Regent's Working Papers in Business & Management 2016
Working Paper 1602: RWPBM1602

Energy Price uncertainty and market collusion: Disequilibrium Regime Switching Model

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Abstract: This article is concerned with Disequilibrium Regime Switching (DRS) model to capture different regimes in the energy markets. The purpose is to illustrate potential regimes in gasoline market. Following a suggestion in Hunter and Tabaghdehi (2013) that gasoline markets may not be efficient either across regions or within local markets. The Markov model may also be used as a benchmark to make comparison with other methods and it specifies that deviations from long-run equilibrium have an effect on gasoline price dynamics and captures two different regimes.

Keywords: Disequilibrium; Regime switching; Market efficiency; Price proportions; Collusion; Supply; Demand.

Word count: 4,761.

1. Introduction

Global demand for gasoline is affected by technological change, global population growth, motor vehicle ownership and heating oil consumption. Since the last decade we can clearly observe that gasoline prices are highly volatile and this makes price modelling and forecasting, and risk management very challenging. Global warming and greenhouse gas emissions interact with the demand for gasoline. However political instability in the oil producing countries caused a remarkable disruption in energy supply, market equilibrium and prices since the 1990s.

In the gasoline market the equilibrium price is set at the intersection point of market aggregated demand and aggregated supply. Gasoline demand modelling, following Ramsey et al (1975), Dhal (1979), and Yang and Hu (1984) considers supply and demand to emphasize supply along with demand in the gasoline market, and also the level of supply-side intervention and policy in the gasoline market. Hunter and Tabaghdehi (2013) examined gasoline price behaviour across different regions and companies in the long-run and the short-run, specifying that the market structures and price dynamics may differ across regions.

For a product such as gasoline there is little quality uncertainty as the quality of the product is regulated for reasons of safety and the manufacturer needs to meet a standard for the product to avoid litigation from the public, corporate employees and the motor vehicle manufacturers who might engage in a class action where such failure to impact their reputation and affect sales.

Hence price uncertainty is an important issue and it might reflect the potential for disequilibrium in the energy market (Arrow, 1962). Hence here, using different regime switching models we investigate the market disequilibrium caused by imperfect competition or price leadership in gasoline market. Yang and Hu (1984) formulate an endogenous switching model to examine a gasoline market but their analysis paid no attention to non-stationarity. Hence, in this article we formulate two different switching models and examine their behaviour and the nature of the different regimes with focus on non-stationarity.

In section 2 we review essential literature on disequilibrium modelling and markov regime switching model. Section 3 identifies the data for the empirical analysis and analyse the disequilibrium model. In part 4 we test for Markov Regime Switching Model to capture different regimes. Finally, in Section 5 we offer our conclusions.

2. Relation between Literature and Methodology

The study of demand and the notion of an economy or a market is not in full equilibrium was investigated in early literature by Hicks (1936), Arrow (1962), Maddala and Nelson (1974), Rosen and Quandt (1978), Maddala (1983), Muellbauer (1983), Andrews and Nickell (1985), and Robinson (1994). Under disequilibrium hypothesis only one regime can be observed at the time[1] . However the disequilibrium approach derived initially to estimate demand and supply equation in a static context was not developed to handle non-stationary series. Here a static switching structure is devised to identify demand via the min condition and to measure the long-run market failure.

At disequilibrium the market follows min condition shown in equation 1;

$$Q_t = \min(D_t, S_t) \qquad (1)$$

where:

- Q_t = St if $D_t > S_t$, this indicates there is excess demand and quantity transacted is equal to quantity supplied in the market
- Q_t = Dt if $D_t < S_t$, this implies there is excess supply in the market and quantity transacted is equal to quantity demanded in the market

[1]Muellbauer (1983) suggested at the aggregate level the switch would be smoothed that gave rise to continuous switching.

Yang and Hu (1984) formulated a gasoline market model testing disequilibrium that may have been caused by either imperfect price adjustment by buyers and sellers or institutional price restrictions. In Yang and Hu (1984) they take no account of non-stationarity or the potential that the estimations may need to handle an autoregressive unit root. In their estimation using the errors are serially correlated and the test statistics are non-standard. To address this, we applied the Phillips-Hansen fully modified regression to estimate the parameter of the long-run relation. Phillips and Hansen (1990) developed a semi parametric method of estimation to take account of moving average or autoregressive errors. The Phillips-Hansen method estimates the parameters of a single cointegration relation by fully modified regression. Consider the OLS regression below;

$$y_t = \alpha_0 + \alpha_1 x_t + \varepsilon_t \qquad (2)$$

where y_t is an I(1) variable, x_t is a k×1 vector of I(1) regressors and the first-difference of x_t is stationary: $\Delta x_t = \mu + \upsilon_t$.

The distribution of the OLS estimator in equation (2) with non-stationary series is non-standard and the parameters are super-consistent when there is cointegration, although the t-tests are not well defined. Hence, The Phillips and Hansen fully-modified OLS estimator computes an estimate of the long-run variance that corrects the regression to takes account of the serial correlation associated with the potential unit root in the error.

3. Data and Methodology

Here we analysed disequilibrium switching model using the regular gasoline sales level (Q), regular retail gasoline real price (RP), WTI crude oil price (P_W), consumer price index (CPI), producer price index (PPI), gasoline unleaded regular cost of insurance and freight (Cost), total energy consumption (EXP), city-gate gas real price (P_{GAS}), disposable income (Y), automobile sales (Auto), price of the residual fuel oil (P_{Res}), price of the distillate fuel oil (P_{dst}), and refineries net input of crude oil (RI) from 1992:1 to 2012:9 in the US[2]. The data in log levels and their differences are graphed in Figures 1 and 3, and the frequency distributions of both datasets are plotted in Figures 2 and 4.

