An Analysis of U.S. Gasoline Demand Elasticities

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1. INTRODUCTION

Understanding the sensitivity of gasoline demand to changes in prices and income has important implications for policies related to climate change, optimal taxation, urban pollution and congestion and national security, to name only a few. While the price and income elasticities of gasoline demand in the United States have been studied extensively, the vast majority of these studies focus on consumer behavior in the 1970s and 1980s, focusing on the price shocks from that period. However, there are a number of reasons to believe that current demand elasticities differ from these previous periods, as transportation analysts have hypothesized those behavioral and structural factors such as changing land-use patterns, implementation of the Corporate Average Fuel Economy program (CAFE), growth of multiple income households and per capita disposable income over the past several decades have changed the responsiveness of U.S. consumers to changes in gasoline price. Several recent studies show that the elasticity of gasoline demand is significantly more inelastic today than in previous decades. Consumers appear significantly less responsive to gasoline price increases (Hooker, 1996 and Jonathan, 2007), which are supposed to be demonstrated in this paper.

In this paper, I will look at more recent monthly time-series data from January 1992 to December 2007 to analyze price and income of elasticities gasoline demand in U.S.. This paper is organized into five sections: the second section does a short review of literature; the second section provides a description of the data, and section 4 analyses the consumption, price and income as a system, testing and interpreting the cointegrating relationship. Based on the weak exogenieity found, section 5 builds a single equation ADL model for consumption in difference and reduces it to the conditional error correction model, which incorporates the long run solutions. Section 6 is the conclusions.

2. LITERATURE REVIEW

This part will try to summarize papers in those following aspects, including what type of data the authors use (time series data, cross-section and time series, cross section only and household level data), what the data interval is (monthly, quarterly, annually), what the estimation methods and models the authors adopt (static, dynamic, partial linear, OLS, maximum likelihood, GLS, ECM). The detailed literature review can be found in the Appendix.

