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A Comparison of Different Time Series Econometric Models of U.S. Gasoline Demand

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Abstract

This research builds upon Huntington (2010), investigating how different modelling approaches for exogenous trends, and time varying elasticities impact on estimated models of U.S. gasoline demand that incorporates asymmetric price responses. Three different approaches are adopted: i) an error correction model with a deterministic trend and constant elasticities (as undertaken in Huntington, 2010), ii) a stochastic exogenous trend model with constant elasticities; and iii) a stochastic trend with time varying elasticities model. The same annual data for 1949-2005 is employed in all three approaches using a general specification that allows both asymmetric price responses (for technical progress to impact endogenously) and an underlying energy demand trend (UEDT) for gasoline (to allow for technical progress and other factors both in a linear and non linear way to impact exogenously). The study suggests that for the deterministic trend approach (i) the estimated long run income, price max, price recovery and price cut elasticities are 1.03, -0.76, 0, and 0 respectively; for the stochastic approach (ii) the same estimated elasticities are 0.45, -0.20, -0.09, and 0 respectively, and for the stochastic trend with time varying elasticities approach (iii) they are 0.46, -0.25, -0.08, and -0.03 respectively (although the elasticities are changing over time the change is so small that when reduced to 2 decimal places they become identical). Furthermore in the deterministic approach the estimated UEDT for gasoline decreases constantly whereas for the other two approaches the estimated UEDT for gasoline is non-linear with periods when it is increasing and periods when it is decreasing. This suggests that the main reason for the different (end) elasticities is the different trend component identified by the three approaches – not the time varying nature of the elasticities.

Please note this is work in progress and must not be referred to without our consent. However, we would be happy to receive any comments or suggestions at Z.Dilaver@surrey.ac.uk.

1. Introduction:

General Background

After the first oil shock in the early 1970s the number of studies focusing on empirical modelling of energy demand increased significantly. The main reasons being i) the perceived need to identify energy demand responses to price and income changes; ii) the perceived need to forecast future energy requirements; and iii) the importance of energy consumption in terms of economic growth and global warming (Ryan and Plourde, 2009).

Technical progress and the Underlying Energy Demand Trend

Energy is a derived demand rather than being a demand for its own sake, a demand for the services it produces with the capital stock in place at a certain time. The amount of energy consumed is therefore connected to the technology level of the energy appliances to assure the demanded level of services. Beenstock and Wilcocks (1981) therefore argued that technological progress should be taken into account in energy modelling studies and used a simple deterministic trend in their study. However, Kouris (1983a, 1983b) criticized this view, arguing that although technology is an important determinant of energy demand, there is no sufficient way to identify its effect on energy demand unless a sufficient way to measure it can be addressed. Moreover, in the absence of the appropriate measure, Kouris argued that the effect of technological progress could therefore be observed via the response to energy price changes, via the price elasticity. In response, Beenstock and Willcocks (1983) argued that it is important to attempt to capture the exogenous effect of technological progress and, although using a linear trend is not an adequate way, it is better than just ignoring it. Therefore in the last three decades researchers have tended to include a deterministic trend into their regression equations for identifying the effect of this (exogenous) technological progress on energy consumption.

However being a derived demand, energy is also affected by other unobserved components such as consumer tastes, change in regulations, economic structure, rebound effect, etc. Hunt et al. (2000 and 2003) therefore introduced the wider concept of the Underlying Energy Demand Trend (UEDT), which encompasses technical change of the capital stock and the other exogenous factors.[1] However, Hunt et al. (2003a and 2003b) argued that given the way technical progress is introduced and the likely 'lumpiness' of a the other exogenous factors, it is unlikely that the UEDT would be linear – as is assumed when incorporating a deterministic time trend in an estimated energy demand function. Instead, they argue that the UEDT is likely to be non-linear and could incorporate periods where it is downward sloping (energy saving) and periods where it might be upward sloping (energy using). Thus, according to Hunt et al. (2003a and 2003b) it is important to model the UEDT in the most general and flexible way possible, and therefore recommend the use of the Structural Time Series Model (STSM) introduced by Harvey et al. (1986) and Harvey (1989).

Time Varying Parameter (TVP) Models

In the last decade researchers including Kim (1993), Brown et al. (1997), Song et al. (1998), Park and Hahn (1999), Song and Wong (2003) examined whether estimated elasticities change over time for the U.S. monetary growth, UK house prices, UK non durable consumption Expenditure, U.S. automobile demand, Hong Kong tourism demand respectively. Furthermore in a recent study Park and Zhao (2010) estimated a TVP U.S. gasoline demand model using monthly aggregate data over period 1976 to 2008. Their results suggest that the price elasticities increased from 1976 to 1980, decreased from 1980 to 1986, increased from 1986 to 1994, decreased from 1995 to 2005, and increased again from 2005 to 2008. The time varying estimated income elasticities follow a similar pattern to the estimated

