



## MICROECONOMIC GASOLINE CONSUMPTION ANOMALIES IN MEXICO: 1997-2007

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### ABSTRACT

*Economic expansion in Mexico has caused fuel consumption to increase. Because Mexico does not have sufficient refinery capacity, over 40 percent of total gasoline consumed is imported. This has implications for the balance of payments. In this paper, gasoline demand is empirically examined using cointegration and error correction approaches. The sample period utilized contains a complete business cycle, but does not include the atypical 2008 financial market collapse downturn. Results indicate that long-run equilibrium in the Mexican gasoline market may not exist during the sample period in question. This is potentially attributable to the regulatory regime that governs energy markets in Mexico. Regulated price adjustments that are not consistent with prevailing market conditions run the risk of misallocating resources. Effective gasoline subsidies currently cost Mexico several billion dollars per year. Permitting greater flexibility in private gasoline retail markets may prove beneficial in Mexico. Parameter estimates indicate that gasoline is a normal good. More provocatively, the demand curve for gasoline is found to be upward sloping. That implies that, over the course of the sample period analyzed, the income effect exceeds the substitution effect. Given recent policy changes in Mexico, the latter outcome is not expected to persist.*

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**JEL Classification:** Q41, Energy Demand, D12, Empirical Consumption Analysis, C51, Model Estimation.

## Contribution/ Originality

This study contributes in the existing literature by using cointegration and error correction modeling techniques to study short and long – run characteristics of gasoline demand in the price regulated setting, and fuel subsidizing setting of Mexico.

## 1. INTRODUCTION

Demand for gasoline in Mexico tends to grow substantially. Between 2000 and 2006, gasoline demand increased 35 percent while diesel demand only increased 21 percent (SENER, 2008). That period precedes the historically atypical global financial collapse of 2008, which affected Mexico even though its mortgage banking system was in relatively good shape (Amiel, 2012). Economic expansion accounts for the increase in fuel demand. As incomes grow in Mexico, increases in car ownership also tend to occur. Gasoline demand, even before the recent international economic upheavals, often followed unexpected patterns.

The objective of this research is to develop an econometric model that analyzes the behavior of gasoline consumption in Mexico between 1997 and 2007. January 1997 is the earliest period for which complete monthly data can be assembled and December 2007 still precedes most of the economic and financial difficulties that emanated out of the United States and affected Mexico during the most recent global recession. Income and price elasticities will be measured for the different product categories employed. Time series estimation techniques are utilized to obtain these estimates. Previous studies of gasoline demand for Mexico have focused on estimating demand and price elasticities for the Northern Border Region (Haro and Ibarrola, 1999; Ayala and Gutiérrez, 2004; Ibarra Salazar and Sotres Cervantes, 2008). Time series approaches have been shown to uncover interesting empirical aspects of gasoline demand in Mexico (Reyes *et al.*, 2010). Employment of such an approach may yield helpful insights.

Greater fuels consumption has attracted political attention because of its importance to the balance of payments and to the fiscal outlooks for federal, state, and local governments. Refinery capacity in Mexico is insufficient to meet gasoline demand (Ruiz Flores *et al.*, 2012). Between 1990 and 2002, energy imports increased 124 percent from 108 thousand barrels per day (kbpd) to 243 kbpd. In recent years and during the sample period under consideration, gasoline imports are required to meet more than 40 percent of total gasoline demand (SENER, 2008).

The price of gasoline is set by the central government and Pemex is the national petroleum company. During the 1997-2007 sample period employed, prices were the same at all gas stations, except for those located in the northern and southern border regions of Mexico. As a consequence of this regional pricing strategy, excise tax rates (ieps) on gasoline frequently differ between Pemex distribution areas around the country. Gasoline pricing inflexibility has sometimes resulted in the producer price exceeding the retail market price. That means, of course, that gasoline consumption is occasionally subsidized by the federal government (SHCP, 2011). Separately, gasoline excise tax collections are used by the central fiscal authority to underwrite federal grants to states and municipalities.

To analyze a microeconomically intriguing period of the Mexican economy, remaining sections of the study are organized as follows. Section 2 provides a review of recent empirical studies on gasoline demand. Section 3 outlines the theoretical model. Section 4 discusses data and empirical results. Section 5 summarizes principal outcomes and policy implications. An appendix is included at the end of the study that provides descriptive statistics of the data used.

## 2. LITERATURE REVIEW

A wide variety of gasoline demand characteristics have been documented over the years (Liu, 2014). The high level of heterogeneity has been confirmed using numerous types of model specifications, data, geographical areas of study, time periods, and econometric estimation techniques (Havranek *et al.*, 2012). Commonly included variables in these models are real income and the real price of gasoline. Empirical analyses may employ individual household data or aggregate data for a region or a country. From these studies it is clear that gasoline usage responds to multiple stimuli and can vary substantially across markets and time (Manzan and Zerom, 2010).