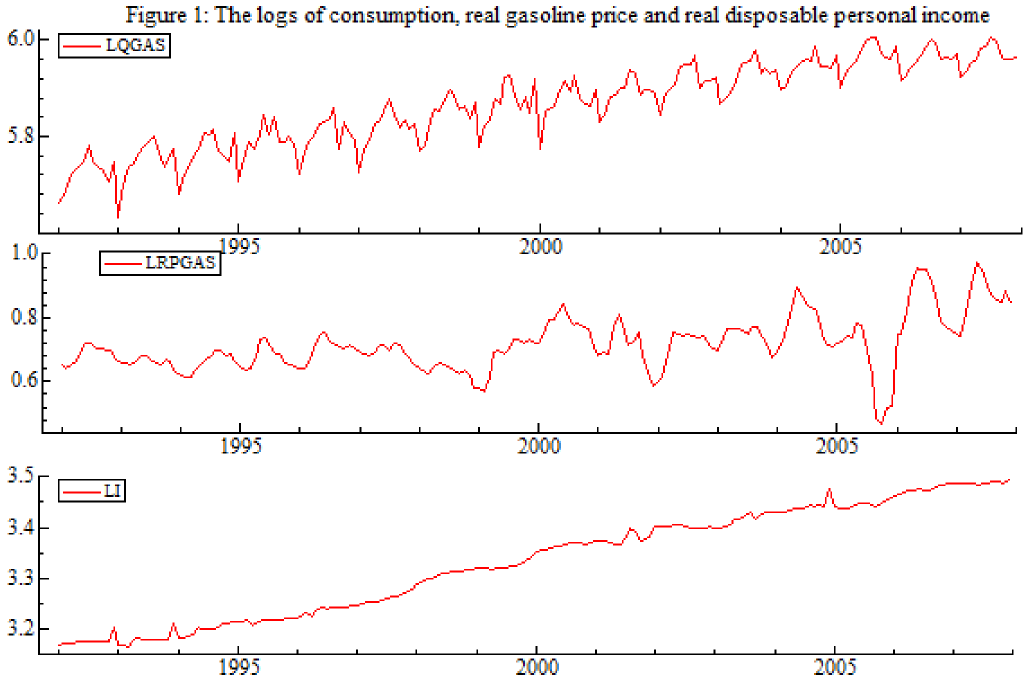
3. DATA DESCRIPTION

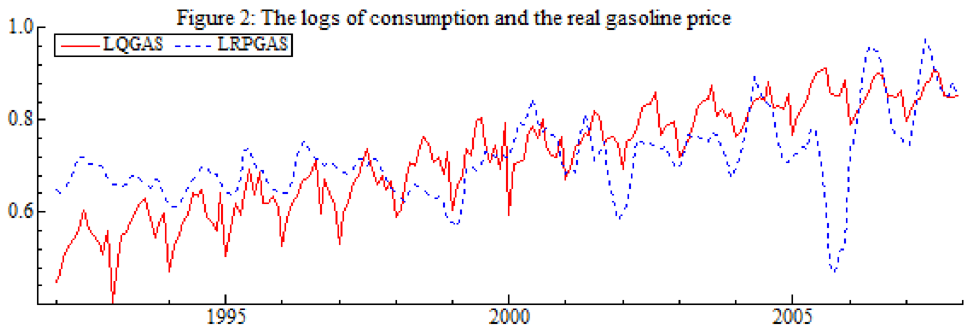
The data in this paper are monthly time-series data from January 1992 to December 2007, the consumption of gasoline is the central series in this study, and other series are real gasoline price and real disposable personal income.

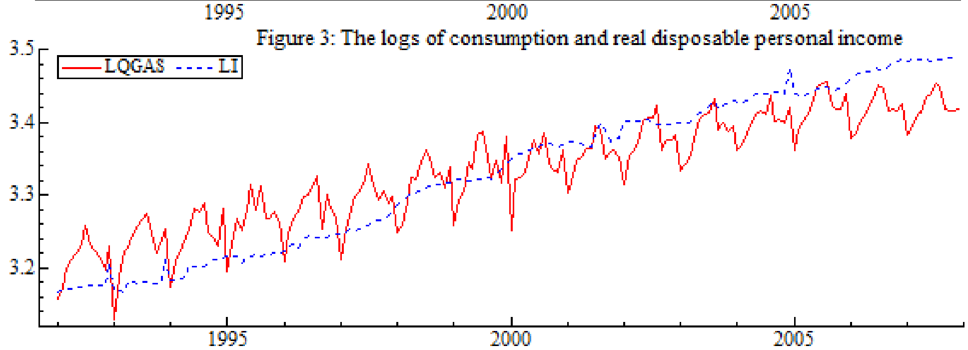
Acronym	Description of Variable	Units	Calculating method	Sources
QGAS	Consumption of gasoline	million gallons per day	Consumption (million barrels per day)*42	US. Energy Information Administration http://www.eia.gov/steo/cf_query/index.cfm
RPGAS	Real Gasoline All Grades Retail Price Including Taxes U.S. Average	cents per gallon Chained (2005)	Nominal Price/Price Indexes for Personal Consumption Expenditures	Bureau of Economic Analysis http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=81&ViewSeries=NO&Java=no&Request3Place=N&3Place=N&FromView=YES&Freq=Month&FirstYear=1992&LastYear=2008&3Place=N&Update=Update&JavaBox=no
I	Real Disposable Personal Income	per capita Chained (2005) dollars		Bureau of Economic Analysis http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=76&ViewSeries=NO&Java=no&Request3Place=N&3Place=N&FromView=YES&Freq=Month&FirstYear=1992&LastYear=2008&3Place=N&Update=Update&JavaBox=no

Figure 1 plot the log of those three variables separately, Figure 2 plot LQGAS and LPGAS jointly, matched by means and ranges, and Figure 3 shows LQGAS and LI jointly, also matched by means and ranges. Over the sample, the price doesn’t show apparent trend relative to the consumption, and the income and consumption tend to move in the same direction.

Figure 1,2,3: Plots of Data Series of gasoline consumption, real gasoline price and real disposable personal income in log level, Jan.1992 to Dec.2007







4. INTEGRATION AND COTNTEGRATION

4.1 Integration

This section tests the order of variables entering the system. The ADF(13) unit root test presents that the price and income are I(1) series, as shown in Table 1

Table 1: Augmented Dickey-Fuller Tests for Unit Roots

Levels - sample 1992(1)- 2007(12)

Variable	t-adf	beta Y_lag	t-DY_lag	Maximum Lags	AIC
LRPGAS	-2.774	0.83982	1.999	10	-6.875
LI	-1.364	0.94390	-1.627	4	-10.14

Constant and Trend Included- Critical Values; 5%=-3.43 1%=-4.01

First Differences - sample 1992(1)- 2007(12)

DLI	-5.556**	-1.1147	3.226	10	-10.16
DLRPGAS	-4.626**	0.35754	-2.200	10	-6.847

Constant and Seasonals Included - Critical Values; 5%=-2.88 1%=-3.46

Constant; Critical Values; 5%=-2.92%= -3.56

Because the consumption of gasoline is monthly, I apply the Franses's method to test the seasonal unit root. The seasonal unit roots' test indicates that no unit root at the zero frequency and no seasonal unit roots are present. Thus, seasonality can be modeled with seasonal dummies, a first difference-seasonal-dummy model may be appropriate. Thus, all three series can be treated as I(1) in the following cointegration analysis.

