

**SEEDS**

**Surrey Energy Economics**

**Discussion paper Series**

**SURREY**

**ENERGY**

**ECONOMICS**

**CENTRE**

---

**Transportation Oil Demand  
Consumer Preferences and  
Asymmetric Price Responses:  
Some UK Evidence**

David C. Broadstock, Alan Collins and Lester C. Hunt

April 2010

---



SEEDS 126  
ISSN 1749-8384

Department of Economics  
University of Surrey

The **Surrey Energy Economics Centre (SEEC)** consists of members of the Department of Economics who work on energy economics, environmental economics and regulation. The Department of Economics has a long-standing tradition of energy economics research from its early origins under the leadership of Professor Colin Robinson. This was consolidated in 1983 when the University established SEEC, with Colin as the Director; to study the economics of energy and energy markets.

SEEC undertakes original energy economics research and since being established it has conducted research across the whole spectrum of energy economics, including the international oil market, North Sea oil & gas, UK & international coal, gas privatisation & regulation, electricity privatisation & regulation, measurement of efficiency in energy industries, energy & development, energy demand modelling & forecasting, and energy & the environment.

SEEC research output includes **SEEDS - Surrey Energy Economic Discussion paper Series** (details at [www.seec.surrey.ac.uk/Research/SEEDS.htm](http://www.seec.surrey.ac.uk/Research/SEEDS.htm)) as well as a range of other academic papers, books and monographs. SEEC also runs workshops and conferences that bring together academics and practitioners to explore and discuss the important energy issues of the day.

SEEC also attracts a large proportion of the department's PhD students and oversees the MSc in Energy Economics & Policy. Many students have successfully completed their MSc and/or PhD in energy economics and gone on to very interesting and rewarding careers, both in academia and the energy industry.

Enquiries:

***Director of SEEC and Editor of SEEDS:***

Lester C Hunt

**SEEC,**

Department of Economics,

University of Surrey,

Guildford GU2 7XH,

UK.

Tel: +44 (0)1483 686956

Fax: +44 (0)1483 689548

Email: [L.Hunt@surrey.ac.uk](mailto:L.Hunt@surrey.ac.uk)

**[www.seec.surrey.ac.uk](http://www.seec.surrey.ac.uk)**

---

**Surrey Energy Economics Centre (SEEC)  
Department of Economics  
University of Surrey**

**SEEDS 126  
ISSN 1749-8384**

---

**TRANSPORTATION OIL DEMAND CONSUMER  
PREFERENCES AND ASYMMETRIC PRICE RESPONSES:  
SOME UK EVIDENCE**

David C. Broadstock, Alan Collins and Lester C. Hunt

April 2010

---

This paper may not be quoted or reproduced without permission.

## **ABSTRACT**

The aim of this paper is to (i) establish the role of asymmetric price decompositions in UK road transportation fuel demand, (ii) make explicit the impact of the underlying energy demand trend and (iii) disaggregate the estimation for gasoline and diesel demand as separate commodities. Dynamic UK transport oil demand functions are estimated using the Seemingly Unrelated Structural Time Series Model with decomposed prices to allow for asymmetric price responses. The importance of starting with a flexible modelling approach that incorporates both an underlying demand trend and asymmetric price response function is highlighted. Furthermore, these features can lead to different insights and policy implications than might arise from a model without them. As an example, a zero elasticity for a price-cut is found (for both gasoline and diesel) implying that price reductions do not induce demand for road transportation fuel in the UK. The paper illustrates the importance of joint modelling of gasoline and diesel demand incorporating both asymmetric price responses and stochastic underlying energy demand trends.