Bhaskara Rao and Rao (2009) compare several alternative time series methods employing data for Fiji from 1970-2005. The selected methods include fully modified ordinary least squares, maximum likelihood methods, and error correction approaches. Estimates of the long-run parameters are found to be similar for all selected methods. Price and income elasticities are about -0.20 and 0.45, respectively.

Graham and Glaister (2002), by compiling the results of a large collection of international gasoline demand studies, find that there exists substantial consistency among results. With respect to price, typically, short-run elasticities are close to -0.3 and for the long-run range between -0.6 and -0.8. Short-run income elasticity is normally estimated in the range of 0.35 and 0.55, while for the long-run it typically falls between 1.1 and 1.3. Short-run and long-run effects of gasoline prices on traffic levels tend to be less pronounced than the impact of prices on gasoline demand. Therefore, it is safe to say that motorists always find ways to economize fuel use once given time to adjust.

Some of the previous work for Mexico has focused on quantifying the impacts on gasoline demand caused by price differentials observed between various regions of Mexico and the United States (Haro and Ibarrola, 1999; Ayala and Gutiérrez, 2004; Ibarra Salazar and Sotres Cervantes, 2008). Many of the studies for other international economies explicitly deal with the non-stationary nature of time-series. Examples include Ramanathan (1999), Bentzen (1994), Alves and De Losso Da Silveira Bueno (2003), Cheung and Thomson (2004), and Akinboade *et al.* (2008). Some empirical work of this nature has also been completed for gasoline demand in Mexico.

Ramanathan (1999) examines the relationship between gasoline consumption, national income, and the price of gasoline for India using cointegration and error correction techniques. In the long run, the income elasticity is found to be quite high at 2.682 while the price elasticity is fairly low at -0.319. The low price elasticity can be explained by the fact that energy is necessary for the development of a low-income country such as India. Short-run income and price elasticity are

1.178 and -0.209, respectively. Gasoline consumption adjusts towards its long-run equilibrium at a relatively slow rate, with only 28 percent of the adjustment taking place within the first year.

Bentzen (1994) confirms the existence of a cointegrating long-run relationship between gasoline consumption, the stock of vehicles, and the real price of gasoline in Denmark. The model specification is based on empirical evidence that shows that miles driven per vehicle remained stable throughout the period 1950-90, and on the assumption that the stock of vehicles is influenced by real income, population, and the real price of gasoline. With this background, the model is specified so that income only affects gasoline demand through the stock of vehicles. The short-run and long-run elasticities for vehicles per capita are in both cases close to one, 0.89 and 1.04 respectively. In the long-run, this can be explained by the fact that an increase in gasoline demand with an increase in the stock of vehicles will be offset by an increase in fuel efficiency. In the short-run, a change in the stock of vehicles must have a nearly equal effect on gasoline demand. The price elasticity in the short-run is -0.32 and -0.41 in the long-run.

Alves and De Losso Da Silveira Bueno (2003) analyze the short-run and long-run behavior of gasoline demand in Brazil using cointegration techniques. Given that alcohol is utilized as an alternative automobile fuel in Brazil, its price is included as an additional variable permitting the estimation of the cross-price elasticity between the two substitutable goods. It is found that gasoline demand is inelastic to both income and price changes. As expected for substitutes, the cross price elasticity is positive. However, its absolute value is relatively low; 0.4803 in the long-run and 0.2297 in the short-run. This potentially reflects the high costs associated with shifting from a gasoline engine to an alcohol fueled engine. Income elasticities are almost identical in the short- and long-run estimated at 0.1217 and 0.1216, respectively. Price elasticity is estimated at -0.4646 in the long-run and -0.0919 in the short-run.

Cheung and Thomson (2004), using cointegration techniques, find that demand for gasoline in China is relatively inelastic to price changes, both in the short-run and in the long-run. The long-run income elasticity is close to one meaning that the future growth of gasoline demand will approximate the growth rate of the economy. The pattern of the short-run income elasticity is quite different when compared to similar studies for other countries. Short-run income elasticity is larger than the long-run income elasticity. This can be explained by the country's rapid economic growth and accompanying increases in disposable income. A variance decomposition analysis of a 10 year forecast shows that per capita gross domestic product (GDP) explains 21 percent of the variance while the price of gasoline explains only 16 percent of it.

Akinboade *et al.* (2008) develop an econometric model to explain the behavior of motor gasoline consumption in South Africa. This study employs the bounds test approach to cointegration to empirically analyze the long-run relationship of price and income in the gasoline demand function. It is found that gasoline demand is both income and price inelastic. The long-run income and price elasticities are 0.36 and -0.47. The low price elasticity is attributed to an unreliable and inefficient public transportation system in South Africa. Price increases do not discourage gasoline consumption.