[1] Hunt et al. (2003a) also argued that if the UEDT is not included (or incorrectly modelled) then this could lead to biases in the estimated price and income elasticities; for example, if the true UEDT is downward sloping and income is generally rising then the estimated income elasticity will be underestimated by not taking account of the UEDT.

price elasticities but the magnitude and variation is much smaller. The researchers argue that the TVP can be explained by variations in the degree of necessity and the proportions of gasoline consumption to the total disposable income. The price elasticities fluctuate between -0.35 to -0.10 over the estimation period, which is consistent with the current literature however the estimated income elasticities are 0.02 to 0.10 which appear to be rather low (lower than the price elasticities, in absolute terms) and inconsistent with the current literature. Furthermore, although the study utilises tests for unit roots and model specification for the TVP model, there are no diagnostics tests for the overall assessment of the model; including normality of residuals, goodness of fit and serial correlation. In addition, although the TVP approach is employed a fixed level is used (i.e. equivalent to a constant but with no trend) which arguably does not allow sufficient flexibility in terms of capturing structural changes over time; hence, this could have resulted in biased estimates (see literature Review of UEDT above for details).

Asymmetric price Responses (ARP)

Another dimension in empirical energy demand modelling is imperfect price reversibility. The imperfect price reversibility concept in energy demand is investigated by a number of studies such as Dargay (1992) Gately (1992), Dargay and Gately (1994, 1995a, 1995b), Gately and Streifel (1997), Haas and Schipper (1998), Gately and Huntington (2002), Griffin and Schulman (2005), Huntington (2006), Adeyami and Hunt (2007), Manzan and Zerom (2008), Huntington (2010). All of these studies except Griffin and Schulman (2005) support the concept of imperfect price reversibility. In summary, a number of studies suggest that consumer respond differently to price increases and decreases and that this should be taken into account for policy evaluation. This study, therefore compares the outcome of different modelling approaches on asymmetric price responses.

This study

This study estimates an APR model for U.S. Gasoline demand over the period 1949 to 2005 using three approaches: i) an error correction model with a deterministic trend and constant elasticities;[2] ii) a stochastic exogenous trend model with constant elasticities; and iii) a stochastic trend with time varying elasticities model. The main aim being to analyse and compare the differences and similarities of the results from the three approaches. The next section considers the empirical methodology followed by Section 3 that discusses and estimation results. In the final section, the outcome of this study is summarised and discussed.

2. Empirical Methodology:

It is assumed that U.S. gasoline demand is characterized by:

$$E_t = f(Y_t, p_t^{max}, p_t^{rec}, p_t^{cut}, \mu_t) \qquad (1)$$

and;

e_t= *Ln* (gasoline consumption per capita);

y_t=*Ln* (GDP per capita);

p_t^{max}= cum. increase in the nat. log. of maximum historical real gasoline prices;

p_t^{rec}= cum. sub-maximum increase in the nat. log. of historical real gasoline prices;

p_t^{cut}= cum. decrease in the nat. log. of historical real gasoline prices;

λ_y= *B(L)/A(L)* = long run income elasticity;

λ_p^{max}= *C(L)/A(L)* = long run price max elasticity;

λ_p^{rec}= *D(L)/A(L)* = long run price recovery elasticity;

λ_p^{cut}= *E(L)/A(L)* = long run price cut elasticity;

μ_t= level of underlying energy demand trend for gasoline (UEDT) in year *t (in stochastic trend)* or value of trend *(in deterministic trend)*;

ε_t= a random error term and $\varepsilon_t \sim NID\ (0, \sigma_\eta^2)$;

A(L) is the polynomial lag operator $1-\lambda_1 L- \lambda_2 L^2- \lambda_3 L^3$, *B(L)* is the polynomial lag operator $1+\alpha_1 L + \alpha_2 L^2+ \alpha_3 L^3$ and *C(L)* is the polynomial lag operator $1+\varphi_1 L +\varphi_2 L^2 +\varphi_3 L^3$

[2] As undertaken in Huntington (2010).

i) For the error correction model with deterministic trend approach: (taken from Huntington 2010); first differences of the variables are used in order to maintain series stationary and U.S. gasoline demand could be identified by:

$$A(L)\Delta e_t = B(L)\Delta y_t + C(L)\Delta p_t^{max} + D(L)\Delta p_t^{rec} + E(L)\Delta p_t^{cut} + \mu_t + EC_{t-1} + \epsilon_t \quad (2)$$

where the deterministic trend, μ_t, *has the following process;*

$$\mu_t = \alpha + \beta t \quad (3)$$

Where α is a fixed level component (or constant) and β is a fixed slope component.

ii) For the stochastic trend approach with fixed elasticities: The STSM approach consists of decomposing the dependent variable (energy consumption) into i) the impact of the explanatory variables (such as price and income/output), ii) the non-linear trend, and iii) the irregular components. It is therefore assumed that a log linear U.S. gasoline demand is driven by an activity variable (GDP), decomposed prices, and the UEDT and an ADRL version is specified as follows:

$$A(L)e_t = B(L)y_t + C(L)p_t^{max} + D(L)p_t^{rec} + E(L)p_t^{cut} + \mu_t + \epsilon_t \quad (4)$$