*Keywords:* Gasoline; Diesel; Asymmetry; Price; Underlying Energy Demand Trend (UEDT)

# Transportation Oil Demand Consumer Preferences and Asymmetric Price Responses: Some UK Evidence<sup>§</sup>

David C. Broadstock<sup>a</sup>, Alan Collins<sup>b</sup> and Lester C. Hunt<sup>a</sup>

*a: Surrey Energy Economics Centre (SEEC), Department of Economics, University of Surrey, Guildford, Surrey, GU2 7XH, UK.*

*b: Corresponding Author, Department of Economics, Portsmouth Business School, University of Portsmouth, Richmond Building, Portland Street, Portsmouth, Hampshire, PO1 3DE, UK., Email: alan.collins@port.ac.uk , Tel: +44 2392 844128*

## 1. Introduction

The overall demand for oil used for road transport continues to rise in the UK leading to pressing environmental concerns. Many studies have sought to estimate transport fuel demand elasticities, the results of which are summarized in Goodwin *et al.* (2004), Graham and Glaister (2004) and Brons *et al.* (2008), *inter alia*. However these (and previous) valuable reviews only briefly discuss the issue of modeling transport oil demand as opposed to diesel and gasoline separately. Moreover, they ignored studies that attempt to incorporate a stochastic Underlying Energy Demand Trend (UEDT) with a Structural Time Series Model (STSM) when estimating transportation fuel demand (e.g. Hunt and Ninomiya, 2003) and failed to discuss the possible importance of modeling Asymmetric Price Responses (APRs) (e.g. similar to that used in Gately & Huntington, 2002). Therefore, this paper assumes that gasoline and diesel are distinct products offering differing service quality characteristics to consumers [1] and presents a general modeling framework that encompasses both a UEDT and APR using the Seemingly Unrelated Structural Time Series ‘unobserved-components’ framework for UK road transport oil demand.

---

### <sup>§</sup> Acknowledgements

We would like to acknowledge useful comments received from an anonymous referee on an earlier version of this paper. All errors and omissions remain the responsibility of the authors.

## 2. Modeling Approach

Harvey's (1989) Structural Time Series Model (STSM) framework is used to estimate UK road transportation gasoline and diesel demand functions as follows:

$$A^i(L)ei_t = \mu_t^i + B^i(L)y_t + C^i(L)pi_t + \varepsilon_t^i \quad \varepsilon_t^i \sim NID(0, \sigma_{\varepsilon^i}^2) \quad (1a)$$

$$\mu_t^i = \mu_{t-1}^i + \beta_{t-1}^i + \eta_t^i \quad \eta_t^i \sim NID(0, \sigma_{\eta^i}^2) \quad (1b)$$

$$\beta_t^i = \beta_{t-1}^i + \xi_t^i \quad \xi_t^i \sim NID(0, \sigma_{\xi^i}^2) \quad (1c)$$

$i = g, d$

Where  $g$  is gasoline,  $d$  is diesel,  $ei_t$  is the natural logarithm of UK road transportation consumption of fuel  $i$ ,  $y_t$  is the natural logarithm of UK GDP,  $pi_t$  is the natural logarithm of the real transportation price of fuel  $i$ , and,  $\varepsilon_t^i$  the error term for equation (1a).  $A^i(L)$ ,  $B^i(L)$ , and  $C^i(L)$  are polynomial lag operators [2] so that  $B^i(L)/A^i(L) = \alpha_y^i$  and  $C^i(L)/A^i(L) = \alpha_p^i$ , which represent the long-run income and price elasticities for  $i$  respectively.

The process produces stochastic trends (the UEDTs) for both gasoline and diesel demand, the shapes of which are governed by  $\mu_t^i$ ,  $\beta_t^i$ ,  $\eta_t^i$ ,  $\xi_t^i$  and the hyperparameters  $\sigma_{\eta^i}^2$ , and  $\sigma_{\xi^i}^2$  (which are mutually uncorrelated white noise disturbances with zero means and variances). Equations (1b) and (1c) represent the level and slope components of the trends thus allowing two mechanisms for stochasticity. This allows the trend terms to be more flexible than if a stochastic slope component was omitted. [3] However, in the limiting case when the hyperparameters are equal to zero, the trends collapse to deterministic trends, identical to conventional least squares regression; see, for example, Iqbal (1984) for one example of a dynamic energy demand function estimated using least squares methods, with a deterministic trend.

Estimates are obtained by maximum likelihood in conjunction with a Kalman filter using STAMP 6.3 (Koopman *et al.*, 2000), assuming all disturbance terms are independent and uncorrelated with each other. A general-to-specific methodology is employed removing insignificant variables and hyperparameters ensuring a range of diagnostic tests are passed, [4] and models conform to economic theory.

