benzene, B, and all other attributes, Z; ie,

$$(2) \quad U = u(M, L, B, Z).$$

Naturally, maximisation of the driver's utility is constrained by limited money, time and information. The driver, therefore, is assumed to be trying to maximise this utility function by searching for and selecting the best alternative out of a feasible set of alternatives available to her. She will select in accordance with her beliefs about the level of attributes contained within each available good.

Beliefs and Information

To form beliefs and reduce uncertainty about attribute-content of goods individuals seek and acquire relevant information. The belief about the moving-power of the fuel can be considered an experience attribute (that is, information about the attribute can be acquired through the experience of consumption (Andrews 1991)). In this case, the experience-information is likely to lead to a rapid and confident appraisal of the attribute. It is assumed, therefore, that information necessary to form beliefs about the moving-power of the fuel is acquired on the first experience and remains constant afterwards. Because of the stability of beliefs about the moving-power of fuels, they are not explicitly modelled here.

Because of the technical nature of petroleum products and the complex and long term nature of lead and benzene's impact on the environment, however, beliefs about the lead and benzene content in super unleaded fuel and their effects on the environment must be based on information from external sources rather than from experience. Beliefs about lead and benzene attributes in the fuels are likely to vary with the provision of information from these external sources. It is, therefore, important to take account of the flows of information when analysing the demand for super unleaded petrol.

The literature on advertising has generally modelled beliefs as dependent not just on present flows of information but also on the cumulation of past flows (for example, Baltagi and Levin 1986). It appears more appropriate to model the relationship between beliefs about lead and benzene and related information, therefore, in terms of the stock (or sum of past acquisitions) of information, although the influence of past information depreciates with time. Following Hu et al (1995), this can be represented as

$$(3) \qquad \phi_{Lt} = \Sigma_{t=1toT}((1 - d_L)^{T-t} . I_{Lt})$$

$$(4) \qquad \phi_{Bt} = \Sigma_{t=1toT}((1 - d_B)^{T-t} . I_{Bt})$$

where ϕ_{Lt} and ϕ_{Bt} are the driver's beliefs about the lead and benzene content in the available petroleum products and their effects on the environment; I_{Lt} and I_{Bt} are the flows of information in period t about the petrol's content and environmental effects of lead and benzene; and d_L and d_B are rates at which the effects of information on an individual's beliefs depreciates - after experimenting with decay rates of information stock, a constant value of 1 percent per month

was chosen, compared with a rate of 5 percent per quarter proposed by McGuiness and Cowling (1975); and T is present time period.

Individual Demand for Super Unleaded Fuel

The solution developed in Chern et al (1995) to the utility maximisation problem incorporating consumer beliefs indicates that demand depends on budget level, relative prices and beliefs about the product's attributes. In the case of the demand for super unleaded,

$$(5) \quad DSUL = f(Y, RPMS, RPUL, RPSUL, \phi_L, \phi_B),$$

where DSUL is individual demand, Y is the budget level, RPMS is the real price of motor spirits, RPUL is a weighted average price of unleaded petrols relative to a weighted average price of all motor spirits, and RPSUL is the price of super unleaded relative to a weighted average price of unleaded petrols; the three relative price variables reflect a three stage decision process in which the driver assesses, first, the average cost of driving per kilometre, second, the relative cost of using any unleaded petrol and, third, the cost of using super unleaded relative to any unleaded petrol.

The log-linear dynamic relationship between demand and its determinants can be represented as

(6) $\ln DSUL_t =$

$$a\alpha_0 + \alpha_{10} \cdot \ln Y_t + \alpha_{11} \cdot \ln Y_{t-1} + ... + \alpha_{1n} \cdot \ln Y_{t-n}$$
$$+ \alpha_{20} \cdot \ln RPMS_t + \alpha_{21} \cdot \ln RPMS_{t-1} + ... + \alpha_{2n} \cdot \ln RPMS_{t-n}$$
$$+ \alpha_{30} \cdot \ln RPUL_t + \alpha_{31} \cdot \ln RPUL_{t-1} + ... + \alpha_{3n} \cdot \ln RPUL_{t-n}$$
$$+ \alpha_{40} \cdot \ln RPSUL_t + \alpha_{41} \cdot \ln RPSUL_{t-1} + ... + \alpha_{4n} \cdot \ln RPSUL_{t-n}$$
$$+ \alpha_{50} \cdot \ln\phi_{Lt} + \alpha_{51} \cdot \ln\phi_{Lt-1} + ... + \alpha_{5n} \cdot \ln\phi_{Lt-n}$$
$$+ \alpha_{60} \cdot \ln\phi_{Bt} + \alpha_{61} \cdot \ln\phi_{Bt-1} + ... + \alpha_{1n} \cdot \ln\phi_{Bt-n}$$
$$+ u_t$$

By combining this general model with relevant statistics, we can examine how drivers in the past have made choices about fuel use as the underlying parameters of the optimisation problem change and, therefore, identify the behavioural relationships between the drivers' demand for super unleaded fuel, their allocated budget to transport energy services, the relative fuel prices they face and their beliefs about environmental effects of fuel use.