Furthermore, μ_t has the following process;

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \ ; \qquad \eta_t \sim NID\ (0, \sigma_\eta^2) \quad (5)$$

$$\beta_t = \beta_{t-1} + \xi_t \ ; \qquad \xi_t \sim NID\ (0, \sigma_\xi^2) \quad (6)$$

where η_t and ξ_t are mutually uncorrelated white noise disturbances with zero means and variances σ_η^2 and σ_ξ^2 respectively (known as the hyperparameters). η_t allows the level of trend to shift up and down whereas ξ_t allows the slope of the trend to change (Harvey and Shephard, 1993).

iii) For the stochastic trend approach with time varying elasticities: The trend component will have the same process with the previous model. For the econometric estimation of equation (1) the log linear specification with time varying parameters is utilised as follows:

$$e_t = \lambda_{1,t} y_t + \lambda_{2,t} p_t^{max} + \lambda_{3,t} p_t^{rec} + \lambda_{4,t} p_t^{cut} + \mu_t + \epsilon_t \qquad (7)$$

$$\lambda_{i,t} = \lambda_{i,t-1} + v_{i,t} \qquad where\ \ i=1,2,3,4 \qquad (8)$$

The software package STAMP8 (Koopman et al, 2007).is used to estimate (ii) and (iii) and apply an array of diagnostic tests to the model. The results of which are given in the next section after discussing the data

3. Data and Estimation Results

Data

The data used for the estimation is that used by Huntington (2010); hence, the definitions and sources of the data can be found in Huntington (2010).

Estimation Results

After eliminating the insignificant variables and including the necessary interventions, the following preferred equation for Δe_t is given by :

i) For the error correction model with deterministic trend approach:

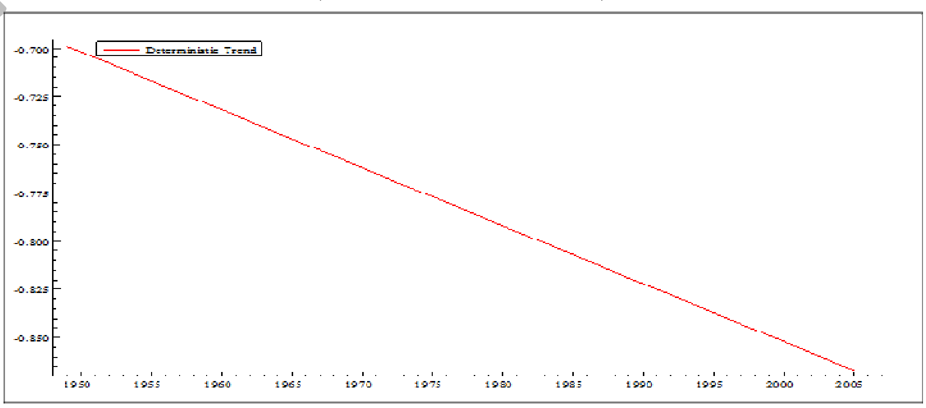
$$\widehat{\Delta e_t} = -0.699 - 0.277\Delta p_t^{max} - 0.505\Delta y_t - 0.072 e_{t-1} - 0.055 p_{t-1}^{max} + 0.205 y_{t-1} - 0.003t - 0.063\, p_t^{submax} + 0.369\Delta e_{t-1} + 0.160\, \Delta p_{t-1}^{max} - 0.006\Delta p_{t-1}^{submax} - 0.368\Delta y_{t-1} - 0.43\rho$$

The ordinary least squares (OLS) estimation of the equation i, produced a Breusch–Godfrey statistic that was significant at the 5% level. To adjust for this potential problem, the coefficients have been corrected for first-order autocorrelation. Due to the presence of the lagged dependent variable, the Cochrane–Orcutt procedure was used. Price recoveries and cuts do not have significantly different responses from each other in either the short or long run. In contrast, prices reaching new peaks have significantly different effects on gasoline consumption than sub-maximum prices in either the short or long run. Sub-maximum prices appear to have no effect on gasoline consumption in the long run, because the t-statistics on the lagged price recovery and cut levels are very close to zero. These terms have been dropped from the equation.

The estimated U.S. gasoline demand model with fixed coefficients, asymmetric price responses and deterministic trend suggests that:

- The trend which stands for technological progress, is stochastic (Figure 2) that can be captured by OLS;
- The signs of all parameters are *a-priori* expecta tions except price recovery and price cuts elasticities are zero and equal given that both of them are insignificant;
- The estimated price elasticities have the following relationship $|\widehat{\lambda_p^{max}}|>\widehat{\lambda_p^{rec}}|=|\widehat{\lambda_p^{cut}}|$ the estimated short run and long run price-max, price-recovery and price-cut elasticities are -0.28,-0.10, and -0.76, 0, 0 respectively;
- the estimated short and long run income elasticities are 0.51 and 1.03 which are somewhat larger than the estimated price-max elasticity - consistent with previous studies.