Among the various studies of gasoline demand of Mexico, [Ibarra Salazar and Sotres Cervantes \(2008\)](#) compare price elasticities in the northern border and non-border regions of Mexico. The main hypothesis is that gasoline service stations located along the northern border face competition from their counterparts in the United States, causing gasoline demand to be more price sensitive than it is in the rest of the country. Several equations are estimated using price, income, and different combinations of other economic variables. The price elasticity for the Northern part of Mexico ranges from -0.67 to -1.57 while that of the rest of the country ranges from -0.15 to -1.06. The recognized disparity of the price elasticity of gasoline demand between the northern border region and the non-border region has been used to justify the price gap between the northern and southern regions of the country and helps clarify the differential impacts of regional prices on fiscal revenues.

[Haro and Ibarrola \(1999\)](#) as well as [Ayala and Gutiérrez \(2004\)](#) focus on the northern border region of Mexico. Both studies use monthly frequency data to estimate price elasticities of gasoline demand in six separate border zones. The estimated elasticities in [Haro and Ibarrola \(1999\)](#) vary from -0.153 to -0.608 among the various geographic zones. Estimated price elasticities reported by [Ayala and Gutiérrez \(2004\)](#) range between -0.104 and -0.410. Those estimates compare favorably with evidence from other regions of the world ([Espey, 1998](#)). In the case of Ciudad Juárez, those estimates are also similar to those reported in [Fullerton et al. \(2012\)](#).

One of the earliest studies for Mexico is [Berndt and Botero \(1985\)](#). Among other things, gasoline demand is found to be inelastic with respect to both short-run price and output changes. Fairly different results are reported by [Eskeland and Feyzioglu \(1997\)](#). In that study, responsiveness to price and income changes is found to be substantially more elastic, with relatively important fiscal implications. [Galindo \(2005\)](#) also obtains econometric results with important fiscal implications. Namely, energy subsidies in Mexico encourage substantially greater consumption than would otherwise be the case. The latter study further indicates that gasoline price elasticities are abnormally low in Mexico during the 1961-2001 sample period employed.

More recently, [Crotte et al. \(2010\)](#) employ cointegration and panel estimation techniques. Results for data through 2006 indicate that the price elasticity of gasoline in Mexico ranges from -0.39 to -0.29. [Reyes et al. \(2010\)](#) examine data through 2008, obtaining some intriguing results. Among them, the short-run price elasticity is estimated to be -0.041, an estimate that is substantially below most estimates for Mexico and other national economies.

### 3. THEORETICAL MODEL

By using cointegration and error correction modeling techniques, this study seeks to explicitly model short-and long-run characteristics of gasoline demand behavior in Mexico. The analysis is conducted using monthly data for 1997 to 2007. Such an approach not only allows distinguishing between short-run and long-run gasoline demand elasticities, but also permits identifying the speeds of adjustment toward long-run equilibrium consumption values. The sample period is selected to exclude the atypical international economic downturn that involved the financial market

collapses of the United States and Western Europe in 2008 that negatively affected Mexico (Amiel, 2012). Initial clues to the so-called great recession date back to the global housing market deceleration that began to emerge in 2007 and intensified in 2008. Data employed are for both regular and premium grades of gasoline in Mexico.

In economics, most observed time series are generated by stochastic processes that are non-stationary. Such data are generally more difficult to model and forecast than stationary data (Ploberger and Phillips, 2003). Gasoline consumption data in Mexico, characteristic of growing economies, tend to be trend non-stationary (Galindo, 2005; Fullerton *et al.*, 2012). In such cases, the analytic framework employed should arguably allow for such a possibility and take it into account. The theoretical model developed below takes such an approach using a variant of a method that has previously been utilized to analyze fuels demand in Mexico (Galindo, 2005).

The model specifications used for this study are based upon Galindo (2005) and similar that utilized in Crotte *et al.* (2010). One equation is estimated for each motor gasoline grade available in Mexico; regular unleaded and premium. The cointegrating equations take the following functional form:

$$\log CU_t = \beta_0 + \beta_1 \log Y_t + \beta_2 \log PU_t + \varepsilon_t \quad (1)$$

$$\log CP_t = \alpha_0 + \alpha_1 \log Y_t + \alpha_2 \log PP_t + v_t \quad (2)$$

where  $CU_t$  and  $CP_t$  are gasoline consumption for regular unleaded and premium gasoline, respectively, in thousand barrels per day (KBPD);  $Y_t$ , is the Industrial Production Index (IPI), used as a proxy for GDP;  $PU_t$  and  $PP_t$  are the real prices of gasoline in 2002 pesos per liter, for regular unleaded and premium gasoline, respectively, and,  $\varepsilon_t$  and  $v_t$  are the stochastic error terms.