4. DATA

The introduction of super unleaded fuel to the UK road fuel market in 1988 means that annual time series analysis is limited. Because, however, much of the relevant data is recorded on a monthly basis, this study has managed to gather a complete set and will be examining evidence for the period between January 1991 and November 1995, which should provide sufficient observations to undertake a first statistical analysis of consumption patterns.

Individual Demand for Super Unleaded Petrol

The main source of monthly statistics on motor spirits, Energy Trends (Department of Trade and Industry (DTI) 1996), does not split unleaded into premium and super types. To acquire data on super unleaded petrol, it was necessary to obtain the data directly from the DTI's statistics division. Monthly figures on super unleaded fuel were provided for the period January 1990 to November 1995, measured in thousands of tonnes.

From 1988 to the end of 1995, the share of unleaded petrols in the motor spirit market in the United Kingdom rose from zero to 60 percent. From 1988 up to 1992, consumption of super unleaded petrol kept growing both in absolute terms and as a share of the market for unleaded petrols (Figure 1). Its share stabilised in 1992 and then declined thereafter, falling from ten percent to under eight percent in November 1994. In absolute terms, consumption fell by more than one third from 120 thousand tonnes to 75 thousand tonnes in the final three months of 1994, and remained relatively stable ever since.

To create an individual demand series per vehicle, the aggregate quantity must be divided by the number of cars in the United Kingdom that can use unleaded petrol. The Great Britain Transport Statistics (Department of Transport 1995) provides annual figures for the total number of vehicles and the percentage of British cars that can use unleaded fuel, based on a Lex survey on motoring. Although this method of analysing individual car rates has been proposed by many undertaking transport studies (see, for example, Dargay 1992), because of the existence of only annual statistics on the number of cars, such a variable risks creating serial correlation. Nevertheless, this is an inevitable risk when following this method under these circumstances. No statistics appear to exist on the

percentage of high performance cars that could use unleaded petrol but could not use standard or premium unleaded. The Department of Transport was contacted directly so as to acquire more frequent statistics; quarterly data were available back to 1993, not before. As a result, both annual observations were interpolated to produce monthly figures. The two series were multiplied together to calculate the vehicle stock able to use unleaded petrol. Aggregate demand was divided by this new series to create an average individual demand for super unleaded petrol.

The total vehicle stock rose by 12.2 percent between 1988 and the third quarter of 1995, to 20.7 million cars. Over the same period, the percentage of cars able to use unleaded rose from 14 to 62. The rapidly growing unleaded vehicle stock moderates the initial growth in individual demand for super unleaded petrol at the beginning of the 1990s and accentuates the drop at the end of 1994.

Budget Level

UK personal disposable income data are not available on a monthly basis. The Central Statistical Office (CSO) does, however, record a monthly measure of retail sales, excluding motor vehicles sales as a durable good. Since no statistical publication provided monthly information on budget levels, the CSO was contacted directly to obtain estimates. Its staff proposed an index of retail sales for the period between January 1987 and January 1996. Although it does not cover services, including holidays which are relevant for motor car use, this time series does work as a proxy for variations in households' budgetary allowances and a reasonable determinant of vehicle fuel demand. As a measure of household budgets, the index varies considerably throughout the months with a jump every December. It also exhibits a rising trend.

Relative Prices

To create the series for the three relative price variables, statistics on super unleaded, premium unleaded and four star prices in pence per litre can be compiled from back issues of Energy Trends (DTI 1996). The DTI did not gather information on super unleaded prices before January 1991; this date, therefore, creates the earliest point at which super unleaded fuel consumption can be examined. Monthly figures for the retail price index can be found in Economic Trends (CSO).