From Figures 1 and 3, the price level has drift whereas the differenced series appear to move randomly around the fixed mean. Furthermore Figure 1 suggests LEXPN, LRI, LCPI, LAUT and LQ are seasonal. Considering Figures 2 and 4, the frequency distributions of all the log data (Figure 2) suggests the series do not revert to mean and overall might suggest two regimes, while the frequency distribution of data in their log differences (Figure 4) seems to be closer to normality.

Hence, using the same variables as Yang and Hu (1984) and by applying Phillips-Hansen modified method we identified following switching disequilibrium equation:

$$Q_t = \gamma_0 + \gamma_1 D_d + \gamma_2 d^d P_t + \gamma_3 d^d Y_t + \gamma_4 d^d Aut_t + \omega_{dt} + \gamma_5 \; d^s P_t + \gamma_6 d^s P_{res\ t} + {}_{\gamma 7}{}^{ds} P_{dst\ t} + \gamma_8 d^s P_w t + \gamma_9{}^{ds} RI_t + \omega_{st}. \qquad (3)$$

In equation 3, D_t is aggregated gasoline demand and S_t is aggregated gasoline supply, P_t is the regular retail gasoline real price, Y_t is disposal income, and Aut_t is automobile sales, and ω_{dt} include explanatory variables not clarified in the demand function. Similarly in the supply side equation the P_w is the WTI crude oil price[3] , P_{res} is price of residual fuel oil, and P_{dst} is price of distillate fuel oil to analyse the substitution effect in the production process[4], RI is refineries net input of crude oil, d^d is dummy demand and d^s is dummy supply, and ω_{st} comprise unexplained explanatory variables not illuminated in the supply function.

[2]The data set have been obtained from energy information administration website (www.eia.gov), and Bureau of Labour Statistics website (www.bls.gov).
[3]Hotelling (1932) determined that profit-maximising price-taking firms based their prices on selection of their input and output levels. Thus the crude oil price plays an important role in the supply function for the gasoline market.
[4]No.2 distillate fuel oil is used in high-speed diesel engines, such as those in railroad locomotives, trucks, and automobiles.

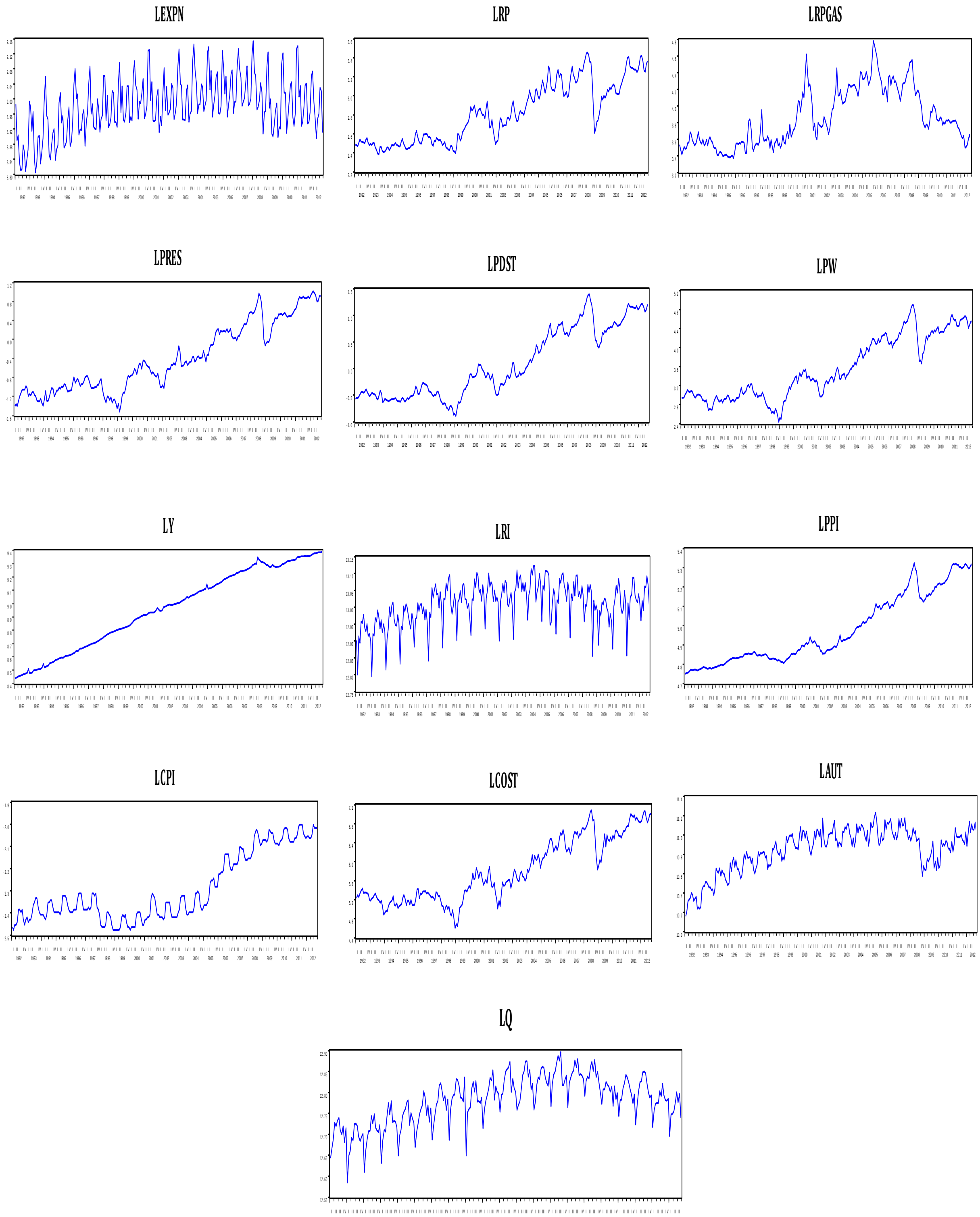

Figure 1: Plot of LExpn, LRP, LRPGas, LPRes, LPdst, LPW, LY, LRI, LPPI, LCPI, LCost, LAUT and LQ in the US.