The variables in Equations (1) and (2) are transformed using natural logarithms. Aside from mathematical convenience, that step is useful for dealing with samples in which growth in variable means is accompanied by increased dispersion of the data about the series trends (Cryer, 1986). In cases when second moments are proportional to the levels of the series in question, logarithmic transformations will yield series with approximately constant variances.

The augmented Dickey-Fuller (ADF) procedure is used to test dependent, and independent, variables for unit roots in level and first or second differenced forms. The test is based on the estimation of the following equation:

$$\Delta Y_t = \delta \cdot Y_{t-1} + \sum_{i=1}^k \delta_i \Delta Y_{t-i} + \varepsilon_t \quad (3)$$

with an inspection of the computed t-ratio for  $\delta$ . Under the null hypothesis that  $\delta=0$ , Equation (3) is a random walk and the process generating  $Y_t$  is nonstationary. Rejection of the null hypothesis, in favor of the alternative hypothesis that  $\delta<0$ , implies that the process generating  $Y_t$  is integrated of order zero and is stationary (Cryer, 1986). The MacKinnon (1996) critical values are utilized for the null hypothesis tests.

In accordance with the methodology described in Charemza and Deadman (1997) for cointegration analysis, the next step is to test the variables for cointegration. That requires running

the OLS regression for the long-run equations (1) and (2). The ADF equation (3) with the estimated residuals for each of the cointegrating regressions is then applied:

$$\Delta \hat{\varepsilon}_t = \delta \cdot \hat{\varepsilon}_{t-1} + \sum_{i=1}^k \delta_i \Delta \hat{\varepsilon}_{t-i} + \varepsilon_{\square t} \quad (4)$$

The residuals from these regressions are tested for stationarity. The residuals from Equations (1) and (2) can be interpreted as deviations from the long run path. As long as these deviations are stationary, the variables are said to be cointegrated.

If the possibility of cointegration is not rejected, OLS applied to Equations (1) and (2) does not lead to spurious regression results. The long-run elasticities for unleaded gasoline are given by:

$$\frac{\partial \log CU_t}{\partial \log Y_t} = \beta_1; \quad \frac{\partial \log CU_t}{\partial \log PU_t} = \beta_2,$$

where  $\beta_1$  and  $\beta_2$  are the income elasticity and the price elasticity of unleaded gasoline, respectively. The long-run elasticities for premium gasoline are given by:

$$\frac{\partial \log CP_t}{\partial \log Y_t} = \alpha_1; \quad \frac{\partial \log CP_t}{\partial \log PP_t} = \alpha_2,$$

where  $\alpha_1$  and  $\alpha_2$  are the income elasticity and the price elasticity respectively.

If all variables from Equation (1) and (2) are  $I(1)$ , and deviations from their long-run path are  $I(0)$ , models in first differences with an error correction mechanism can be developed. The short-term error correction models (ECM) are estimated using the following equations:

$$\Delta \log CU_t = \theta_0 + \theta_1 \Delta \log Y_t + \theta_2 \Delta \log PU_t + \theta_3 \hat{\varepsilon}_{t-1} + v_t \quad (5)$$

$$\Delta \log CP_t = \omega_0 + \omega_1 \Delta \log Y_t + \omega_2 \Delta \log PP_t + \omega_3 \hat{v}_{t-1} + u_t \quad (6)$$

The ECM's are used to estimate the short-run behavior of gasoline consumption. The coefficients  $\theta_1$  and  $\theta_2$  are, respectively, the short-run income elasticity and the short-run price elasticity for unleaded gasoline consumption. The coefficients  $\omega_1$  and  $\omega_2$  are, respectively, the short-run income and short-run price elasticities for premium gasoline consumption. In addition,  $\theta_3$  and  $\omega_3$  are interpreted as the speeds of adjustment for any shock leading to a deviation from the long-run consumption equilibria.

#### 4. DATA AND EMPIRICAL RESULTS

The sample data used for estimation include 132 monthly observations for regular and premium gasoline consumption from January 1997 to December 2007. These data have been obtained from the National Statistics Institute in Mexico (INEGI, 2009). The dependent variable for each equation is the total sales volume for each gasoline grade measured in thousand barrels per day (KBPD). The nominal price of each gasoline grade is a simple average between the price in the northern border region of Mexico and the price in non border regions as published by INEGI. Data constraints during the sample period in question prevent constructing a weighted nominal

price measure. The Consumer Price Index (CPI) is employed to deflate the nominal gasoline prices. The CPI base period is June 2002 (06/2002 = 100).