Information about Lead and Benzene

Despite growing research into information supply and demand, statistical evidence on information provision is limited. This is mainly due to the difficulties of trying to measure such a heterogeneous and intangible commodity as information. In past research, a series of indicators have been used. Some developed out of the literature on advertising, such as the expenditure on it in the media (Hu et al 1995), its size and positioning in newspapers, magazines or specialised journals (Berndt et al 1995), and the variation in regulation on types of advertising between regions (Benham 1972). An alternative approach, especially practical with the emergence of CD-ROMs, is to use indices to count the frequency with which particular subjects appear in the news (van Ravenswaay and Hoehn 1991) or in specialised journals (Brown and Schrader 1990).

The problem is particularly relevant to information on the environment. To compile statistical evidence, it was necessary to create a set specifically for the study. Following the approach developed in van Ravenswaay and Hoehn (1991),

the British Newspapers Index on CD-ROM (1995) was used to search for articles mentioning 'super unleaded' and relating to its hazardous effect in British broadsheet newspapers for the period between January 1990 and December 1995. This approach was complemented by a manual index search in the Environmental Digest (1991-1995), a monthly review of articles in the press about environmental issues. Limited to just a part of the written media, the study assumes a close correlation between different types of media; naturally, there may be some bias in information provided between television, radio, broadsheet and tabloid newspapers, and magazines which is likely to skew population beliefs and responses, if they occur.

In 1993, a study, building on previous epidemiological research (see for example Ashmore and Loth 1994 for details), suggested a link between unleaded petrol and non-lymphocytic leukaemia (Department of the Environment 1994). Aromatic hydrocarbons and olefines are used instead of lead as a means of raising unleaded fuel's octane level. In the case of super unleaded petrol, more of these compounds are added to the fuel in order to raise the octane level and, therefore, achieve greater combustion power. After combustion, these additives form into volatile organic compounds (VOCs) in the exhaust gases. Benzene, one of these compounds, is retained within the lungs after inhalation; it is then dissolved in fat and distributed around the body to fatty tissue, including the brain and bone marrow. While most of the toxin is eliminated within a couple of days, some can remain, particularly on exposure to high doses. At exceptionally high levels of exposure, the remaining benzene can damage elements of the bone marrow essential for the production of blood cells; this loss of production can be fatal.

Despite previous knowledge of the dangers of benzene, the press appears to have only begun its coverage of the issue in November 1993 (see Table 1). Even then, the media's distribution of information about the risks was gradual and sporadic. Momentum gathered, however, as related studies raised concerns about exposure to benzene and bodies, such as the National Society for Clean Air (which initially encouraged the use of unleaded petrol) and the Royal Commission on the Environment, advised drivers to stop using super unleaded petrol, and recommended a ban on its sale. All the newspapers headlined the Royal Commission's report and therefore, ensured most of the public would be informed of the risks associated with super unleaded petrol. The fears have continued to resurface in the newspapers, particularly after calls from MPs to ban the fuel. In March 1995, the Government formally rejected the ban. It stated that as the old car stock fell to zero, the demand for super unleaded petrol would disappear. (This argument is based presumably on the fact that most old cars cannot run on low-octane petrol; it appears to ignore the demand for high octane fuel from newer cars, particularly amongst high performance cars). Nevertheless, the on-going debate, and the attention it has been given in the media, has ensured that drivers were supplied with a regular flow of information about the environmental and health risks of benzene and super unleaded petrol.

Table 1: Major Flows of Information about Environmental Effects of Benzene from the Media (Broadsheet Newspapers) 1990-1995

Date	Major flows of information	Sources	Impact*
November 1993	A study links VOCs, released after the combustion of unleaded petrol, with cancer and respiratory problems.	Independent	1
December 1993	Following study's report, National Society for Clean Air stops advising drivers to use unleaded petrol.	Sunday Times	1
May 1994	New study indicates that benzene levels are up to four times higher than maximum recommended level near petrol stations.	Guardian	1
July 1994	MPs call for a ban on super unleaded petrol.	Financial Times	1
October 1994	Royal Commission on the Environment recommends the removal of super unleaded petrol from the market, due to its high benzene content, which is linked to child leukaemia.	All Papers	5
March 1995	Despite additional pressure from MPs, Government formally rejects ban on super unleaded petrol.	Guardian	1
September 1995	Shell and Rover advise motorists to not use unleaded petrol and use four star instead; the Automobile Association calls on the Government to clear up the confusion.	Times	1

*The impact is the number of broadsheet newspapers that appeared to have covered the event. This value acts as a proxy for the level of information provided by the media.

Source: Compiled from the British Newspaper Index (1995) and the Environmental Digest (1991-1995).