Figure 2: Estimated Trend for U.S. per capita Gasoline Demand (Deterministic Trend)



The regression output and diagnostic tests are given in Table 1 below.

Table 1: Regression Output and Diagonistic Tests

Variable	*Coefficient*	*Std. Errors*	*Significance*
constant	-0.699	0.15	1%
$\Delta\, p_t^{max}$	-0.277	0.034	1%
$\Delta\, y$	0.505	0.077	1%
e_{t-1}	-0.072	0.016	1%
p_{t-1}^{max}	-0.055	0.010	1%
y_{t-1}	0.205	0.048	1%
time	-0.003	0.001	1%
$\Delta\, p_t^{submax}$	-0.063	0.013	1%
$\Delta\, e_{t-1}$	0.369	0.118	1%
$\Delta\, p_{t-1}^{max}$	0.160	0.037	1%
$\Delta\, p_{t-1}^{submax}$	-0.006	0.015	1%
$\Delta\, y_{t-1}$	-0.368	0.079	1%
Rho	-0.434	0.145	1%
Diagonistics			
Sum of squared residuals	0.005	Scwarz B.I.C.	-148.85
Std. Error of regressions	0.011	Akaike Information Criteria	-161.78
Adjusted R squares	0.794	Log Likelihood	-174.78

ii) For the stochastic trend approach with fixed elasticities:

$$\widehat{e_t} = 0.45112y_t - 0.20385p_t^{max} - 0.09453p_t^{rec} - 0.03463\ Level\ Break\ 1979 + \mu_{2005}$$

where μ_{2005} = -4.47289 with a slope 0.00453

It was necessary to include a level intervention in 1979 in order to maintain the normality of the residuals and auxiliary residuals. As discussed in the methodology section the irregular, the slope and level residuals should be normally distributed, and during the estimation process it was found that some interventions were needed to ensure this condition is maintained. From a statistical standpoint, the existence of such interventions in the STSM might be a sign of a structural break and instability over the estimation period; however, from an economic standpoint, according to Harvey (1997) the interventions provide valuable information about certain events and periods that affects energy consumption behaviour and therefore warrants further investigation.

The estimated U.S. gasoline demand model with fixed coefficients, asymmetric price responses and stochastic trend suggests that:

- the level intervention in 1979 might reflect a big change in price expectations that is not captured by the price-max variable, resulting in a permanent decrease in the U.S. per capita gasoline consumption of about 3½%;
- The UEDT is stochastic (Figure 4) that can be captured by STSM;
- the signs of all parameters accord with *a-priori* expectations;
- the estimated price elasticities have the following relationship $|\widehat{\lambda_p^{max}}|>\widehat{\lambda_p^{rec}}|>|\widehat{\lambda_p^{cut}}|$[3] which also accords with *a-priori* expectations, i.e. the estimated price-max, price-recovery and price-cut elasticities are -0.20,-0.10 and 0 respectively;
- the estimated income elasticity is 0.45 which is somewhat larger than the estimated price-max elasticity - consistent with previous studies.

The regression output and diagnostic tests are given in Table 2 below.

[3] $\widehat{\lambda_p^{cut}}$ being zero given it is insignificant and hence excluded from the preferred equation.

Table 2: Regression Output and Diagnostic Tests (Stochastic Trend)

Variable	*Coefficient*	*T-Value*	*Probability*
Level Break 1979	-0.0346	2.99	0.004
λ_y	0.4511	6.49	0.000
λ_p^{max}	-0.2039	5.21	0.000
λ_p^{rec}	-0.0945	3.91	0.000

Residuals		***Auxiliary Residuals***	***Irregular***	***Level***	***Slope***
Std. Error	0.974	*Std. Error*	0.965	0.982	0.980
Normality	0.265	*Normality*	0.346	0.667	0.133
Skewness	0.903	*Skewness*	0.912	0.452	0.164
Kurtosis	0.104	*Kurtosis*	0.146	0.622	0.147
H(17)	0.510				
r(1)	-0.008				
r(8)	-0.032				
DW	1.957				
Q(8,6)	2.501				

Goodness of Fit		***Hyperparameters***	
p.e.v.	0.0002	Level	0.00008
p.e.v./m.d.^{2}	0.8747	Slope	0.00004
R^2	0.9959	Irregular	0.000001
R_d^2	0.7974	*Nature Of Trend*	*Local Trend Model*

Prediction Tests:		***Information criterion Akaike (AIC)***	
Cusum t(8)	0.49	AIC	-8.59
Failure χ^2 (8)	0.69		