Because gross domestic product (GDP) is only available at a quarterly frequency in Mexico, the monthly frequency Industrial Production Index (IPI) is used as a proxy for GDP in this study. The IPI covers four major divisions of economic activity in Mexico: electricity, water, and gas; mining; construction; and manufacturing. The IPI is an inflation-adjusted measure of industrial activity with 1993 as its base year (1993 = 100).

Stationarity test results are summarized in Table 1. The table shows the t-statistics from the ADF test for the variables in level and first differenced forms. Schwartz (SIC) and Akaike (AIC) information criteria were used to determine lag lengths. All of the t-statistics for the variables in levels are statistically insignificant, which means that the unit root null hypotheses cannot be rejected. In contrast, the t-statistics for  $\log(CP_t)$ ,  $\log(CU_t)$ ,  $\log(PP_t)$ , and  $\log(PU_t)$  in their first differenced forms are statistically significant at the one-percent level. The t-statistic for  $Y_t$  in its first differenced form is statistically significant at the five-percent level. This implies that all of the variables are integrated of order one. Consequently, cointegration models are estimated with data that are not differenced, while error correction models are estimated using first-differenced data.

**Table-1.** Augmented Dickey-Fuller Test for Stationarity

Variables	Levels	First differences
$\log(CU_t)$	4.431	-4.564**
$\log(CP_t)$	1.912	-4.737**
$\log(PU_t)$	-2.646	-12.542**
$\log(PP_t)$	-1.304	-13.016**
$\log(Y_t)$	-1.419	-2.942*

\*Denotes significance at the 5 percent level.

\*\* Denotes significance at the 1 percent level.

Regression output for the long-run consumption Equations (1) (regular gasoline) and (2) (premium gasoline) is reported in Table 2. Computed t-statistics for parameter estimates appear in parentheses. Both models fail to provide solid evidence of cointegration. In both cases the low Durbin Watson (DW) statistic is a potential indication of non-stationary residuals. Inspection of the Q-statistic, which is used for a multi-period autocorrelation test, helps confirm this result. The critical value at the one-percent significance level is 158.95. As the Q-statistic for both models is greater than the critical value, the null of no cointegration cannot be rejected.

**Table-2.** Results for Long-Term Cointegrating Regressions

Variable	Regular	Premium
C	-0.4505 (-0.8464)	0.2324 (0.4072)
LOG(PRICE)	0.3536 (1.5381)	0.3943 (1.8038)
LOG(INCOME)	1.2722 (8.1149)**	1.0794 (6.2489)**
R-squared	0.6203	0.5831
Adjusted R-squared	0.6144	0.5766
Standard error of regression	0.0897	0.0890
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Sum of squared residuals	1.0382	1.0227
Log likelihood	132.4939	133.4815
F-statistic	105.3531	90.2118
Durbin-Watson statistic	0.4864	0.4357
Augmented Dickey-Fuller t-statistic of residual	-0.4748	-2.0871
Q-statistic of residual	727.98**	356**

\*\* Denotes significance at the 1 percent level.

The apparent lack of cointegration is associated with the price variables and implies there is no long-run equilibrium between the dependent variables and those regressors. Also, unexpectedly, the price elasticity coefficients have positive signs. Those outcomes imply that, during the sample period under consideration, upward sloping demand curves were observed for both of these grades of gasoline in Mexico. Additional information regarding this outcome will be provided below.

The long-run income elasticities for unleaded and premium gasoline in Table 2 are 1.27 and 1.07, respectively, implying that gasoline is treated as a normal good by consumers in Mexico. These coefficients are close to those reported by other countries. The income coefficients appear to be statistically significant at the one-and five-percent criteria. However, these estimated parameter values are somewhat high in comparison to the computed elasticities reported for Mexico in at least one recent study (Crotte *et al.*, 2010). Estimation results for the traditional ECM procedure appear in Table 3. The short-run income elasticities have the correct sign for both models and satisfy the one-percent significance criterion. The short-run price elasticity for regular gasoline exhibits the hypothesized algebraic sign for the unleaded gasoline consumption model and confirms results reported in recent gasoline demand studies for various regions in Mexico (Crotte *et al.*, 2010; Fullerton *et al.*, 2012). It should also be noted, however, that neither of the short-run price elasticities satisfy conventional significance criteria. In the case of premium gasoline, the estimated coefficient is fairly close to zero, but that for regular gasoline appears economically plausible.