Given potential interconnections between the gasoline and diesel markets, a joint model is also estimated by a ‘Seemingly Unrelated’ version of the STSM (SUSTSM). The equation specifications being the same as above but also allowing for covariance between cross-equation errors via the covariance term  $\sigma_{\varepsilon_t^g \varepsilon_t^d}$ . [5]

Equation (1a) assumes symmetric price responses, but to consider APRs, similar to Gately and Huntington (2002),  $pi_t$  is decomposed as follows:

$$pi_t = pi_1 + pi_t^M + pi_t^R + pi_t^c$$

Where:

- $pi_1$  is the value of the price in the first period
  - i.e. this variable is a constant taking the value of the first observation in the sample;
- $pi_t^M$  is the cumulative increases in the log of maximum historical prices
  - i.e. the first period is set equal to zero ( $pi_{t|t=1}^M = 0$ ) given  $pi_1$  captures the first ‘maximum’ but thereafter at time period  $t$  the price is

compared to the maximum observed price prior to that period. If it is greater i.e.  $pi_t > \max (pi_{t|t=1}, \dots, pi_{t|t=t-1})$ , then its value is added/accumulated to the current value of the variable;.

- $pi_t^R$  is the cumulative sub-maximum increases in the log of prices
  - i.e. the first period is set equal to zero ( $pi_{t|t=1}^M = 0$ ) and thereafter at time period  $t$  the current price is compared to the price in the previous period. If it increases i.e.  $pi_t > pi_{t-1}$ , then its value is added/accumulated to the current value of the variable *if and only if* it remains below the historical maximum observed prior to that period i.e.  $pi_t \leq pi_{t-1}^M$ . If this condition is not met (i.e.  $pi_t > pi_{t-1}^M$ ), then the increase is already captured in  $pi_t^M$  and should not be included again here (to ensure double counting is avoided).;
- $pi_t^C$  is the cumulative decreases in the log of prices
  - i.e. again the first period is set equal to zero ( $pi_{t|t=1}^M = 0$ ) and thereafter at time period  $t$  the current price is compared to the price in the previous period. If it decreases i.e.  $pi_t < pi_{t-1}$ , then its value is added/accumulated to the current value of the variable. If this condition is not met (i.e.  $pi_t \geq pi_{t-1}$ ), then the information regarding price behaviour is already captured in either  $pi_t^M$  or  $pi_t^R$  and should not be included again here (to ensure double counting is avoided).

Thus  $pi_t$  is replaced in Equation (1a) by  $pi_t^M$ ,  $pi_t^R$ , and  $pi_t^C$  to give the following asymmetric specifications:

$$A^i(L)ei_t = \mu_t^i + B^i(L)y_t + C^{M^i}(L)pi_t^M + C^{R^i}(L)pi_t^R + C^{C^i}(L)pi_t^C + \varepsilon_t^i \quad (1a')$$