- *Model estimation and t-statistics are from STAMP 8;*
- *Model includes an level break for the year 1979;*
- *Prediction Error Variance (p.e.v.), Prediction Error Mean Deviation (p.e.v./m.d.2) and the Coefficients of Determination (R^2 and $R_d{}^2$) are all measures of goodness-of-fit;*
- *Normality (corrected Bowman - Shenton), Kurtosis and Skewness are error normality statistics, all approximately distributed as χ^2 (2); as χ^2 (1); as χ^2 (1) respectively;*
- *H(17) is a Heteroscedasticity statistic distributed as F(17,17);*
- *r(1) and r(8) are the serial correlation coefficients at the equivalent residual lags, approximately normally distributed;*
- *DW is the Durbin-Watson statistic;*
- *Q(8,6) is the Box – Ljung statistic distributed as χ^2(6);*
- *Failure is a predictive failure statistic distributed as χ^2 (8);*
- *Cusum is a mean stability statistic distributed as the Student t distribution; both found by forecasting the preferred model 1998 thru 2005;*
- *The graphical presentation of Prediction tests are given in Figure 2.*
- *Information Criterion Akaike (AIC) compensates for the number of estimated parameters in the model so that comparing models that have different number of parameters become possible, with smaller AIC values indicating better fitting model.*

Figure 3: Prediction Graphics

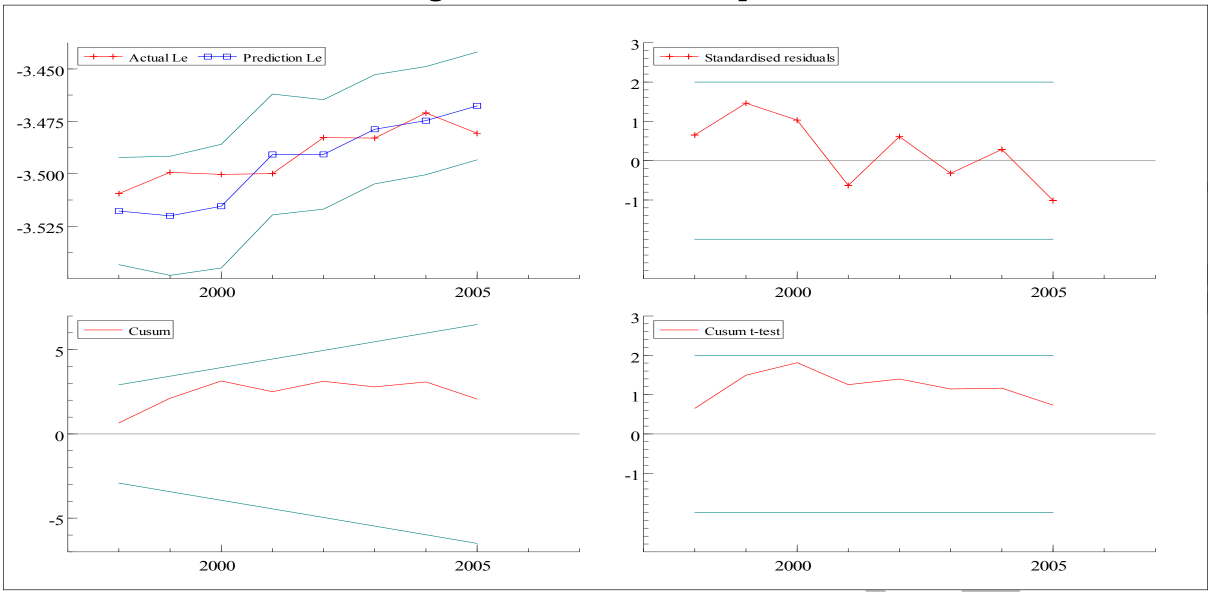
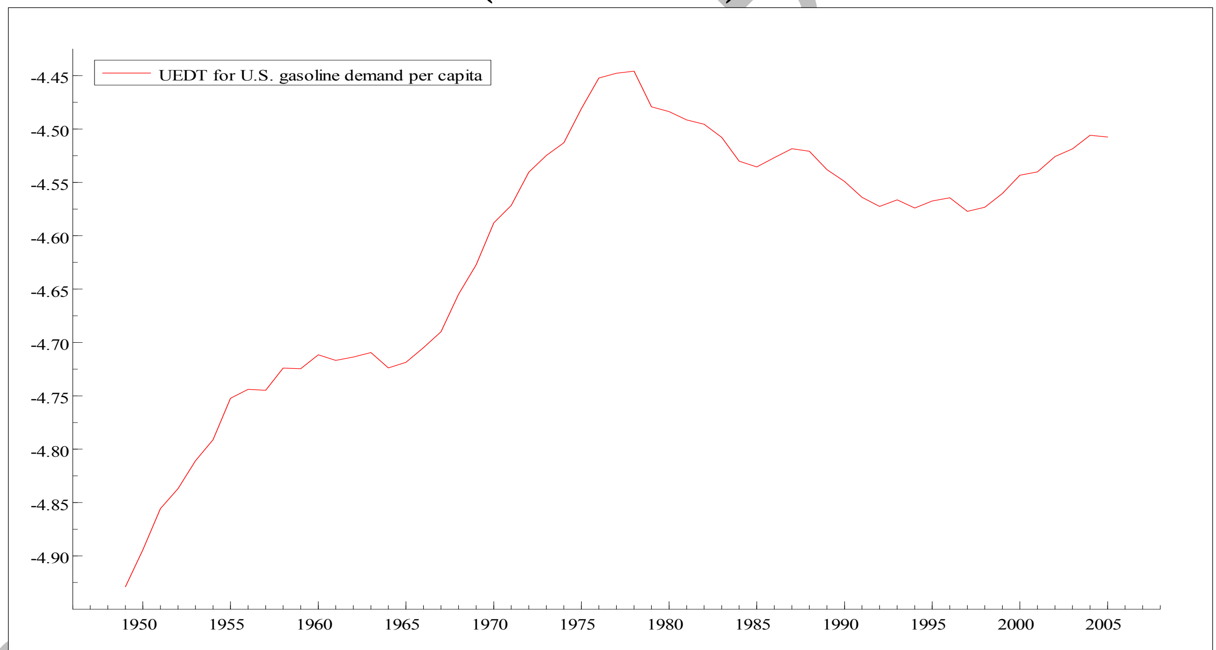