**Table-3.** Traditional Error Correction Empirical Output

Variable	Regular	Premium
C	0.0032 (0.7803)	0.0045 (1.0404)
D(LOG(INCOME))	0.3855 (3.6056)**	0.3931 (3.5547)**
D(LOG(PRICE))	-0.2706 (-1.4612)	0.1414 (0.4372)
RESIDUALS(-1)	-0.1470 (-3.0470)**	-0.1721 (-3.4254)**
R-squared	0.1470	0.1439
Adjusted R-squared	0.1268	0.1237
Standard error of regression	0.0470	0.0491
Sum of squared residuals	0.2801	0.3057
Log likelihood	216.8081	211.0819
F-statistic	7.2954	7.1180
Durbin-Watson statistic	2.8149	2.7022
Augmented Dickey-Fuller t-statistic of residual	-0.3093	-1.5624
Q-statistic of residual	186.71**	168.59**

\*\* Denotes significance at the 1-percent level.

The error correction terms represent the speed of adjustment toward the long-run equilibrium. In Table 3, they are estimated to be -0.1470 and -0.1721 for regular and premium consumption respectively, signifying 14.7 percent and 17.2 percent of the adjustments towards long-run equilibrium occur during the first month. Therefore, it takes regular and premium gasoline consumption 6.8 and 5.8 months respectively, for the disequilibrium in the prior period to be fully reversed. The error correction mechanisms in both models exhibit the expected algebraic sign and are statistically significant. However, the autocorrelation test fails to provide evidence in favor of cointegration. Both Q-statistics exceed the one-percent significance level critical value of 158.95. This means that the short-run equation residuals are autocorrelated. This is not very surprising given that the long-run cointegrating equation residuals are not stationary.

Empirical results obtained suggest gasoline price adjustment magnitudes are different from those required to produce market equilibria for the two fuel grades used in this study. This is not completely surprising given the relatively rigid prices set by the federal government. In Mexico, gasoline prices are determined by the government based on an international reference cost of production, transportation costs, retailer margin, and taxes. Under these circumstances, prices are at least temporarily insensitive to changes in the supply-and-demand balance on an ongoing basis.

As noted by Lajous (2009), government entities responsible for setting prices do not have the technical and financial resources to adequately perform regulatory functions. It is unlikely, under these circumstances, that the public sector will be able to administer gasoline markets efficiently in Mexico. Results obtained in this study indicate that is potentially what occurred during the sample period in question.

Some final observations regarding the results shown in Table 2 are in order. From a microeconomic standpoint, the evidence of an upward sloping demand curve for a normal good is highly unique. From a theoretical perspective, this admittedly rare circumstance can occur in cases when the income effect exceeds the substitution effect in absolute value (Vandermeulen, 1972). Few other studies have reported positive price elasticities of gasoline demand (Kraft and Rodekoher, 1978; Bhattacharyya and Blake, 2009). From a practical perspective, it probably requires real price movements that are flat, declining, or at least fail to keep pace with real income growth. The behavior of price elasticity may also behave differently in fuel-subsidizing economies (Arzaghi and Squalli, 2015), just as the Mexican in the period analyzed in this paper. During January 1997 – December 2007 sample period under consideration, the real prices for both regular and premium grades of gasoline barely exceeded the rate of growth in consumer prices (INEGI, 2009; Crotte *et al.*, 2010). Using different sub-sample periods, it is possible to obtain negative price elasticities, but these estimates also tend to indicate substantially less price sensitivity than what is documented in most other studies (Crotte *et al.*, 2009; Reyes *et al.*, 2010).

Irrespective of the price coefficient signs obtained during different sample periods, empirical evidence to date indicates that the “green taxes” assessed on gasoline, diesel, and jet fuel purchases that went into effect in January 2014 are likely to generate badly needed tax revenues for infrastructure investment. The ad valorem taxes implemented, less than 15 centavos per liter for

each of the fuels in question, are in addition to the 16 percent value-added tax also charged on fuel purchases (Arenaza Cortés, 2014). As the tax burden on oil exports is reduced in future years, there appears to be ample room for increasing fuel taxes even further. The latter will hold even if the results shown in Table 2 are affected by the absence of cointegration between the series during the sample period selected.

Is such a circumstance likely to persist in Mexico? Although it cannot be ruled out, the answer is probably no due to recent changes in energy policy. Most obviously, the new energy reform measures are expected to introduce more efficiency in downstream fuel markets within the country (Snow, 2014). Any moves in that direction raise the likelihood of eventually attaining a more smoothly, or at least flexibly, operating national market in which price signals play a more prominent role in resource allocation. Such developments would potentially allow equilibrium to be attained on a long-run basis. Ironically, if new resources are invested in greater refinery capacity, domestic gasoline prices may again fail to keep pace with inflation, albeit due to greater supply availability. Greater volumes of oil production in the United States may also cause prices to decline in the near-term, as well, by leading to lower prices for imported gasoline.