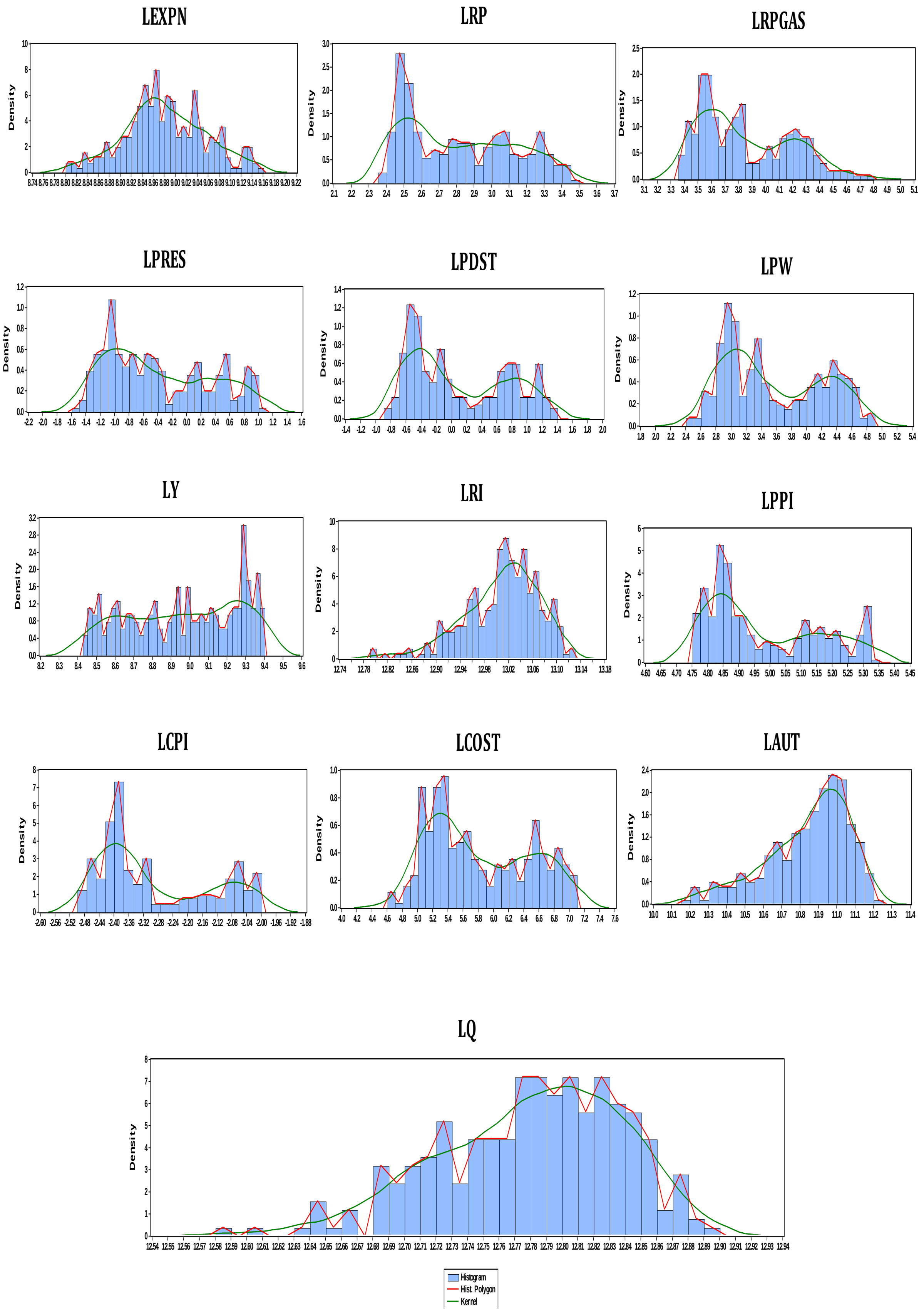

Figure 2: Frequency distributions of LExpn, LRP, LRPGas, LPRes, LPdst, LPW, LY, LRI, LPPI, LCPI, LCost, LAUT and LQ in the US.