Figure 4: Estimated UEDT for U.S. per capita Gasoline Demand (Stochastic Trend)



iii) For the stochastic trend approach with time varying elasticities:

$$e_{2005} = 0.455534y_{2005} - 0.24831p_{2005}^{max} - 0.083233p_{2005}^{rec} — 0.0305781p_{2005}^{cut} -$$

$$0.1793\ Outlier1979\ \ - 0.02309Slopebreak1978\ + \mu_{2005}$$

where μ_{2005} = -3.86202

The estimated U.S. gasoline consumption model with time varying coefficients, stochastic trend and asymmetric price responses suggest that:

- the slope intervention in 1978 might reflect a big change in price expectations that is not captured by the price-max variable, resulting in a permanent slope decrease in the U.S. per capita gasoline consumption of about 2%;
- the outlier in 1979 might reflect a supply disruption because of the oil shock which cause a temporary decrease (pulse effect) of about 1.8%;
- The UEDT (Figure 6) is stochastic that can be captured by STSM;
- the signs of all parameters accord with *a-priori* expectations;
- the estimated price elasticities have the following relationship $|\widehat{\lambda_p^{max}}|>\widehat{\lambda_p^{rec}}|>|\widehat{\lambda_p^{cut}}|$ which also accords with *a-priori* expectations, i.e. the estimated price-max, price-recovery and price-cut elasticities are -0.25,-0.08 and -0.03 respectively;
- the estimated income elasticity is 0.45 which is somewhat larger than the estimated price-max elasticity - consistent with previous studies.

The regression output and diagnostic test are given in Table 3 below.

Table 3: Regression Output and Diagnostic Tests (Stochastic Trend with TVP)

Variable	***Coefficient***	***T-Value***	***Probability***
Slope Break 1978	-0.0179	-2.30	0.026
Outlier 1979	-0.0231	-2.21	0.031
λ_y	0.4555	-	-
λ_p^{max}	-0.2483	-	-
λ_p^{rec}	-0.0832	-	-
λ_p^{cut}	-0.0305	-	-

Residuals		***Auxiliary Residuals***	***Irregular***	***Level***	***Slope***
Std. Error	0.966	*Std. Error*	0.994	1.002	0.972
Normality	0.502	*Normality*	0.331	0.494	0.643
Skewness	0.758	*Skewness*	0.978	0.956	0.376
Kurtosis	0.257	*Kurtosis*	0.137	0.236	0.750
H(16)	0.550				
r(1)	0.048				
r(8)	-0.078				
DW	1.863				
Q(8,6)	4.276				

Goodness of Fit		***Hyperparameters***	
p.e.v.	0.0001	Level	0.00008
p.e.v./m.d.^{2}	0.9623	Slope	0.00003
R^2	0.9963	Irregular	0.000003
R_d^2	0.8188	*Nature Of Trend*	*Local Trend Model*

Prediction Tests:		***Information criterion Akaike (AIC)***	
Cusum t(8)	0.48	AIC	-8.59
Failure χ^2 (8)	0.69		

Model estimation and t-statistics are from STAMP 8;