4.2 Cointegration

Cointegration analysis helps study the long run relationship between the integrated variables in the system. The variables in unrestricted VAR are consumption, price, income, a constant and centered seasonal dummies. Beginning with 13 lags because of the monthly data used, lag structure test finds that 3 lag is the appropriate lag length, Table A1 in Appendix shows that it is statistically acceptable to simplify to a three-order VAR.

The graphical tests inspecting the residuals and model stability shows that residuals appear to be approximately white noise and these is no serial correlation for consumption's equation; also the equation for consumption is stable. Especially the graph shows that the VAR(3) improves the model stability from the VAR(13). Figure 4 and 5 here shows the residual diagnostic and the recursive analysis (one step Chow and break point Chow) for the VAR(3), while the results for VAR(13) are presented in Figure A1 and A2 in Appendix.

Figure 4: Residual Diagnostic test in Var(3) for LQGAS, LRPGAS, LI, Jan.1992 to Dec.2007

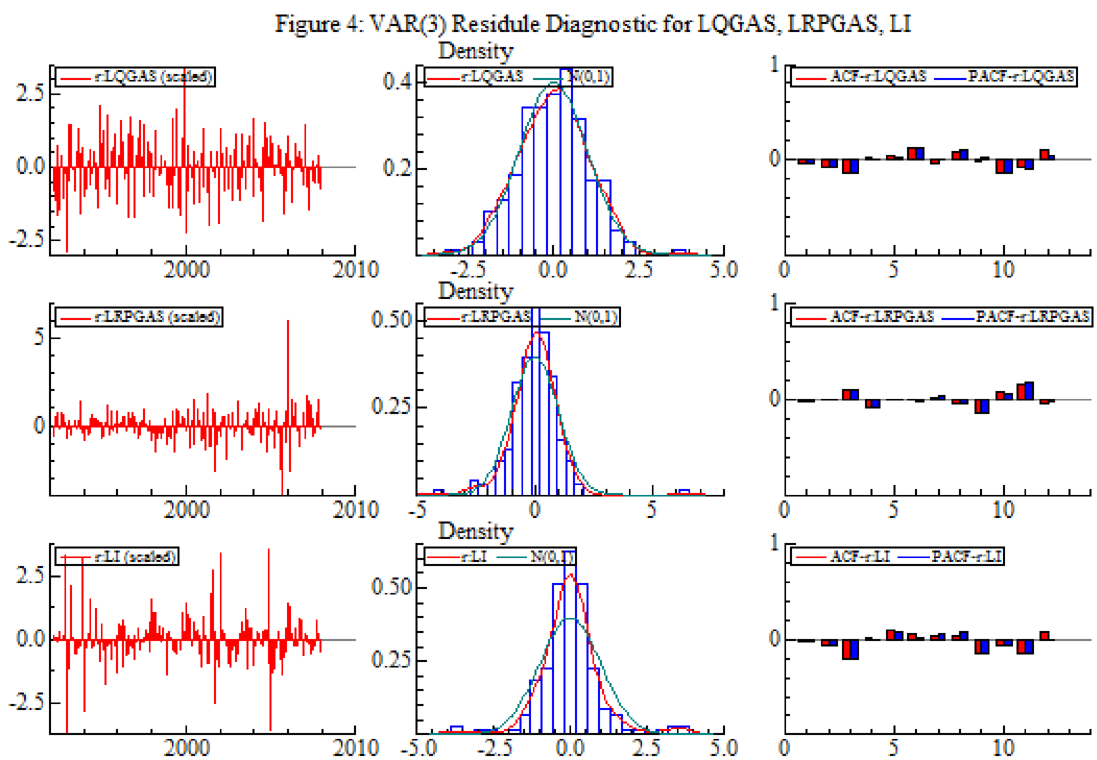
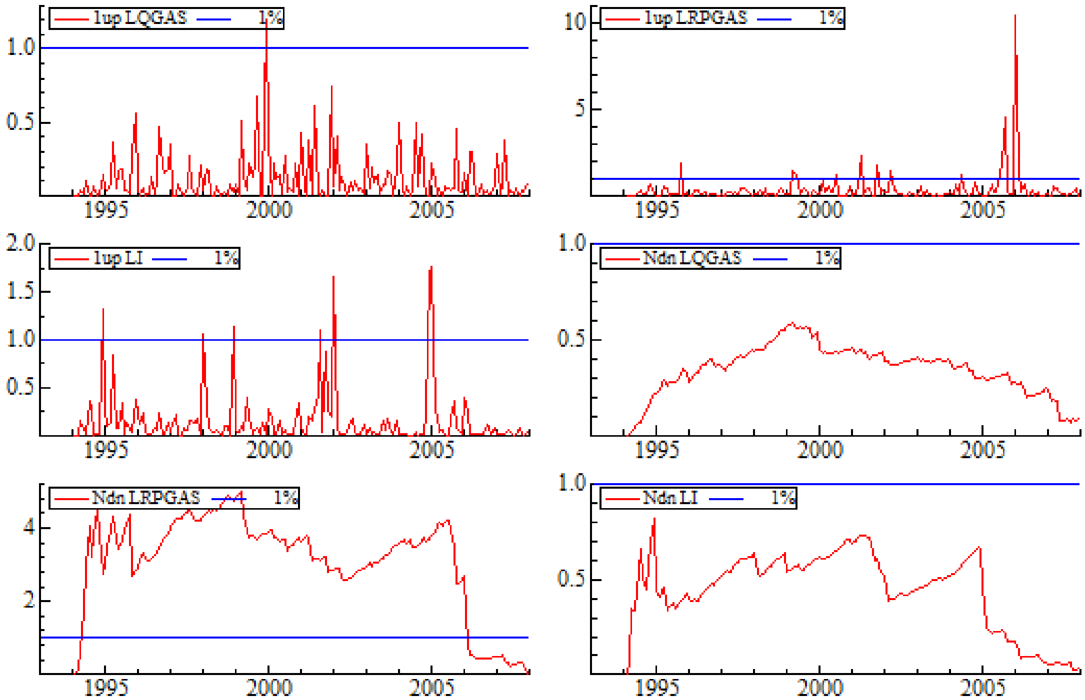