5. METHOD OF ESTIMATION

Choice of Method

In the last five years, the cointegration approach has been used relatively frequently to estimate these relationships between demand for road fuel and its determinants (Dargay 1992; Fouquet et al 1993, 1995; Bentzen 1994; Eltony and Al-Mutari 1995, Samimi 1995). There are, however, limitations as well as advantages with the use of the cointegration approach in the modelling of dynamic relationships (Fouquet 1996). Most using the approach base the use of cointegration and the error correction model on empirical grounds, which limits its suitability for interpreting the optimising behaviour of consumers. This basis is not entirely justified since the error correction mechanism has been explained theoretically as a form of partial adjustment, when time series are generated by unit root processes (Nickell 1985). The approach, therefore, has more theoretically credibility than it is often given credit for. Second, unit root tests are not definitive; there are likely to be series that appear to be non-stationary although the external shocks (see e_t in equation (7)) only have a temporary effect. It is possible that some of the variables in this study are only near-unit root processes, particularly the stock of information on lead and benzene in super unleaded fuel (ϕ_{Lt} and ϕ_{Bt}) which has an in-built depreciation rate ultimately driving the value to zero (or it could be modelled to converge towards some non-zero). Nevertheless, reasonably close proximity to unit root processes should be satisfactory for examining the relationships (Granger 1993). Third, direction of causality is not always uni-directional.

The short period under analysis does, however, cause a concern about using the cointegration technique because agents may not have sufficient time to

adjust to their long run equilibrium. The cointegration approach bases itself on the assumption that individuals have time to adjust to minimise their long run expenditure function. Over the five years between January 1991 and December 1995, the study is unlikely fully to capture drivers' ability to replace their car stock and to minimise their long run expenditure functions; thus, the car stock can be considered only partially flexible in this study. Nevertheless, many drivers can adjust to changes by switching to premium unleaded petrol.

Despite these reservations, several features of super unleaded fuel demand make the use of the cointegration technique an appropriate modelling approach. First, as stated earlier, demand appears to be non-stationary. Also, as will be seen later, demand does appear to be cointegrated with its determinants, retail sales index, real fuel price and environmental information provision. Third, although not all customers had time to adjust to their long run expenditure patterns in the five years studied, the error correction model does reflect drivers' gradual adjustment to their long run equilibrium as they buy new cars and scrap old ones. In addition, the method is relatively straightforward to use (ie running two OLS regressions). Finally, the method produces short and long run elasticities that are easy to interpret and can be compared with elasticity estimates from previous studies; thus, the role of environmental information in influencing consumption, which is the main focus of the study, can be examined using a relatively reliable technique.

Non-Stationarity of Data

The nature of the data and its generating process are important factors in deciding how to estimate its relationship with other variables. Over the last two decades, much emphasis has been placed on whether time series are *stationary*

or not. Although the definition of stationarity is complex (see for example Banerjee et al 1993), stationary series are characterised by erratic fluctuations not influenced by previous observations and gravitate towards a constant value. In contrast, non-stationary series tend to be smooth with high correlation between the values of observations through time; they do not gravitate to any particular value and in the long run have infinite variance (Granger 1993). The source of non-stationarity is the existence of *unit root processes* in the generation of the data. That is, for a demand time series

$$(7) \quad DSUL_t = \alpha.DSUL_{t-1} + e_t,$$

when $\alpha = 1$, where et is a residual with zero mean and constant variance.

If a fuel demand series is non-stationary, the effect of a shock - such as perhaps adverse publicity about the environmental impact of the fuel - is permanent. For example, in the model

$$(8) \quad DSUL_t = DSUL_{t-1} + e_t$$

and e_t reflects a decline I, then all future values of D (ie D_{t+1}, D_{t+2}, ..) will fall by I and, thus, the impact upon demand is permanent.

From an economic perspective, non-stationary time series are explained by the presence of habit-forming behaviour - actions today are influenced by past actions and not just today's prices and permanent income. For example, a driver may continue to drive the same car even after changes in prices, income or knowledge about the environmental impact of her actions mean that she is no

longer minimising the value of her long run expenditure function. Eventually, she will buy a new car that is more suitable for the new conditions.

If the time series under analysis are non-stationary, estimates produced by Ordinary Least Squares (OLS) of relationships between the dependent variables (eg energy demand) and its determinants are generally unreliable because the parameters have nonstandard distributions. Such long memory series can, however, be transformed into stationary series by differentiation. The number of times the series requires differentiation before it becomes stationary indicates its *order of integration*. Many economic series, such as most energy demand series, are I(1); and, in the past, many studies differentiated the series to estimate the relationships. Unfortunately, this approach loses all information about the long run relationships.