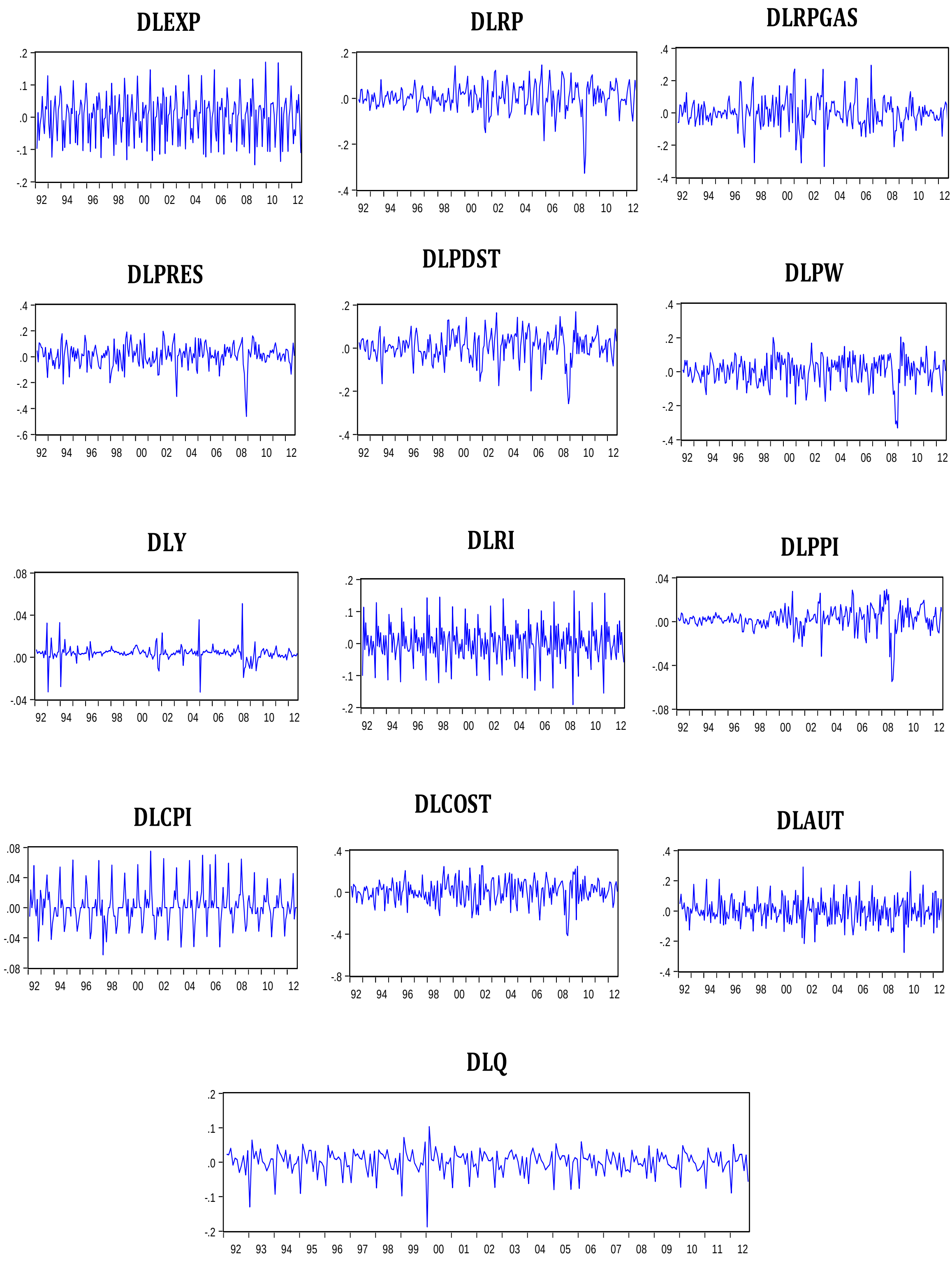

Figure 3: Plot of DLEXP, DLRP, DLRPGAS, DLPRES, DLPDST, DLPW, DLY, DLRI, DLPPI, DLCPI, DLCOST, DLAUT and DLQ in the US.

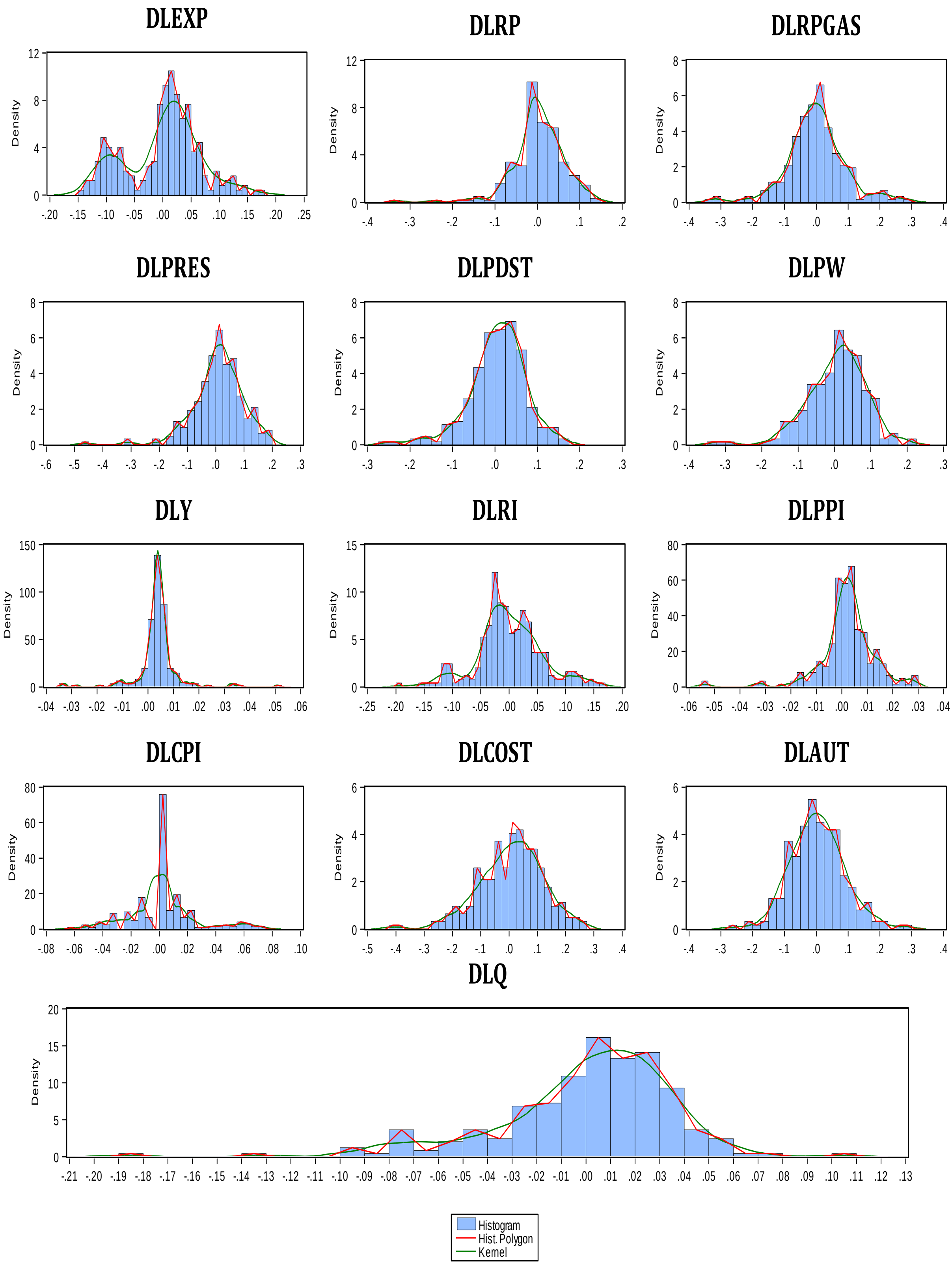

Figure 4: Frequency distributions of DLEXP, DLRP, DLRPGAS, DLPRES, DLPDST, DLPW, DLY, DLRI, DLPPI, DLCPI, DLCOST, DLAUT and DLQ in the US.