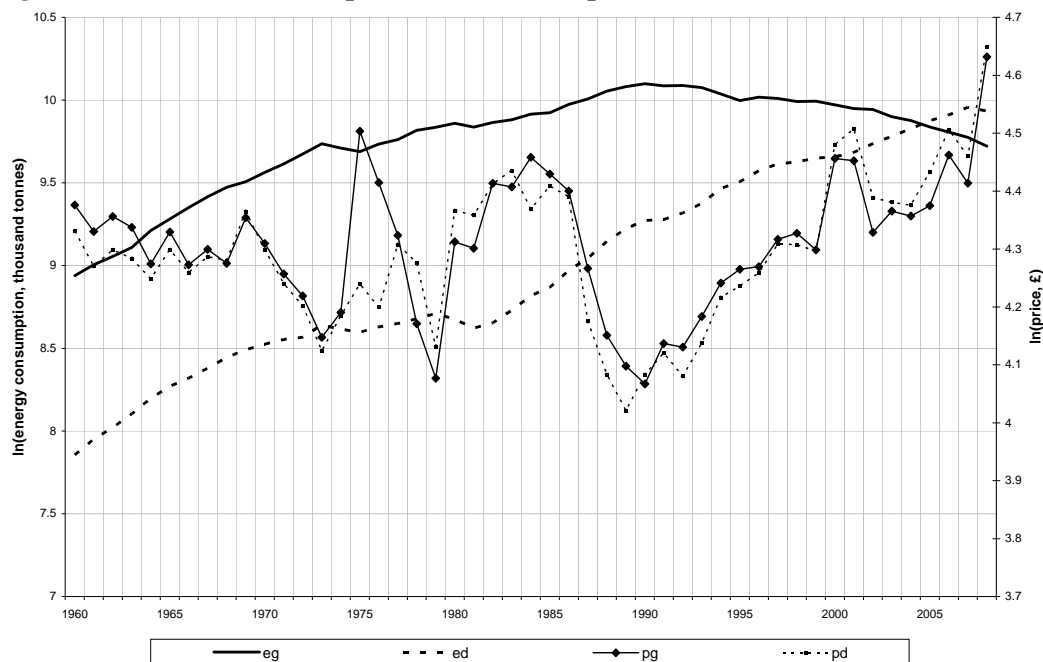


With the long run price elasticities replaced by the decomposed long run price elasticities;  $C^{M^i}(L)/A^i(L) = \alpha_{p^M}^i$ ,  $C^{R^i}(L)/A^i(L) = \alpha_{p^R}^i$  and  $C^{C^i}(L)/A^i(L) = \alpha_{p^C}^i$  represent the long-run price-max, price-recovery, and price-cut elasticities for  $i$  respectively.

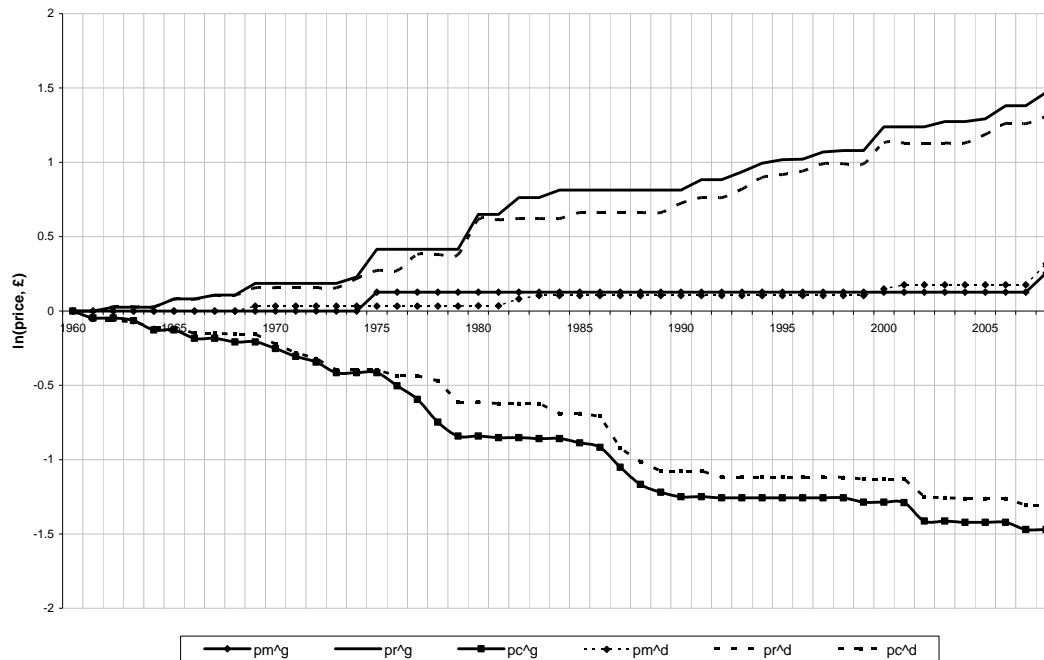
### 3. Data

The energy data (gasoline and diesel consumption in thousands of tonnes, and the weighted nominal prices of gasoline and diesel) are derived from the Digest of United Kingdom Energy Statistics (DUKES). GDP in £m at 2005 market prices and the implicit GDP deflator 2005=100 (data series ABMI and YBGB respectively) come from the UK Office for National Statistics (ONS). The real gasoline and diesel prices are calculated by deflating the nominal prices by the GDP deflator. [6] This gives annual data for 1960 to 2008. The fuel data and their prices are presented in Figure 1 and the decomposed price data in Figure 2.