Cointegration

If the series are *cointegrated*, OLS estimations of several non-stationary series can be undertaken without compromising the reliability of parameter estimates. For example, energy demand and its determinants will be cointegrated I(1) series when demand is regressed on the determinants and the error terms (u_t) in

$$(9) \quad \ln DSUL_t = a\alpha_0 + \alpha_1 . \ln Y_t + \alpha_2 . \ln RPMS_t + \alpha_3 . \ln RPUL_t + \alpha_4 . \ln RPSUL_t + \alpha_5 . \ln \phi_{Lt} + \alpha_6 . \ln \phi_{Bt} + u_t$$

form a stationary I(0) series.

External shocks, not modelled by the determinants but reflected in u_t, only have a temporary effect on the relationship between demand and its determinants. Changes in determinants, however, will have long run effects (α_i) on the dependent variable. So, for example, a change in the supply of environmental information about the impact of lead and benzene (ϕ_{Lt} and ϕ_{Bt}) will have a long run or permanent impact α_5 and α_6 on the demand for super unleaded fuel ($DSUL_t$). In the long run the difference between the variables remains constant: after shocks (u_t), they return to the original equilibrium and, after changes in determinants, they move to a new equilibrium.

Error Correction Model

All cointegrated series have an error correcting mechanism returning them from any dis-equilibria back to their long run equilibrium relationship (Engle and Granger 1987). To analyse the disequilibrium relationship, the change in individual demand for super unleaded fuel is regressed on the contemporary and lagged determinants differenced and the error correcting term (ie the error in the equation (9)). This error correction model (ECM) can be represented as

(10) $\Delta DSUL_t =$

$$\alpha_0 + (\ln Y_{t-1} - \alpha_1 . \ln RPMS_{t-1} - \alpha_2 . \ln RPUL_{t-1} - \alpha_3 . \ln RPSUL_{t-1}$$
$$- \alpha_4 . \ln \phi_{Lt-1} - \alpha_5 . \ln \phi_{Bt-1})$$
$$+\beta_{10}.\Delta Y_t + \beta_{11}.\Delta Y_{t-1} + ... + \beta_{1n}.\Delta Y_{t-n}$$
$$+\beta_{20}.\Delta RPMS_t + \beta_{21}.\Delta RPMS_{t-1} + ... + \beta_{2n}.\Delta RPMS_{t-n}$$
$$+\beta_{30}.\Delta RPUL_t + \beta_{31}.\Delta RPUL_{t-1} + ... + \beta_{3n}.\Delta RPUL_{t-n}$$
$$+\beta_{40}.\Delta RPSUL_t + \beta_{41}.\Delta RPSUL_{t-1} + ... + \beta_{4n}.\Delta RPSUL_{t-n}$$
$$+\beta_{50}.\Delta \phi_{Lt} + \beta_{51}.\Delta \phi_{Lt-1} + ... + \beta_{5n}.\Delta \phi_{Lt-n}$$
$$+\beta_{60}.\Delta \phi_{Bt} + \beta_{61}.\Delta \phi_{Bt-1} + ... + \beta_{6n} \Delta \phi_{Bt-n}$$
$$+ v_t.$$

So, for example, new information about the benzene impact of super unleaded fuel will have an initial effect (β_{60}) on fuel consumption. The variables in levels provide long run elasticity estimate, while the difference variables produce short run elasticity estimates, valuable for studying immediate and gradual impact of economic activity, prices and information on super unleaded fuel consumption.

6. RESULTS

Non-Stationary Time Series

The series used in the study were first tested for the existence of unit root processes. In all cases, the Augmented Dickey-Fuller (ADF) test, with up to 12 lags, did not reject the null hypothesis of a unit root and, thus, the assumption of non-stationary series.

Cointegrated Relationships

A test is performed to see whether the long run relationship between demand and its determinants is cointegrated. The error terms of the long run regression (u_t in equation (9)) are tested for non-stationarity using the Augmented Dickey-Fuller test. In this case, the hypothesis of a unit root process is rejected. This suggests that, from 1990 to 1995, the relationship is cointegrated. That is, any deviation of individual fuel consumption away from the equilibrium relationship as a result of a sudden change in the underlying determinants will be rectified such that the driver will gradually return to her equilibrium relationship between fuel consumption and budget, relative prices and beliefs.