To identify the dummy for demand (d^d) and supply (d^s) we evaluated relative price from the following equation;

$$\Delta lp_{\text{Retail Price}} - \Delta lp_{\text{Consumer Price Index}}$$

where:
• $\Delta lp_{\text{Retail Price}} - \Delta lp_{\text{Consumer Price Index}} > 0$, indicates that the relative price is increasing and D>S which classifies d^s
• $\Delta lp_{\text{Retail Price}} - \Delta lp_{\text{Consumer Price Index}} < 0$, specifies that there is a decrease in the relative price identifying that D<S and that indicates d^d

All the above are in logarithms and regime dependent. The results for the above disequilibrium switching estimations are presented in Table 1. In the demand-side equation all estimated parameters are statistically significant with their expected sign. A 1% increase in the retail gasoline price will reduce the demand for gasoline by 3.43% and this implies that consumers are sensitive to gasoline price changes in changing their gasoline consumption level. A significant positive income coefficient indicates that an increase in consumer income and automobile sales level may increase gasoline demand in the market. This result indicates that a 1% increase in the consumer income will increase the gasoline demand by 2.87% and it shows consumers are responsive to their income changes in changing gasoline demand.

The positive sign of γ_5 indicates that the price of gasoline affect a gasoline supply positively that is consistent with economic theory. Its significance value of 3.07 identifies that refiners are sensitive to gasoline price changes in changing output level. However the negative sign of γ_6 and γ_7 indicates that residual fuel oil and distillate fuel oil price rises will reduce the supply of gasoline. While insignificant coefficients γ_6 and γ_7 identify that change in gasoline production cannot be attributed to fluctuations in price of residuals and distillate fuel oil. The crude oil price, which explains the effect of the input price on gasoline supply, has an expected negative sign but statistically insignificant identifying that change in gasoline production cannot be impacted by input price fluctuations significantly. Finally, the refineries net input of crude oil which explains the scale effect in the supply equation has a negative sign and it is statistically insignificant indicating that it appears not to affect gasoline supply consequently.

As we see in Table 1 the supply equation mostly contains insignificant coefficients and to further investigate this relation we estimate the new model below. However, from economics theory gasoline consumption might be highly dependent on other factors such as: consumer price index, total energy expenditure, and the city-gate real gas price as a substitute good that affects gasoline consumer's consumption behaviour. Similarly the firm supply may be affected by other factors such as the cost of production and producer price index. Hence we estimated the following disequilibrium switching equation using Phillips and Hansen modified method;

$$Q_t = \varphi_0 + \varphi_1 D_d + \varphi_2 d^d P_t + \varphi_3 d^d CPI_t + \varphi_4 d^d EXP_t + \varphi_5 d^d P_{Gas} + \varphi_6 d^d Y_t + v_{dt} + \varphi_7 {}^{ds} P_t + \varphi_8 d^s C_t + \varphi_9 {}^{ds} PPI + \varphi_{10} {}^{ds} PW_t + v_{st} \quad (4)$$

where P_t is the price of the gasoline, CPI is consumer price index, and EXP is total energy expenditure, and P_{Gas} is city-gate gas real price, Y_t is disposal income, and v_{di} includes explanatory variables not clarified in the demand function. Also in the supply-side equation P_W is the price of the WTI crude oil[5], PPI is the producer price index, and C_t is unleaded regular gasoline costs (insurance and freight), and v_{st} comprise unexplained explanatory variables in the supply equation.

[5]Hotelling (1932) identified that profit-maximising price-taking firms based to their prices they determine their input and output level. Thus crude oil price plays an important role in the supply function of the gasoline market.

The results for the estimation of equation 4 are presented in the Table 2. For the demand-side equation all estimated parameters are significant with expected sign except φ_3 that could be due to the high usage of the other energy sources in comparison with gasoline. The φ_2 indicates that a 1% increase in the retail gasoline price will reduce the demand for gasoline by 11.19%, this implies that consumers are highly sensitive to gasoline price in changing their gasoline consumption level. The income coefficient (φ_6) suggests that a 1% increase in consumer income will increase the gasoline demand by 6.26% and it shows consumers are responsive to income in changing their gasoline demand level. In the supply-side of the equation only φ_{10} has the expected sign but it is statistically insignificant signifying that gasoline supply is not strongly affected by other factors.

Comparing estimations 3 and 4 via the regression that imposes the switch, the variables used in equation 4 seem to explain the model more appropriately as most of the variables are statistically significant. The significant coefficient subject to all series being I(1) implies that there is a long-run relation and this suggests that models based on the supply and demand regimes give rise to meaningful long-run equations.

	Variable	Parameter	Bartlett Weighs, truncation lag=64
Demand-side Equation		γ_0	14.16** [0.00] (0.89)
	D_d	γ_1	-3.78** [0.00] (0.94)
	P_t	γ_2	-3.43** [0.00] (0.03)
	Y_t	γ_3	2.87** [0.00] (0.04)
	Aut_t	γ_4	10.21** [0.00] (0.03)
Supply-side Equation	P_t	γ_5	3.07** [0.00] (0.05)
	$P_{res\ t}$	γ_6	-1.005 [0.92] (0.03)
	$P_{dst\ t}$	γ_7	-3.26 [0.74] (0.05)
	$P_{w\ t}$	γ_8	-0.02 [0.98] (0.05)
	RI_t	γ_9	-0.34 [0.73] (0.07)

Note: $Q_t = \gamma_0 + \gamma_1 D_d + \gamma_2 d^d P_t + \gamma_3 d^d Y_t + \gamma_4 d^d {}_{Autt} + \omega_{dt} + \gamma_5 d^s P_t + \gamma_6 d^s P_{res\ t} + {}^{\gamma 7ds} P_{dst\ t} + \gamma_8\ d^s P_{w\ t} + \gamma_9\ d^s RI_t + \omega_{st}$. All variables are in log scales and all prices are real price data. Values without the brackets presents Fully Modified Phillips-Hansen t-statistic, values in ( ) shows standard errors, and values in [ ] displays p-values. **is significant at the 1% and*is significant at the 5%.