Figure 5: 1-step Chow and Break-point Chow tests in Var(3) for LQGAS, LRPGAS, LI
Jan.1992 to Dec.2007

Figure 5: Var(3) Recursive Analysis to test the model stability



Next, the Johanson test is used to identify the cointegrating relations, Table 2 reports the Johanson's process to this three-order VAR. The maximal eigenvalue test and trace test both present that there exists only one cointegration relationship. The rejection at the rank 1 is not strong because the eigenvalue at rank one is far less than 1. Table 2 also reports the cointegrating vector and the vector of speed of adjustment, denoted as β' and α. The cointegrating vector shows negative price elasticity and positive income elasticity as anticipated. Table 2 also shows the hypothesis tests for betas and alphas individually and jointly, all betas in the cointegrating vector are significantly different from zero, and weak exogeniety is found in price and income. Thus, the beta terms or the long-run equilibrium do not provide explanatory power in the price equation and income equation, so a conditional model of consumption can be built conditioning on price and income. Weak exogeniety leads to a single-equation analysis.

Table 2: Gasoline Demand Model

Cointegration Analysis with Johansen Test: sample 1992(1)-2007(12)

H0:rank	**eigenvalue**	**loglik for**	**Trace test [Prob]**	**Max test [Prob]**	**Trace test (T-nm)**	**Max test (T-nm)**
		1621.003				
0	0.14367	1635.427	47.15 [0.000]**	28.85 [0.002]**	44.87 [0.000]**	27.45 [0.004]**
1	0.089354	1644.132	18.31 [0.017]*	17.41 [0.014]*	17.42 [0.024]*	16.57 [0.019]*
2	0.0048103	1644.58	0.90 [0.344]	0.90 [0.344]	0.85 [0.356]	0.85 [0.356]

Reduced Rank Standardized Coefficients

	Beta Vector	*Std Err*	*Alpha Vector*	*Std Err*
LQGAS	1	0	-0.25525	0.072831
LRPGAS	0.2500	0.04442	-0.48076	0.16217
LI	-0.83969	0.030868	0.029425	0.03761

Hypotheses Tests for the Beta Vector

LRPGAS	Zero	Chi^2(1)	9.4556 [0.0021]**
LI	Zero	Chi^2(2)	7.0345 [0.0080]**
LPGAS and LI	Zero		24.656 [0.0000]**