Long Run Elasticity Estimates

The estimates of the long run relationship are generated from placing the chosen series within equation (9). Table 2 presents the results. All the economic activity or relative price estimates are either the opposite from the anticipated signs or insignificant at the 95 percent confidence level. This suggests that super unleaded demand shows no sensitivity to changes in income and two of the price variables - estimates from other studies have found highly inelastic (between -0.07 to -0.46) road fuel demand to price changes both in the short and long run (Eltony 1993; Fouquet et al 1993, 1995; Eltony and Al-Mutari 1995; Samimi 1995).

Table 2: Long Run Elasticity Estimates of the Log of Individual UK Demand for Super Unleaded Petrol ($LnDSUL_t$) 1991M1-1995M11*

Explanatory Variable	**Coefficient estimate**	**t-ratio**	**p-value****
Log of economic activity (LnY_t)	0.14	0.85	0.40
Log of real price of motor spirit ($LnRPMS_t$)	1.26	2.24	0.03
Log of relative price of unleaded petrol ($LnRPUL_t$)	-0.19	-0.36	0.71
Log of relative price of super unleaded petrol ($LnRPSUL_t$)	1.08	0.56	0.57
Log of Beliefs about Lead ($Ln\phi_{Lt}$)	1.98	3.36	0.00
Log of Beliefs about Benzene ($Ln\phi_{Bt}$)	-0.05	-2.36	0.02
	$R^2 = 0.78$	F(6,52) = 30.83	DW = 0.99

* The retail sales index used as an indicator of economic activity, the three price variables chosen to replicate the decision making process and the novelty of belief variables make direct comparisons with previous studies difficult.

** The p-value indicates the probability that the coefficient estimate is equal to zero; ie there is no long run relationship between demand and the explanatory variable.

The real (weighted average) price of motor spirit, however, is significantly different from zero. The coefficient is positive, suggesting that an increase in the real price of motor spirit increases demand in the long run. It might be explained by looking at changes in the retail price index. An important reduction in the retail price index leads to both a substitution effect and an income effect. A decrease in retail prices signifies a positive income effect - individual incomes will buy more goods than before the reduction. Since the real price of motor spirit is the nominal price divided by the retail price index, a stable or declining retail price index will put upward pressure on the real price of petrol and yet generate positive income effects. In the early 1990s, retail prices remained mostly stable, declining some months. Thus, a driver with a greater expenditure will have a tendency to spend this increase more than proportionally on luxuries. Non-essential travelling and super unleaded petrol can be considered luxuries - the petrol both for its additional power to move the car and its low lead content (naturally, it has a high benzene content, however). Thus, the real price of motor spirits can be positively correlated with the demand for super unleaded petrol.

In relation to the impact of information on behaviour, the study has modelled information flow as leading to a depreciating stock of information or beliefs about environmental relations. To decide on a suitable rate of depreciation of information, experminents of a realistic decay rates of information stock were undertaken. If it was too large, the beliefs about the environment would converge to zero within a short period of time and people would almost immediately forget about it; too small and any belief would remain unchanged for years. Based on the measures of information previously used, a constant value of 1 percent per month was chosen, compared with a rate of 5 percent per quarter proposed by McGuiness and Cowling (1975).

Demand appears to be sensitive to changes in beliefs, which are the only variables for which estimates are both as expected and significantly different from zero. Beliefs about lead are positive (1.98) indicating one percent increase in the stock of information about the low lead content of or the reductions in environmental damage from unleaded fuel (ie the index of newspaper articles) leads to a long run two percent rise in individual demand for super unleaded petrol.

Similarly, beliefs about benzene content seem to be negatively associated with individual demand. The long run effect, however, was only -0.05. That is, a 1% increase in the information about hazardous effect of benzene may have led to an initially high reduction in demand for super unleaded but in the long run only lead to a 0.05% reduction in demand. Nevertheless, the growth in information about the damaging effects leads eventually to a lower demand for super unleaded, indicating that the drop in demand for the product was not temporary and that drivers have been permanently dissuaded from using a fuel with benzene in it. This long run effect is, however, small[2]. Interestingly, the data shows a large initial decline in demand, which suggest a large proportion of the drivers initially being willing to pay for low benzene fuel and with the passage of time becoming less willing to pay. This has to be confirmed by examining the short run estimates.

[2] Studies looking at reductions in consumption related to direct health effects show larger long run reductions. For example, Burton and Young (1996) found that the publicity about BSE led to a 4.5% reduction in the demand for beef in the long run. This is only about double the positive impact of lead information on unleaded fuel consumption, but quite a bit larger than the long run impact of benzene effects on super unleaded demand.