## 5. SUMMARY

The demand for gasoline in Mexico is empirically examined in this study using cointegration and error-correction techniques. This approach has proven useful in similar studies and provides long- and short-run elasticities for gasoline demand. In this paper, the two gasoline grades available in Mexico are analyzed separately. The sample period under consideration is from 1997 to 2007 and avoids the atypical business cycle downturn of 2008.

Gasoline demand is modeled as a function of price and income. Price elasticities are of interest to the federal government. They help estimate the effect of gasoline prices in fiscal revenue collected through taxes applied to gasoline sales. Therefore, understanding gasoline demand responses to price and income changes is critical for structuring a policy that helps support the public sector budget.

Empirical results show no evidence of a cointegrating relationship between the variables. Serially correlated residuals are observed for the long-run cointegrating equation. The latter circumstance points to a lack of long-run equilibrium in the Mexican gasoline market. The long-run cointegrating equation also presents evidence of upward sloping demand curves for both grades of gasoline modeled. Also surprising in this context is that both types of gasoline are treated as normal goods.

The regulatory price regime that exists in Mexico's gasoline market may be the source of market disequilibrium. Regulated price adjustments that are inconsistent with prevailing market conditions run the risk of misallocating resources. The latter may hamper economic performance and retard development. Permitting greater flexibility in private gasoline retail markets may prove beneficial in Mexico. In recent months, the average price of gasoline across Mexico has been below the Pemex producer price (SHCP, 2011). That implies subsidization via an effective

negative excise tax rate (ieps). The subsidy expense totaled 23.462 billion pesos (approximately US\$ 2 billion) during the first quarter of 2011. In 2010 the subsidy amounted to 76.963 billion pesos (approximately US\$ 6.5 billion). For a cash-strapped economy such as Mexico, the latter figures are not insubstantial.

Perhaps the most intriguing aspect of the empirical results obtained is the evidence of an upward sloping gasoline demand curve in Mexico during the January 1997 – December 2007 sample period. From a strict microeconomic perspective, that result indicates that the income effect outweighs the substitution effect over the course of the sample period employed. From a policy perspective, it also implies that fuel taxes represent a reliable source of public sector revenues for a cash strapped government. The latter will hold even if the demand curve slope for gasoline subsequently turns negative as it is almost assuredly price inelastic.

## REFERENCES

- Akinboade, O.A., E. Ziramba and W.L. Kumo, 2008. The demand for gasoline in South Africa: An empirical analysis using co-integration techniques. *Energy Economics*, 30(6): 3222-3229.
- Alves, D.C.O. and R. De Losso Da Silveira Bueno, 2003. Short-run, long-run and cross elasticities of gasoline demand in Brazil. *Energy Economics*, 25(2): 191-199.
- Amiel, R., 2012. Síntesis. IHS global insight perspectivas económicas de México. Primer Trimestre: 1-8.
- Arenaza Cortés, A., 2014. An overview of the 2013 fiscal reform package. *México Consensus Economic Forecast*, 17(2): 1-7.
- Arzaghi, M. and J. Squalli, 2015. How inelastic is demand for gasoline in fuel-subsidizing economies? *Energy Economics*. Available from publication, [doi:10.1016/j.eneco.2015.04.009](https://doi.org/10.1016/j.eneco.2015.04.009).
- Ayala, E. and L. Gutiérrez, 2004. Distorsiones de la política de precios de la gasolina en la frontera norte de México. *Comercio Exterior*, 54(8): 704-711.
- Bentzen, J., 1994. An empirical analysis of gasoline demand in Denmark using cointegration techniques. *Energy Economics*, 16(2): 139-143.
- Berndt, E. and G. Botero, 1985. Energy demand in the transportation sector of Mexico. *Journal of Development Economics*, 17(3): 219-238.
- Bhaskara Rao, B. and G. Rao, 2009. Cointegration and the demand for gasoline. *Energy Policy*, 37(10): 3978-3983.
- Bhattacharyya, S. and A. Blake, 2009. Domestic demand for petroleum products in MENA countries. *Energy Policy*, 37(4): 1552-1560.
- Charemza, W. and D. Deadman, 1997. *New directions in econometric practice: General to specific modelling, cointegration, and vector autoregression*. Lyme, NH: Edward Elgar.
- Cheung, K. and E. Thomson, 2004. The demand for gasoline in China: A cointegration analysis. *Journal of Applied Statistics*, 31(5): 533-544.
- Crotte, A., R.B. Noland and D.J. Graham, 2009. Estimation of road traffic demand elasticities for Mexico City, Mexico. *Transportation Research Record*, 2134: 99-105.