Hypotheses Tests for the Alpha Vector: Weak Exogeneity

LQGAS	Zero	Chi^2(1)	6.8904 [0.0087]**
LRPGAS	Zero	Chi^2(1)	3.9638 [0.0465]*
LI	Zero	Chi^2(1)	0.48251 [0.4873]
LRPGAS and LI	Zero	Chi^2(2)	7.3099 [0.0259]*

Final Reduced Rank Cointegrating Relation

	Beta Vector	Std Err	Alpha Vector	Std Err
LQGAS	1		-0.38681	0.089706
LRPGAS	0.1497	0.04138		
LI	-0.78763	0.028756		

P-values are in brackets.

5. GENERAL TO SPECIFIC MODELLING

In this section, a conditional error correction model in difference is obtained from an autoregressive distributed lag model for consumption. A single-equation eleventh-order ADL including seasonal dummies is simplified to ECM incorporating the long-run solution. In the unrestricted ECM, many of the coefficients are insignificant. Excluding those insignificant coefficients naturally leads to a highly parsimonious, economically interpretable, and statistically acceptable ECM.

$$\begin{aligned} DLQGAS = {} & \underset{(5.41)}{1.7831} - \underset{(-6.38)}{0.5503}DLQGAS\_1 - \underset{(-5.37)}{0.3618}\,DLQGAS\_2 + \underset{(2.64)}{0.388074}DLI \\ & - \underset{(-5.39)}{0.5212}\,LQGAS\_1 - \underset{(-4.11)}{0.0671}\,LRPGAS\_1 + \underset{(5.37)}{0.397214}\,LI\_1 \end{aligned} \quad (1)$$

T=180 [1992(1)—2007(12)] $R^2 = 0.87$

AR: F (7,155) = 1.1755 [0.3199] DW = 2.00097

Normality test: Chi^2(2) = 1.5929 [0.4509]

$$\begin{aligned} DLQGAS = {} & \underset{(6.21)}{1.7536} - \underset{(-7.02)}{0.5467}DLQGAS\_1 - \underset{(-6.05)}{0.3802}\,DLQGAS\_2 \\ & - \underset{(-6.20)}{0.5230}\,(LQGAS + 0.1497\,LRPGAS - 0.7876LI)\_1 \end{aligned} \quad (2)$$

The equation (1) and (2) are final ECM with t-statistics in the parenthesis (the ten centered seasonal dummies are all significant in the model but are not shown here). In (2), ECM incorporates the long run relationship directly, but it makes the current change in income and price both insignificant, i.e., the short run income elasticity and income elasticity don't appear. So the equation (1) should be focused on. In (1), variables are all significant, and in Appendix, Figure 6 shows that the ECM appears well-specified with approximately white-noise residuals, Figure 7 shows that the coefficients of DLI are stable. Also Equation (1) lists several diagnostic statistics against various alternative hypothesis: residual autocorrelation (AR and DW), Normality. Because no rejections appear, the ECM seems well-specified.