Short Run Elasticity Estimates

Within the error correction model, demand was regressed on contemporary and lagged, differenced variables of the determinants. Following Hendry's general-to-specific methodology (Hendry 1995), coefficients with high p-values were progressively removed until either only one of each determinant remained or the p-values were below 0.15[3].

The signs of the short run estimates are more as theory dictates (see Table 3), although most of the values are not significantly different from zero with 95 percent certainty. The variables retained using the general-to-specific methodology are on the whole lagged one period. This suggests that consumers main response to changes in budget, relative prices or information occurs with a delay of one month.

Economic activity is highly significant. Two lagged variables remained, Y_{t-1} and Y_{t-2}. They are, however, both negative. This requires an explanation. It is possibly the result of the indicator of economic activity used. As discussed in the data section, the retail sales index (ie expenditure of non-durable goods) was the only indicator available from the CSO. This can be considered a form of budget variable. Increases in expenditure in one period, such as in December, have to be compensated for in later periods by tightening the budget, equivalent to a negative income substitution effect. Thus, the increases in expenditure in one month leads to a more than proportional reduction in expenditure on luxuries, such as non-essential travelling and the use super unleaded petrol.

[3] The threshold between rejecting values genuinely different from zero and accepting values actually zero has not been specifed in the literature. A value of 0.15 indicates that there is an 85% probablity that the variable is not equal to zero. This seems a useful starting value. Studies such as Gilbert (1986) on econometric methodology and the rejection of variables does not provide any clues on the appropriate value.

Table 3: Short Run Elasticity Estimates of the Change of Log Individual UK Demand for Super Unleaded Petrol ($\Delta LnDSUL_t$) 1991M1-1995M11*

Explanatory Variable	**Coefficient estimate**	**t-ratio**	**p-value****
Change in log of economic activity lagged 1 (ΔlnY_{t-1})	-0.33	-4.04	0.00
Change in log of economic activity lagged 2 (ΔlnY_{t-2})	-0.32	-4.08	0.00
Log of real price of motor spirit lagged 1 ($\Delta lnRPMS_{t-1}$)	0.69	1.61	0.11
Log of relative price of unleaded petrol lagged 1 ($\Delta lnRPUL_{t-1}$)	-0.67	-0.77	0.45
Log of relative price of super unleaded petrol lagged 2 ($\Delta lnRPSUL_{t-2}$)	-1.47	-1.35	0.18
Change in log of Beliefs about Lead lagged 1 ($\Delta ln\phi_{Lt-1}$)	0.54	0.85	0.40
Change in log of Beliefs about Benzene lagged 1 ($\Delta ln\phi_{Lt-1}$)	-0.04	-1.65	0.10
Change in log of Beliefs about Benzene lagged 2 ($\Delta ln\phi_{Lt-2}$)	-0.04	-1.66	0.10
Error Correction term	-0.19	-2.31	0.02
	$R^2 = 0.59$	F(10,45) = 6.48	DW = 2.26

* The retail sales index used as an indicator of economic activity, the three price variables chosen to replicate the decision making process and the novelty of belief variables make direct comparisons with previous studies difficult.

** The p-value indicates the probability that the coefficient estimate is equal to zero; ie there is no long run relationship between demand and the explanatory variable.

Again, the real price of motor spirits is positive. This supports the earlier explanation of a positive relationship between this variable and individual demand. Other short run price elasticities are negative; the coefficient for the relative price of unleaded is -0.67 and for the relative price of super unleaded is -1.34. This indicates there appears to be more initial shifting between the two unleaded fuels than between unleaded and leaded fuels after changes in relative prices. This is confirmed by the long run estimates in Table 2.

The response to changes in information about lead is large but insignificant. The short and long run response to information about lead are very close. Consumers appear to make all their increase in demand in the second month after receiving favourable news - although it is not certain to be different from zero.

The information about benzene drivers appears more certainly to have an effect on demand, although much smaller. The short run estimates are -0.38 for a change one period ago and -0.37 for a change two periods ago. That is, the long run effect took several months to occur - and was evenly distributed over that period. Although not individually significant at the 95 percent level, a hypothesis test for the fact that both coefficients are equal to zero was rejected with 95 percent certainty in favour of the existence of an effect of information about benzene on demand.