- *Model includes an level break for the year 1979;*
- *Prediction Error Variance (p.e.v.), Prediction Error Mean Deviation (p.e.v./m.d.2) and the Coefficients of Determination (R^2 and $R_d{}^2$) are all measures of goodness-of-fit;*
- *Normality (corrected Bowman - Shenton), Kurtosis and Skewness are error normality statistics, all approximately distributed as χ^2 (2); as χ^2 (1); as χ^2 (1) respectively;*
- *H(16) is a Heteroscedasticity statistic distributed as F(16,16);*
- *r(1) and r(8) are the serial correlation coefficients at the equivalent residual lags, approximately normally distributed;*
- *DW is the Durbin-Watson statistic;*
- *Q(8,6) is the Box – Ljung statistic distributed as χ^2(6);*
- *Failure is a predictive failure statistic distributed as χ^2 (8);*
- *Cusum is a mean stability statistic distributed as the Student t distribution; both found by forecasting the preferred model 1998 thru 2005;*
- *The graphical presentation of Prediction tests are given in Figure 4.*

- *Information Criterion Akaike (AIC) compensates for the number of estimated parameters in the model so that comparing models that have different number of parameters become possible, with smaller AIC values indicating better fitting model.*

Figure-5 Prediction Graphics(Stochastic Trend with TVP)

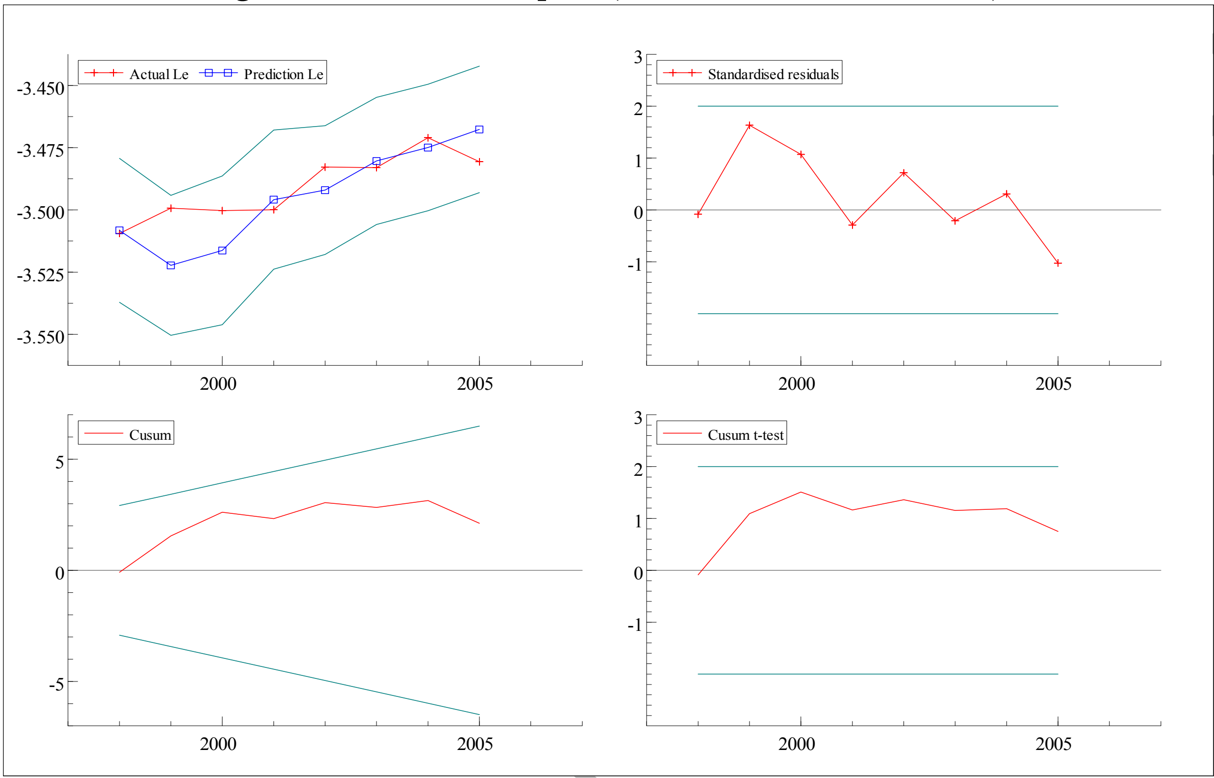
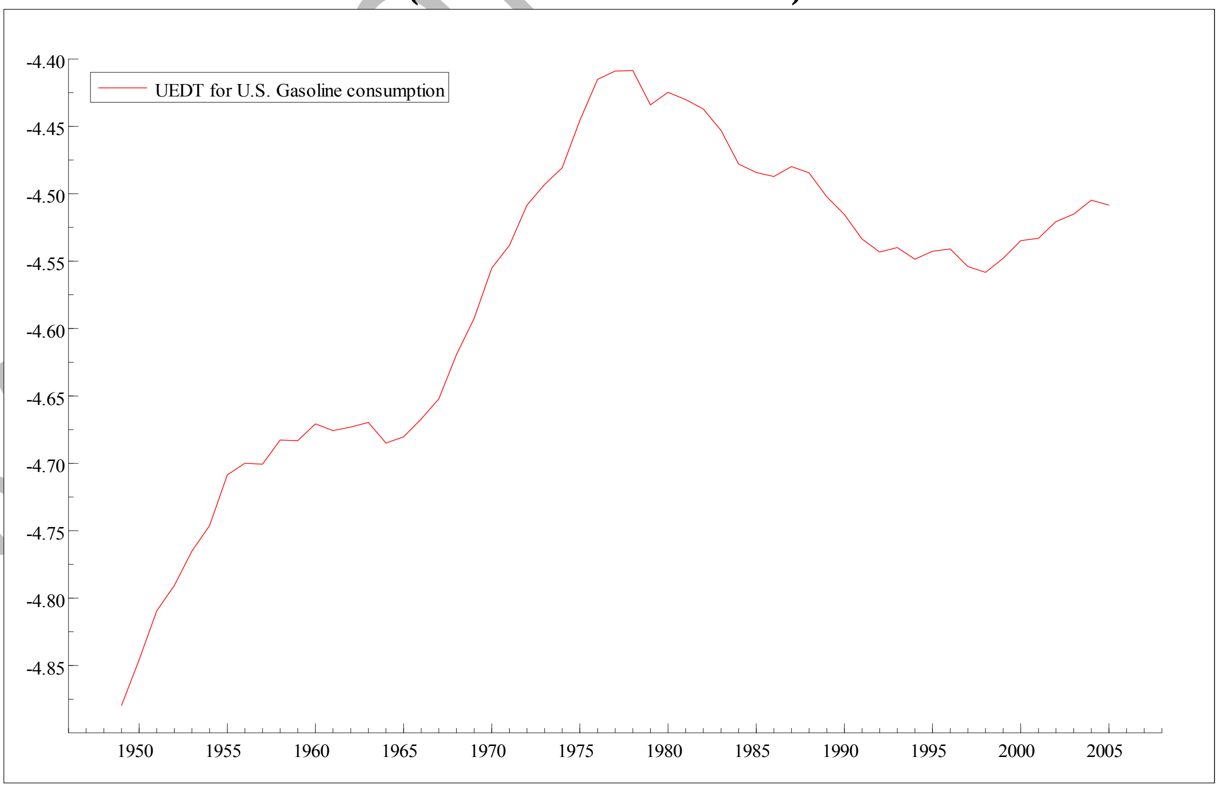