**Figure 1: UK Road Transport Fuel Consumption and Prices 1960-2008**



**Figure 2: UK Decomposed Road Transport Fuel Prices 1960-2008.**



#### 4. Results

Table 1 gives the preferred estimation results showing that all specifications fit the data well with almost all diagnostic tests passed. The only slight issue is that the diesel equation, whether estimated separately or jointly, forecasts well in the post estimation period up to 2007 but not 2008 when diesel consumption fell by just over 2% after growing by nearly 4½% per annum from 2000 to 2007. However, it is not surprising that the equation estimated up to 2002 does not manage to predict the total impact of the recent severe recession. In all probability this would need an intervention to ensure the normality of the auxiliary residuals (irregular, level and slope) if estimated up to and including 2008 given these generally provide information about important breaks and structural changes at certain dates within the estimation period, such as a severe recession (Koopman *et al.*, 2000). For gasoline, this is not a problem given that consumption fell by about 2¾% per annum from 2000 to 2007 so that, although the decline in 2008, at about 5¼% was faster, it was still part

of the general downward trend during the 2000s and thus captured adequately by the equation estimated up to 2002.

The results indicate that the UEDT and APRs are complementary given they are both retained in the preferred models. Furthermore, the long-run gasoline and diesel APRs are in line with expected intuition given  $|\alpha_{p^M}^i| > |\alpha_{p^R}^i| > |\alpha_{p^C}^i|$ , hence, they are plausible both conceptually and empirically (which is not always the case in such APR models). It can also be seen that in the long-run diesel demand is somewhat more responsive than gasoline demand to a price rise above the previous maximum. However, the estimates suggest that both gasoline and diesel demand respond similarly to a price recovery below the previous maximum and both do not respond at all to a price cut.

The income elasticities portray an interesting story suggesting that in the long-run rising income will lead to a slightly higher rise in the demand for diesel than for gasoline, moreover, in the short run diesel is significantly more responsive than gasoline to income changes. A similar story holds for the price elasticities, with diesel being generally more responsive than gasoline in both the long run and the short run. This may, in part, be due to the nature of demand for the different fuel types and that historically they have reflected non-homogenous types of automobiles i.e. diesel being used for business and freight purposes, while gasoline had been more widely used by the general public. As such the econometric results might imply that businesses reduce demand more rapidly than consumers who may well be more deeply 'locked in' to their consumption patterns.

**Table 1: Estimation Results (1963-2002) – Preferred specifications**

Variable	Asymmetric Prices			
	STSM		SUSTSM	
	<i>g</i>	<i>d</i>	<i>g</i>	<i>d</i>
$y_t$	0.675***	1.193***	0.688***	1.182***
$y_{t-3}$	0.406**		0.400***	
$pt_t^M$	-0.334**		-0.275*	
$pt_{t-3}^M$		-0.775***		-0.801***
$pt_{t-1}^R$	-0.104*	-0.151***	-0.102*	-0.141***
<b>Interventions</b>		Slp1982***		Slp1982***
		Lv11986***		Lv11986***
		Slp1997***		Slp1997***
		Slp2000***		Slp2000***
<b>Hyperparameters</b>				
$\sigma_\varepsilon^2 \times 10^{-5}$	4.77	2.67	3.94	2.31
$\sigma_\eta^2 \times 10^{-5}$	13.96	0.00	15.31	1.93
$\sigma_\zeta^2 \times 10^{-5}$	6.43	5.65	6.04	4.13
<b>Long run Elasticities</b>				
$Y$	1.08	1.19	1.08	1.18
$P_t^M$	-0.33	-0.77	-0.28	-0.80
$P_t^R$	-0.10	-0.15	-0.10	-0.14
$P_t^C$	0.00	0.00	0.00	0.00
<b>Residual diagnostics</b>				
<b>Normality</b>	0.23	0.89	1.06	1.20
$H_{(12)}$	1.21	1.42	1.61	1.11
$r_{(1)}$	-0.13	-0.12	-0.07	-0.16
$r_{(2)}$	-0.14	-0.02	-0.05	-0.00
$r_{(3)}$	-0.06	-0.13	-0.02	-0.11
$r_{(4)}$	-0.14	0.09	-0.09	-0.08
$DW$	2.00	2.03	1.95	2.09
$Q_{(8,6)}$	6.17	3.55	4.08	4.46
$R_d^2$	0.71	0.91	0.75	0.91
<b>Auxiliary residuals</b>				
<b>Irregular-normality</b>	0.97	1.32	0.42	1.46
<b>Level-normality</b>	2.64	0.68	4.38	0.19
<b>Slope-normality</b>	0.49	1.82	1.35	1.07
<b>Predictive tests</b>				
<b>Failure (2003-2007)</b>	3.62	4.86	3.74	4.97
<b>Failure (2003-2008)</b>	5.13	18.40***	4.91	19.40***