Figure 6: Residual Diagnostic test in ECM for LQGAS, Jan.1992 to Dec.2007

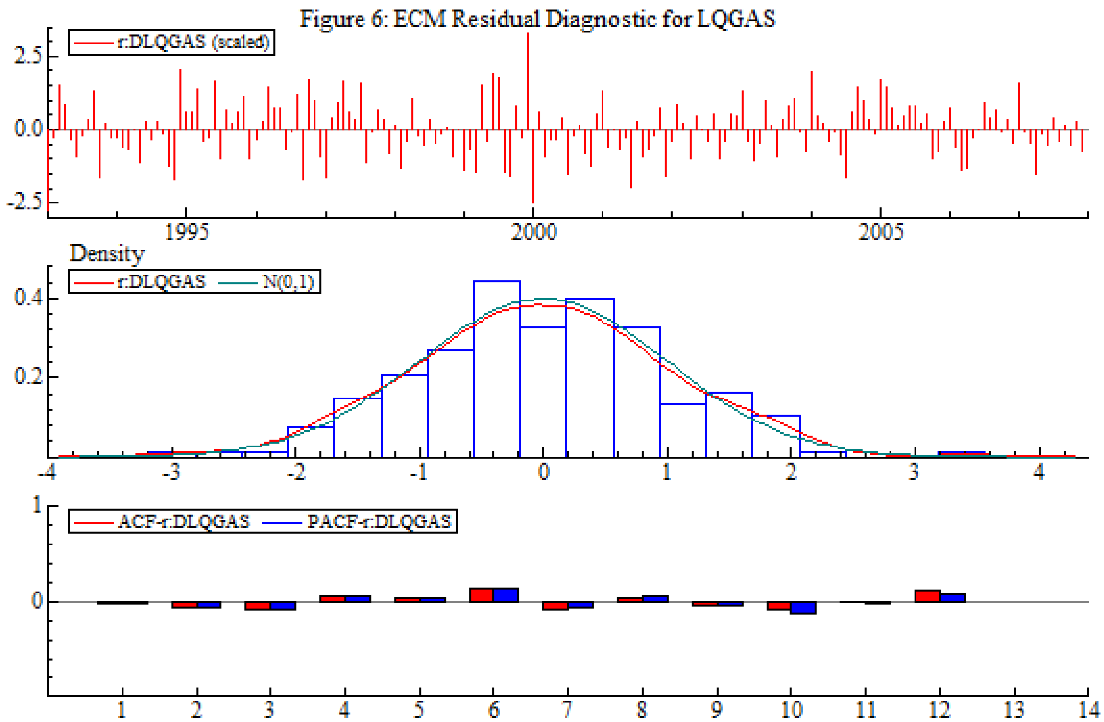
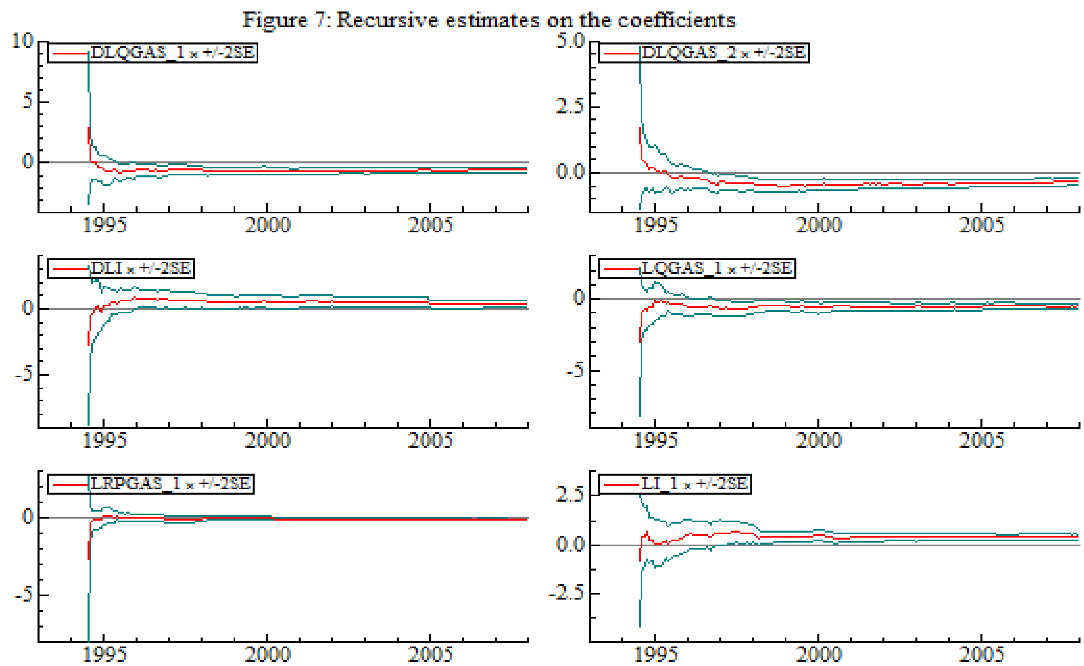


Figure 7: Recursive tests in ECM for LQGAS, LRPGAS, LI, Jan.1992 to Dec.2007



6. CONCLUSIONS

The long-run price and income elasticity can be perceived from the Long-run Solution of the Model got from the cointegrating analysis:

LQGAS= -0.1497 LRPGAS+ 0.7876LI

The long-run price elasticity is -0.1497 and the long-run income elasticity is 0.7876. The short-run gasoline demand elasticities are presented in the ECM, equation (1) presents that the short-run price elasticity is zero and short-run income elasticity is 0.3881. The long-run elasticities are larger than the short-run elasticies, which satisfies the first and second law of demand. Besides, the elasticities I got proves my hypothesis that the price elasticity in the short-run is significantly more inelastic today than in previous decades, Consumers appear significantly less responsive to gasoline price increases.