Figure-6: Estimated UEDT for U.S. per capita Gasoline Demand (Stochastic Trend with TVP)



5. Summary and Conclusion

This paper estimates a U.S. gasoline demand per capita demand function by applying three different techniques namely i) an error correction model with a deterministic trend with constant elasticities, ii) a stochastic exogenous trend model with constant elasticities; and iii) a stochastic trend with time varying elasticities model over the period 1949 to 2005.

The empirical outcome of this study suggests that;

- For the deterministic trend approach the estimated income, price max, price recovery and price cut elasticities are 0.51, -0.28, 0, 0 in the short run and 1.03, -0.76, 0, 0 in the long run respectively and the estimated UEDT is decreasing constantly with a slope of -0.003 over the estimation period;
- For the stochastic approach the estimated income, price max, price recovery and price cut elasticities are 0.45, -0.20, -0.09, 0 respectively, both in the long run and the short run and the estimated UEDT is decreasing and increasing (stochastic process) over the estimation period;
- For the stochastic trend with time varying elasticities approach the estimated income, price max, price recovery and price cut elasticities are 0.46, -0.25, -0.08 and -0.03 respectively (although the elasticities are changing over time the change is insignificant), both in the short term and long term and the estimated UEDT is non-linear with periods when it is increasing and periods when it is decreasing.

In all these three approaches the asymmetric price responses are take into account with different trend and coefficient specifications. The similarity of the stochastic trend model with fixed coefficients and the stochastic trend with time varying coefficients suggest that the main reason for the different (end) elasticities is the different trend component identified by the three approaches – not the time varying nature of the elasticities. However the short run elasticities of all three approaches are similar as well suggesting that in stochastic trend approach the long run income and price responses are included in the trend component with a set of unobserved components together.

In Huntington (2010) although the asymmetric price responses are investigated the UEDT is not taken into account and the research concluded that income, price max, price recovery and price cut elasticities are 1.03, -0.76, 0 and 0 respectively in the long run. However the fixed coefficients model with stochastic trend suggests that these elasticities are 0.45, -0.20, -0.10 and 0 respectively. Furthermore the TVP model with stochastic trend suggests the same elasticities are 0.46, -0.25, -0.08 and -0.03 respectively.

Therefore, the different estimation and the inclusion of the UEDT appear to have a large impact. Arguably, given that that a more general specification is used ii and iii, the results are more robust. However, the failure to capture any dynamics in the model by these two approaches, may suggest that the Huntington (2010) results are more robust. As the outcome of ii and iii are similar, it is believed that the source of different elasticities might be as a result of different estimation techniques (MLE Vs OLS) or different trend structure (Stochastic Vs. Deterministic). More research is needed to attempt to reconcile these differences.

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