**Notes for Table 1:**

- \*\*\*, \*\* and \* represent statistically significant at the 1%, 5% and 10% levels respectively.
- Normality is the Bowman-Shenton test, approximately distributed as  $\chi^2_{(2)}$ .
- $H(n)$  is the test for heteroscedasticity, approximately distributed as  $F_{(n,n)}$ .
- $r_{(1)}, \dots, r_{(4)}$  are the serial correlation coefficients for lags 1-4 respectively, approximately distributed as  $N(0, 1/T)$ .
- $DW$  is the Durbin Watson statistic.
- $Q_{(8,n)}$  is the Box-Ljung Q-statistic based on the first n residuals autocorrelation; distributed as  $\chi^2_{(n)}$ .
- $R_d^2$  is the coefficient of determination based on differences.
- *Failure (2003-2007)* is the post-sample predictive failure test, approx. distributed as  $\chi^2_{(5)}$ ;
- *Failure (2003-2008)* is the post-sample predictive failure test, approx. distributed as  $\chi^2_{(6)}$ .

The UEDTs, given in Figure 3, show that in the first half of the sample period the estimated UEDTs for gasoline are rising almost continually until the mid 1980s, but generally falls quite sharp thereafter. This suggests that the exogenous factors increased the demand for gasoline over the early part of the sample but reduced demand over the latter part – perhaps reflecting greater vehicle efficiency. However, for diesel the estimated UEDTs are generally rising through the sample other than a slight decline during the 1970s and a sharp decline in the late 1990s. These different estimated exogenous impacts (in addition to the different estimated elasticities) highlights the importance of modeling gasoline and diesel separately (unlike Hunt and Ninomiya, 2003).

**Figure 3: Estimated Stochastic UEDTs for UK Road Oil Transport Demand, APR-SUSTSM 1963-2002.**



## 5. Discussion and Concluding Remarks

The elucidation of consumer responses as measured through the UEDT is a critically important extension to the more ‘traditional’ methods used to model fuel demand elasticities. The inclusion of such features, combined with APRs, arguably provides more detailed policy relevant information than models without such features. Moreover, evidence is provided here to suggest that the two fuels are not viewed in the same way by consumers, and in particular, in recent decades consumers have followed quite divergent underlying trends. This therefore suggests that aggregation of the two fuel types into a single commodity might lead to the consideration of blunt policy instruments trying to alleviate to a ‘happy medium’ for two conflicting markets.

Differences are found in the short-run and long-run dynamics of the two fuel types, both for the income and the price elasticities, and it is further found that APRs prevail over more conventional symmetric responses. Perhaps most interestingly, it is found that the impact of price decreases are statistically insignificant, therefore *ceteris paribus*, price reductions do not induce demand for road transportation fuel in the UK. This could be symptomatic of a number of issues, such as rising congestion, reduced on-street parking (and with higher parking costs) etc., which themselves would be reflected in the UEDT, albeit implicitly. From a policy perspective, the implication of a zero price cut elasticity is that the price of fuel could potentially be reduced, ergo reducing the overall service cost of transportation and hence generating an indirect income boost to the economy, without leading to detrimental growth in the demand for these highly polluting fuels.