Overall, the estimates of response to information about lead were - in both the short and long run regressions - larger but less significantly different from zero than estimates related to benzene information. It may be that drivers had already received favourable information about unleaded petrol before the period

of analysis. Thus, consumers already had a chance to form their beliefs about unleaded petrol, and provided their cars could use the fuel, they may or may not have shifted out of leaded petrol to unleaded petrol based on their beliefs. Drivers only learnt about benzene in 1994. They quickly formed their beliefs which possibly influenced their fuel choices thereafter. Thus, this would suggest that the new information influences beliefs, and these may alter consumer patterns; as the diffusion of information reaches the whole population, beliefs are no longer as sensitive to additional information on a particular and aggregate demand will not change greatly with additional information. It may be that, in the future, additional information about benzene will not alter beliefs or demand greatly.

7. CONCLUSION

This paper has examined the hypothesis that information provided by the media about the environmental effects of lead and benzene had a significant impact on the demand for super unleaded petrol in the United Kingdom between 1991 and 1995. Of an exploratory and speculative nature, the study assumes that drivers value the attributes within petrol, such as its power to move a vehicle and its lead and benzene content and resulting environmental damage. This enables the demand for super unleaded petrol to be modelled as a function of economic activity, three relative price variables and beliefs about its lead and benzene content and resulting environmental damage. Beliefs were modelled as the stock of information provided to individuals, with a monthly depreciation rate of one percent.

Because of the introduction of super unleaded petrol in 1988 and the lack of statistics on information provision, data collection was problematic. Monthly data were used to enable sufficient observations of behaviour to be made, which limited the availability of variables on economic activity. A data set was created about the media's provision of information on lead and benzene in super unleaded petrol. Placed within an error correction model, estimates of the relationship between demand and its determinants were estimated. The estimates reflected problems with the novelty of modelling environmental information and the problems of data collection. Nevertheless, they provide evidence to support the hypothesis that information about benzene did have a significant impact on the demand for super unleaded in the United Kingdom. This indicates that the three factors necessary for information to alter behaviour were present: first, that information provided by the media did alter drivers' beliefs; second, that there existed a willingness to pay to reduce environmental damage; and, third, that drivers did not always free ride even when opportunities to do so existed.

It is not surprising that beliefs about environmental risks changed as a result of the considerable media attention the damaging effects of benzene received, particularly in 1994. Benzene had been associated with child leukaemia. Issues related to child health are particularly sensitive and the public is likely to be willing to pay for minimising these health risks. Thus, the information provision created or increased willingness to pay to reduce benzene in super unleaded petrol.

This study highlights the relationship between information, beliefs and decision-making, which is vital in explaining consumption patterns (Burton and Young 1996, De Varny and Walls 1996). And, in particular, it suggests that

certain events can generate large amounts of information flow in a short period of time, causing dramatic reactions in consumer behaviour. The behaviour may revert, however, to an original - or a new but only marginally different - long run equilibrium. Other events may appear to generate information over a more dispersed period of time but leave long run trends in consumption significantly different. Also, positive and negative publicity may lead to different dynamic effects; the variations in impact of different types of information appear not to have been investigated in detail. While unravelling how a flow of information can alter beliefs and then direct consumption both in the short and the long seems particularly difficult, the recent methods in econometrics do provide some hope.

They do not, however, explain why individuals declined to free-ride. The impact of individual efforts to reduce the environmental damage and, thus, any health risks is usually negligible. The value to the individual of choosing a fuel with a lower benzene content should, therefore, also be negligible. Various explanations for declining to free-ride can be offered. First, perhaps consumers believed that by choosing low-benzene fuel they were reducing considerably their (or their children's') health risks. Second, it is possible that when confronted with certain issues, such as decisions that relate to - although only negligibly affect - child health risks, individuals have a tendency to become more altruistic. Third, certain individuals may behave in a docile manner; that is, they follow advice about appropriate actions despite the advice not being directly beneficial to the individuals (Simon 1993)[4].

[4] David Hawdon has suggested that although consumers may behave altruistically, their apparent altruistic behaviour could be the result of anticipating future shifts in policy regime to reflect social or environmental concern. Thus, for example, public concern about the environmental and health effects of a particular fuel may lead to an increase in tax on this fuel relative to others, and by the time the tax was introduced many consumers would have prepared for the policy by buying alternative types of petrol. This suggests the opportunity for an analysis into the credibility of policy action, and when do consumers believe the government will intervene to encourage fuel users to internalise externalities.

The empirical results and the foregoing arguments do indicate that opportunities for policy-makers to achieve environmental objectives might be assisted by the provision of suitably-directed information. The paper does not, however, attempt to state under what circumstances information alters beliefs or willingness to pay for environmental quality changes with beliefs, and when individuals decline to free ride. A better understanding of these three factors and the circumstances under which they occur is essential for policy-makers to achieve environmental objectives through information and educational campaigns and should be an avenue for future research.

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