Appendix:

Literature Review:

In the survey of studies on gasoline demand of Dahl and Sterner (1991), they classify studies by data type and by ten different categories of model and with the exception of estimates on seasonal data. They find that there is some evidence that strict cross-section measures a larger price response than time series. But as for average results, there is little statistical difference between cross-section time series and ordinary time series. And they also determine an average short-run price elasticity of gasoline demand of -0.26 and an average short-run income elasticity of gasoline demand of 0.48.

Houthakker, Verleger and Sheehan (1974) estimate the demand function using pooled time series data from different states; the data for gasoline consumption is quarterly data from 1963 to 1972. A logarithmic dynamic demand function of flow-adjustment model is used, since the stock of energy is assumed to be fixed over the short run. The estimation technique used in this paper is the error component technique, and the short run price elasticity is estimated to be 0.075.

Dahl(1992) employed a flow adjustment in log-linear specification model using a cross-section time series from 1970 to 1978. The ordinary least squares technique is used since Dahl finds the price is exogenous, and the model is based on per capita gasoline consumption, per capita income and per capita stock of vehicles. In the end, Dahl states that the short-run elasticity for price, income and vehicle elasticities are estimated to be -0.2, .11 and .12 respectively. The long-run estimates are -.98, .50 and .57 respectively.

Jonathan and Christoper (2007) focus on the short-run price and income elasticities using a consistent dataset that spans the 1970s and 2000s, which leads a direct comparison of the price and income elasticities between two periods, from 1975 through 1980 and from 2001 to 2006. Aggregate monthly data of average U.S. per capita gasoline consumption, personal disposable income and average retail price are used in the model. The basic model is in log linear form, and a partial adjustment model is also used. Their conclusion is that the short-run price elasticity in recent period is significantly more inelastic today than in previous decades.

Table A1:

Table A1: Gasoline Demand Model Lag Structure and Reduction Tests, Sample 1992(1)-2007(12)

	Unrestricted Models			
Restricted Lags	13	12	11	10
13	1.2939 [0.2393]			
12	2.0046 [0.0091]**	2.5644 [0.0074]**		
11	1.6020 [0.0310]*	1.7131 [0.0351]*	0.84069 [0.5791]	
10	1.4497 [0.0497]*	1.5140 [0.0503]	0.96014 [0.5057]	1.0842 [0.3738]
9	1.4191 [0.0448]*	1.4963 [0.0365]*	1.1051 [0.3296]	1.2420 [0.2241]
8	1.2796 [0.0995]	1.3344 [0.0805]	0.99488 [0.4810]	1.0501 [0.3988]
7	1.2231 [0.1323]	1.2792 [0.0992]	0.98982 [0.4947]	1.0308 [0.4238]
6	1.2808 [0.0752]	1.2923 [0.0778]	1.0455 [0.3936]	1.0904 [0.3255]
5	1.2631 [0.0781]	1.2719 [0.0805]	1.0521 [0.3773]	1.0913 [0.3147]
4	1.2816 [0.0588]	1.2727 [0.0710]	1.0751 [0.3284]	1.1125 [0.2710]
3	1.5498 [0.0020]**	1.5681 [0.0020]**	1.4094 [0.0178]*	1.4858 [0.0099]**
2	1.8333 [0.0000]**	2.0048 [0.0000]**	1.8842 [0.0000]**	2.0072 [0.0000]**
1	51.290 [0.0000]**	53.984 [0.0000]**	56.709 [0.0000]**	62.562 [0.0000]**

Figure A1 and A2:

Figure A1: VAR(13) Residual Diagnostic

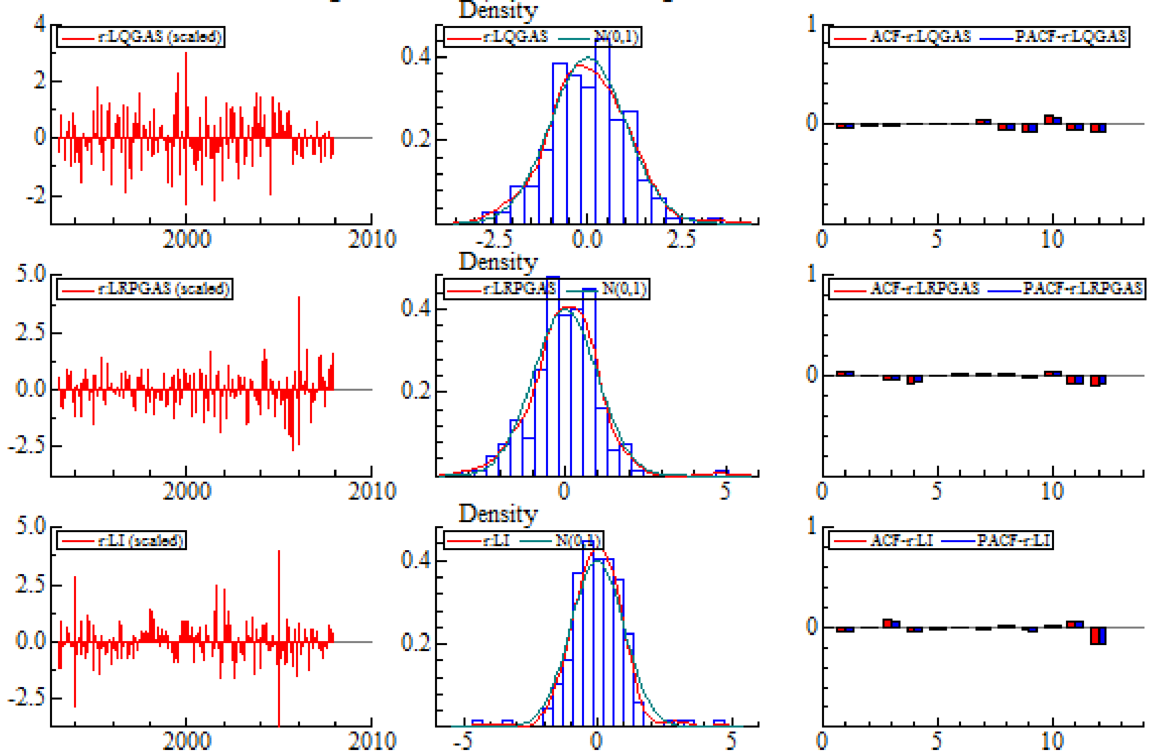
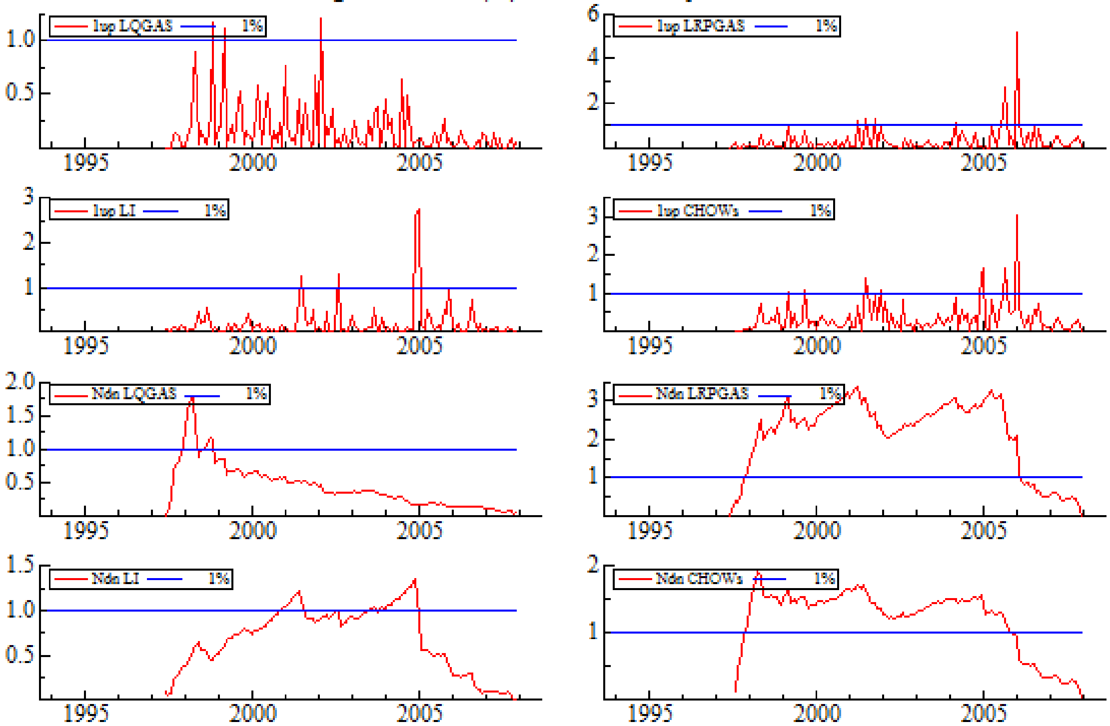


Figure A2: VAR(13) Recursive Analysis



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