## Notes

1. Due to (i) real service-cost differentials and (ii) differing rates of technological progress in automotive technologies for gasoline and diesel; an assumption reinforced by the subsequent empirical analysis.
2. With a lag of four years.
3. There is a wide and rapidly growing literature relating to state space modelling of time series processes. For an accessible introduction to such processes in economic analyses see for example Commandeur and Koopman (2007).
4. In addition, impulse dummies are included where there is some evidence of non-normality of the auxiliary residuals following Harvey and Koopman (1992).
5. We note that the present study is primarily concerned with (i) the structure of the demand function and (ii) highlight the potential role of the UEDT within it. Many studies take alternative approaches to analysis and consider inter-fuel substitution elasticities, for example Westoby (1984). However, these studies are normally based upon factor-share based relationships, and while of significant importance in their own right, are less concerned with identifying individual fuel demand relationships.
6. Noting that as gasoline demand is made up of a number of separate grades of gasoline the price series for gasoline is defined using a quantity-weighted average including the following components: 2 Star (1960-1989), 3 Star (1967-1989), 4 Star (1960-2005), 5 Star (1961-1979), Super Premium Unleaded (1990-2008) and Premium Unleaded (1988-2008). Noting that a number of the fuel types of the period either/both entered or left the market for various reasons. Unique price series are not available for 3 Star and 5 Star fuel, therefore it is assumed that they have the same prices as 4 Star fuel, which is much closer in quality than 2 Star fuel.

## References

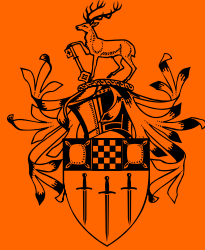
- Brons, M., Nijkamp, P., Pels, E. and Rietveld, P., (2008), A meta-analysis of the price elasticity of gasoline demand. A SUR approach, *Energy Economics*, Vol. 30, pp. 2105-2122.
- Commandeur, J. and Koopman, J., (2007), *An introduction to state space time series analysis*, Oxford University Press, New York, USA.
- Gately, D. and Huntington, H. G., (2002), The asymmetric effects of changes in price and income on energy and oil demand, *The Energy Journal*, Vol 23, pp. 19-55.
- Goodwin, P., Dargay, J. and Hanly, M., (2004), Elasticities of road traffic and fuel consumption with respect to price and income: A review, *Transport Reviews*, Vol. 24, pp. 275-292.
- Graham, D. and Glaister, S., (2002), The demand for automobile fuel, *Journal of Transport Economics and Policy*, Vol. 36, pp. 1-26.
- Harvey, A. C. and Koopman, S. J., (1992), Diagnostic checking of unobserved-components time series, *Journal of Business and Economic Statistics*, Vol. 10, pp. 377-89.
- Harvey, A. C., 1989, *Forecasting, Structural Time Series Models and Kalman Filters*, Cambridge University Press, Cambridge, UK.
- Hunt, L. C. and Ninomiya, Y., (2003) Unravelling Trends and Seasonality: A Structural Time Series Analysis of Transport Oil Demand in the UK and Japan, *The Energy Journal*, Vol. 24, pp. 63-96.
- Huntington, H. G., (2006), A Note on Price Asymmetry as Induced Technical Change, *The Energy Journal*, Vol. 27, pp. 1-7.
- Iqbal, M., (1984), Residential Energy Demand: A Case Study of Pakistan, *Journal of Economic Studies*, Vol. 11, pp. 40-48.
- Koopman, S. J., Harvey, A. C., Doornik J. A. and Shephard N., (2000), *Stamp: Structural Time Series Analyser, Modeller and Predictor*, London, Timberlake Consultants Press.
- Westoby, R., (1984), Models of Interfuel Substitution in the UK, *Journal of Economic Studies*, Vol. 11, pp. 27-39.



Note:

*This paper may not be quoted or reproduced  
without permission*

**Surrey Energy Economics Centre (SEEC)  
Department of Economics  
University of Surrey  
Guildford  
Surrey GU2 7XH**



**S**URREY

**E**NERGY

**E**CONOMICS

**D**ISCUSSION PAPER

**S**ERIES

**For further information about  
SEEC please go to:**

**[www.seec.surrey.ac.uk](http://www.seec.surrey.ac.uk)**