Table 1: Static Disequilibrium Switching Estimation 1.

	Variable	Parameter	Bartlett Weighs, truncation lag=64
Demand-side Equation		φ_0	24.17** [0.00] (0.62)
	D_d	φ_1	-8.91** [0.00] (1.19)
	P_t	φ_2	-11.19** [0.00] (0.06)
	CPI_t	φ_3	9.71** [0.00] (0.09)
	EXP_t	φ_4	7.15** [0.00] (0.13)
	P_{Gas}	φ_5	-3.21** [0.00] (0.06)
	Y_t	φ_6	6.26** [0.00] (0.00)
Supply-side Equation	P_t	φ_7	-0.82 [0.41] (0.09)
	C_t	φ_8	4.31** [0.00] (0.09)
	PPI	φ_9	-5.31** [0.00] (0.15)
	$P_{W\,t}$	φ_{10}	-1.18 [0.24] (0.08)

Note: $Q_t = \varphi_0 + \varphi_1 D_d + \varphi_2 d^d P_t + \varphi_3 d^d CPI_t + \varphi_4 d^d EXP_t + \varphi_5 d^d P_{Gas} + \varphi_6 d^d Y_t + v_{dt} + \varphi_7 d^s P_t + \varphi_8 d^s C_t + \varphi_9 d^s PPI + \varphi_{10} d^s P_{W\,t} + v_{st}$. All variables are in log scales and all prices are real price data. Values without the brackets presents Fully Modified Phillips-Hansen t-statistic, values in ( ) shows standard errors, and values in [ ] displays p-values**is significant at the 1% and*is significant at the 5%.

Table 2: Static Disequilibrium Switching Estimation 2.

4. Markov Regime Switching Model (MRSM)

Here, the intention is to use Markov switching method as a mechanism to identify supply and demand regimes in the long-run. Each regime is characterized by a different parameterisation. We focus on modelling the gasoline market as a single market and to observe both sides of the market. The primary method to estimate disequilibrium models was investigated in a static context by Fair and Jaffee (1972), Fair and Kelejian (1974), and Maddala and Nelson (1974).

Considering a static model would usually be poorly specified especially in relation to serial correlation. In Robinson (1994) a number of corrections were applied to take account of this serial correlation and also in Davidson et al (1978) the notion of disequilibrium in dynamic equations was embedded in error correction models. Furthermore, Muellbauer (1983) developed at the macro level continuous switching when markets are aggregated. Also Maddala (1983) discussed disequilibrium where the latent variable equilibrium term is determined by switching and this is embedded in an error correction term. Hence here we analysed a dynamic model of Markov switching error correction model (MSECM) to describe the short-run variation in gasoline sales in the US from 1993 to 2012. The regime switching ECM can be explained as an expanded linear error correction model by allowing the short-run parameters to switch in different regimes. MSECM signifies that when the system is in a stable state the error correction takes place and in the unstable state there are deviations from the long-run equilibrium that cannot be corrected through the ECM.

In terms of the disequilibrium model these would be the same when there is correction to another equilibrium state.

Here the error correction model is also embedded in a Markov switching equation as Markov regime switching error-correction model (MRSECM) to determine regimes that are latent in the data.

Let us assume that the linear regression model is; $y_t = \beta X_{ti} + u_t$

where y_t denotes the dependent variable, X_{ti} denotes the matrix of independent variables. The above regression model is separated into two relations for;

Regime (1): $y_i = \beta_1' X_{1i} + u_{1i}$ if $\gamma' Z_i \geq u_i$ (5)
Regime (2): $y_i = \beta_2' X_{2i} + u_{2i}$ if $\gamma' Z_i < u_i$ (6)

where Z_i determines the i^{th} observation that is generated for each regime, based on the unknown coefficient vector γ' that defines the switch and u_{1i} and u_{2i}, are assumed normally distributed with mean zero and variance-covariance matrix;

$$\boldsymbol{\sigma} = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{1u} \\ \sigma_{21} & \sigma_2^2 & \sigma_{2u} \\ \sigma_{1u} & \sigma_{2u} & 1 \end{bmatrix}$$

where σ_1 shows the variance of the first regime and σ_2 indicates the variance of the second regime. If $\sigma_1 \neq \sigma_2$ and $\beta_1 \neq \beta_2$ then the regression relation switches between two regimes[6]. The Markov regime switching error correction model is defined on the first-differenced monthly relative gasoline price;

$$(\Delta LP_g - \Delta LCPI)_t = \beta_{r,i}(LP_g - LCPI)_{t-1} + \sum_{i=1}^{p-1}\gamma_{s,i}(\Delta LP_g - \Delta LCPI)_{t-i} + \delta_{s,i}(LCPI - LPPI)_{t-1} + \sum_{i=1}^{p-1}\zeta_{s,i}(\Delta LCPI - \Delta LPPI)_{t-i} + \sum_{i=1}^{p-1}\eta_{s,i}(\Delta LCost)_{t-i} + \sum_{i=1}^{p-1}\theta_{s,i}(\Delta LP_{WTI})_{t-i} + \sum_{i=1}^{p-1}\lambda_{s,i}(\Delta LP_{GAS})_{t-i} + \sum_{i=1}^{p-1}\kappa_{s,i}(\Delta LP_{dst})_{t-i} + \sum_{i=1}^{p-1}\nu_{s,i}(\Delta LP_{res})_{t-i} + \varepsilon_t \quad (7)$$