- Crotte, A., R.B. Noland and D.J. Graham, 2010. An analysis of gasoline demand elasticities at the national and local levels in Mexico. *Energy Policy*, 38(8): 4445-4456.
- Cryer, J.D., 1986. *Time series analysis*. Boston, MA: Duxbury Press.
- Eskeland, G. and T. Feyzioglu, 1997. Is demand for polluting goods manageable? An econometric study of car ownership and use in Mexico. *Journal of Development Economics*, 53(2): 423-445.
- Espey, M., 1998. Gasoline demand revisited: An international meta-analysis of elasticities. *Energy Economics*, 20(3): 273-295.
- Fullerton, T.M.J., G. Muñoz Sapien, M.P. Barraza De Anda and L. Domínguez Ruvalcaba, 2012. Dinámica del consumo de gasolina en Ciudad Juárez, Chihuahua. *Estudios Fronterizos*, 13(26): 91-107.
- Galindo, L.M., 2005. Short- and long-run demand for energy in Mexico: A cointegration approach. *Energy Policy*, 33(9): 1179-1185.
- Graham, D.J. and S. Glaister, 2002. The demand for automobile fuel: A survey of elasticities. *Journal of Transport Economics and Policy*, 36(1): 1-26.
- Haro, R. and J. Ibarrola, 1999. Cálculo de la elasticidad precio de la demanda de gasolina en la zona fronteriza norte de México. *Gaceta de Economía*, 6(11): 237-262.
- Havranek, T., Z. Irsova and K. Janda, 2012. Demand for gasoline is more price inelastic than commonly thought. *Energy Economics*, 34(1): 201-207.
- Ibarra Salazar, J. and L.K. Sotres Cervantes, 2008. La demanda de gasolina en México. *Frontera Norte*, 20(39): 131-156.
- INEGI, 2009. *Anuario estadístico de los estados unidos Mexicanos*. México, DF: Instituto Nacional De Estadística Geografía e Informática.
- Kraft, J. and M. Rodekohr, 1978. Regional demand for gasoline: A temporal cross-section specification. *Journal of Regional Science*, 18(1): 45-55.
- Lajous, A., 2009. The governance of Mexico's oil industry, in: Levy, S., Walton, M. (Eds). *No growth without equity? Inequality, interests, and competition in Mexico*. Washington, DC: World Bank.
- Liu, W., 2014. Modeling gasoline demand in the United States. *Energy Economics*, 45: 244-253.
- MacKinnon, J.G., 1996. Numerical distribution functions for unit root and cointegration tests. *Journal of Applied Econometrics*, 11(6): 601-618.
- Manzan, S. and D. Zerom, 2010. A semi-parametric analysis of gasoline demand in the United States re-examining the role of price. *Econometric Reviews*, 29(4): 439-468.
- Ploberger, W. and P. Phillips, 2003. Empirical limits for time series econometric models. *Econometrica*, 71(2): 627 – 674.
- Ramanathan, R., 1999. Short- and long-run elasticities of gasoline demand in India: An empirical analysis using cointegration techniques. *Energy Economics*, 21(4): 321-330.
- Reyes, O., R. Escalante and A. Matas, 2010. La demanda de gasolinas en México: Efectos y alternativas ante el cambio climático. *Economía Teoría y Práctica*, 32(1): 83-111.
- Ruiz Flores, L.I., J.H. Rodríguez Martínez, G.D. Taboada and J. Pano Jimenez, 2012. Assessment and planning of the electrical systems in Mexican refineries by 2014. *Proceedings of the ASME Power Conference – 2011*, 2: 193-200.

SENER, 2008. Balance nacional de Energía. México, DF: Secretaría De Energía.

SHCP, 2011. Informe sobre la situación económica, las finanzas públicas y la deuda pública, primer trimestre.

México, DF: Secretaría De Hacienda Y Crédito Público.

Snow, N., 2014. Mexico to temper expectations as it implements energy reforms. Oil & Gas Journal, 112(1A): 18-19.

Vandermeulen, D.C., 1972. Upward sloping demand curves without the Giffen paradox. American Economic Review, 62(3): 453-458.

## Appendix

Descriptive statistics.

	Gasoline consumption (kbpd)		Price North Region <sup>1</sup> (pesos per liter)		Price all other regions <sup>1</sup> (pesos per liter)		Industrial Production Index	CPI
	Unleaded	Premium	Unleaded	Premium	Unleaded	Premium		
Average	595.64	515.42	5.29	5.94	5.41	6.21	134.28	97.08
Max	820.00	718.00	8.27	8.35	7.01	8.73	156.34	125.56
Min	479.00	334.00	2.79	3.10	2.91	3.20	106.55	56.94
Std Dev	88.77	70.91	1.36	1.46	1.17	1.54	10.28	19.14

<sup>1</sup>A simple average between these two prices is used as nominal price for each gasoline grade.

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