where[7] $\gamma_{r,i}$, $\zeta_{r,i}$, $\eta_{r,i}$,$\theta_{r,i}$, $\lambda_{r,i}$, $\kappa_{r,i}$, and $\nu_{r,i}$ are the short-run dynamics of price data which is allowed to change within the regimes, s identifies the regime at time t, and εt is the vector of error terms. Using the Markov regime switching model we describe the equilibrium correction via a non-linear algorithm that computes and maximises the empirical likelihood in this two-regime model. With a Markov process at each period (t), the probability of the switch from regime i to j can be calculated using the equation below;

$$p_{ij} = \Pr(s_{t+1} = j \mid s_t = i)$$

where the probability of remaining in a given regime i is signified as p_{ii}, consequently $p_{ij} = 1 - p_{ii}$ signifies the probability of switching from regime i to the other regime, j. Similarly p_{jj} is the probability of remaining in the regime j and $p_{ji} = 1 - p_{jj}$ is probability of switching from regime j to other regime i.

[6]By knowing which observation of the dependent variable of y was generated by which regime a Chow test can examine whether $\sigma_1 = \sigma_2$ and $\beta_1 = \beta_2$. However if this is unknown and it is not clear which of the dependent variable (y) was generated by, then Goldfeld and Quandt's D-method for switching regression might clarify this problem.
[7]P_g is gasoline retail price, P_{GAS} is gas retail real price to analyse the substitute effect in the demand process, CPI is consumer price index, PPI is producer price index, COST is unleaded regular gasoline costs (insurance and freight), P_{WTI} is WTI spot price, P_{res} is residual fuel oil price and P_{dst} is distillate fuel oil price.

Figure 5 provides a graphical illustration of smoothed regime probability of US gasoline relative price. This figure reflects the model that indicates the existence of two regimes and the switch among them. First figure in Fig. 5 indicates the real price information that we used to identify the regimes of demand and supply for the switching model.

Correspondingly Table 3 shows that parameters used in switching equation 7 are affected by the regimes and we identified that regimes are persistent and the probability of staying in regime 0 is 0.502 and the probability of staying in regime 1 is 0.465. By comparing the demand and supply dummies (d^d and d^s used in equation 3 and 4) with the regimes, we identified that regime 0 is demand regime and regime 1 is supply regime. This implies that regular gasoline costs (insurance and freight), gas retail real price, residual fuel oil price, and distillate fuel oil price significantly affect the relative real gasoline price. It is of interest to note that this would seem to lend support to the notion of switching and that equilibrium may not just be captured by the disequilibrium term related to error correction behaviour.

Assuming stationarity of price proportion based on conventional inference the two correction terms in Table 3 are significant and this implies negative reaction of gasoline market prices to CPI as indicative of demand responds, and positive reaction of gasoline market price to PPI as indicative of supply responds.

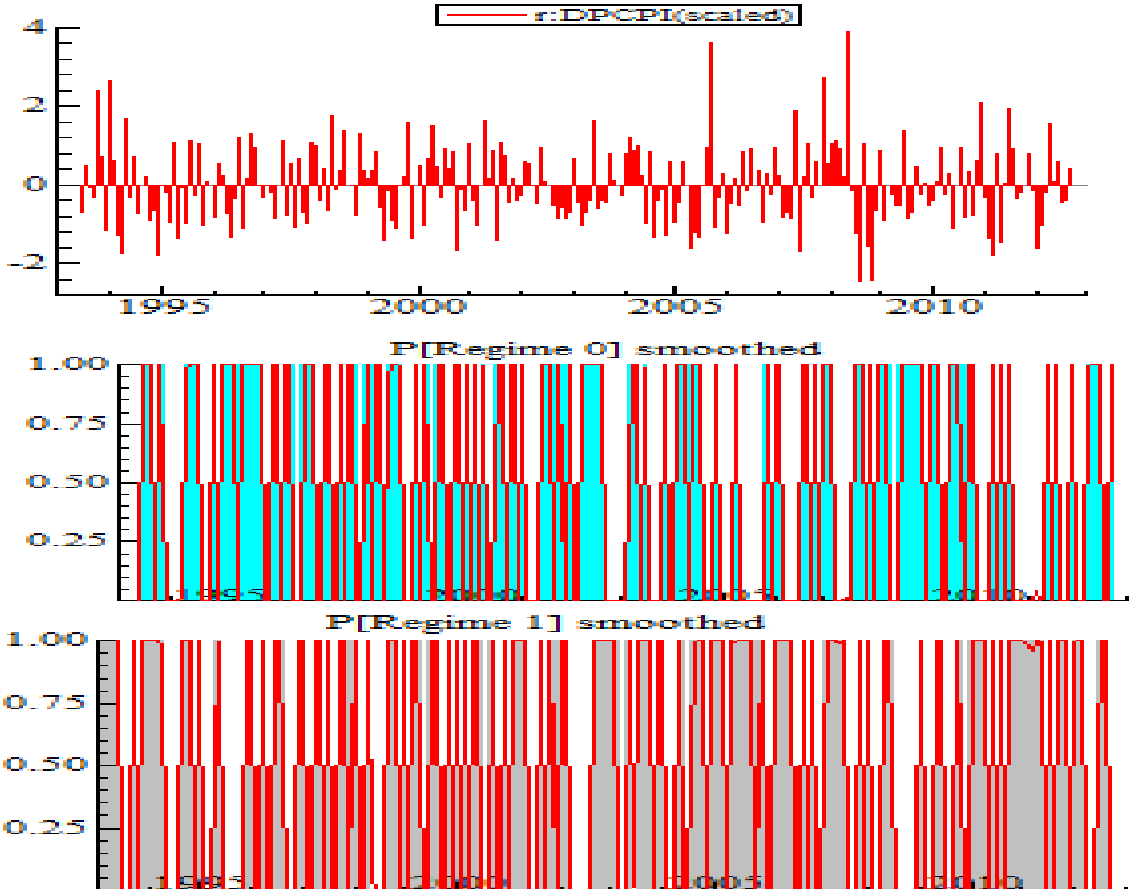

Figure 5: Smoothed regime-probability estimates for two-regime MRS EC model of US gasoline relative prices.

Variables in eq. 7	*coefficient*	*t-Statistics*	*Variables in eq. 7*	*coefficient*	*t-Statistics*	*Variables in eq. 7*	*coefficient*	*t-Statistics*
DPCPI_2	-0.668**	-16.7	DLCOST_1	0.097**	5.46	DLRPGAS_1	0.020	6.16

DPCPI_3	-0.425**	-8.86	DLCOST_2	0.157**	7.20	DLRPGAS_2	0.043**	2.78
DPCPI_5	-0.359**	-7.79	DLCOST_3	0.241**	10.3	DLRPGAS_3	0.064**	8.55
DPCPI_6	-0.295**	-5.91	DLCOST_4	0.063**	3.19	DLRPGAS_6	-0.100**	-7.22
DPCPI_7	-0.338**	-6.67	DLCOST_6	0.164**	7.61	DLRPGAS_8	0.091**	6.68
DPCPI_8	0.150**	2.76	DLCOST_7	0.225**	8.94	DLRPGAS_9	-0.070**	-3.54
DPCPI_9	-0.570**	-11.0	DLCOST_8	0.135**	5.55	DLRPGAS_10	-0.049**	2.68
DPCPI_10	0.226**	4.48	DLCOST_9	0.155**	6.60	DLRPGAS_11	-0.072**	4.02
DPCPI_12	-0.184**	-4.38	DLCOST_10	0.065**	2.96	DLPDST_2	0.070*	-5.95
DPCPI_14	0.092**	3.65	DLCOST_11	0.162**	8.54	DLPDST_4	0.240**	-3.64
DPCPI_15	-0.171**	-6.64	DLPW_1	0.137**	6.16	DLPDST_5	-0.411**	-2.43
DPCPI_16	0.338**	14.2	DLPW_2	0.074**	2.78	DLPDST_7	-0.188**	1.51
LPCPI_1	-0.011**	-2.00	DLPW_3	0.203**	8.55	DLPDST_8	-0.421**	3.26
LCPIPPI_1	0.058**	1.95	DLPW_4	-0.199**	-7.22	DLPDST_9	0.198**	4.83
DCPIPPI_1	-0.333**	-4.82	DLPW_5	0.181**	6.68	DLPDST_11	0.086**	-7.13
DCPIPPI_3	0.186**	2.34	DLPW_6	-0.088**	-3.54	DLPDST_13	-0.050	6.37
DCPIPPI_5	-0.869**	-10.8	DLPW_7	0.075**	2.68	DLPRES_1	0.070**	-4.93
DCPIPPI_6	-0.956**	-12.1	DLPW_8	0.105**	4.02	DLPRES_3	-0.071**	-3.35
DCPIPPI_7	-0.491**	-5.99	DLPW_11	-0.157**	-5.95	DLPRES_5	0.069**	-5.50
DCPIPPI_8	0.314**	3.95	DLPW_12	-0.080**	-3.64	DLPRES_6	0.074**	1.80
DCPIPPI_9	-0.228**	-2.64	DLPW_13	-0.060**	-2.43	DLPRES_7	-0.113**	6.37
DCPIPPI_10	0.520**	6.54				Constant(0)	0.417**	-9.94
DCPIPPI_12	-0.874**	-12.6				Constant(1)	0.489**	-4.78

P_{11}	0.502
P_{22}	0.465
Log-likelihood	502.20

Table 3: Dynamic Disequilibrium Switching.

5. Conclusion

In this paper we applied regime switching model on market data to identify any potential disequilibrium in the long-run. Long-run disequilibrium in energy markets indicates the need to consider the demand and supply management to improve energy market efficiency and stability. The results on the disequilibrium study, implies that the long-run gasoline price dynamics may not always correct the system. Furthermore the Markov regime switching model with two different regimes identifies there is a significant effect of regular gasoline costs, gas retail real price, residual fuel oil price, and distillate fuel oil price on retail gasoline prices in the US and consequently on the stability of correction to these regimes.

Here it has been shown that the switch model can be estimated by a single regression with the series being scaled by dummy variables of DS and DD. The dummy DS is 1 when the change in the relative price exceeds zero while DD is 1 when the change in the relative price is less than zero. With sufficient data it should be possible to utilise the two steps regression method of Engle and Granger (1987) to test whether the regression residuals are stationary. Unfortunately, the switch increases the number of parameters as the demand and supply equations are being computed simultaneously so with more than two hundred observations the available software cannot compute the critical value of Dickey Fuller test. To determine the importance of the parameters in the cointegrating regression we applied the fully modified estimation procedure of Phillips and Hansen (1990). The semi-parametric method corrects the estimator for both autoregressive and moving average errors and this implies that it is possible to determine the significance of these parameters via conventional inference as long as the regressors are I(1) except for series that are truly exogenous.

The data are then separated using the relative as compared with absolute price changes. This separation is applied to the static model of Yang and Hu (1984) on a more recent data set. However, the static model only has a long-run interpretation. Based on the estimation results, the demand curve seems well defined, while it is less easy to interpret the second relation as a supply equation. Furthermore the supply equations is that the long-run supply function is flat suggesting firms set price as a mark-up of cost.

Furthermore, the result of Markov regime switching model based on an error correction model where the adjustment coefficients switch between regimes indicates that disequilibrium is captured by the correction, but this may be unstable or relate to a further equilibrium. Moreover it indicates that deviations from long-run equilibrium have an effect on gasoline price dynamics and there are two different regimes consequently.

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