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The University of Texas at El Paso
UTEP Border Region
Modeling Project

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North Borderplex Retail Gasoline Price Fluctuations: 2000-2013*

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Abstract
Previous studies show that a variety of different variables influence retail gasoline price fluctuations. In the case of El Paso, Texas, those variables would include wholesale gasoline prices, local economic conditions, weather, and, more uniquely, cross-border economic variables associated with Ciudad Juarez, Chihuahua, in Mexico. To analyze the contributions of these variables to monthly price movements for gasoline in El Paso, a theoretical model is specified. From the latter construct, a reduced form equation is extracted. That specification is then expressed within an error correction framework to allow accounting for both long-run and short-run behaviors in this metropolitan economy. Results indicate that the border poses a fairly substantial barrier to normal trade and purchasing patterns for this product within this specific region.

Keywords
Border Economics, Gasoline Prices, Business Economics, Applied Econometrics

JEL Categories
F15 Economic Integration; Q41 Energy Prices; M21 Business Economics; R15 Regional Econometrics

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1. Introduction

The purpose of this study is to examine the determinants of local gasoline prices in the El Paso metropolitan economy and how they vary over time. Many studies of the border region have analyzed gasoline demand, but not price (Haro and Ibarrola, 1999; Ayala and Gutiérrez, 2004; Ibarra and Sortres, 2008). This issue is of interest as many cities encourage ownership of personal vehicles due to urban sprawl and lack of options for pedestrians (Sinha, 2003; Bento et al., 2005). Consequently, families allocate significant fractions of household income for gasoline purchases. Because of its location on the U.S.-Mexico border, consumers in El Paso can treat gasoline from either country as substitute goods (Fullerton et al., 2012). Gasoline prices, thus, provide one indicator of how closely the metropolitan components of the Borderplex economy are integrated with each other.

Gasoline prices in Mexico are set by the Ministry of Finance on a monthly basis that takes into account, among other things, production and distribution costs faced by Pemex (Plante and Jordan, 2013; Ramos, 2014). The price set by Pemex must be the same at all stations throughout the country with the exception of those along the border in northern Mexico. Although a single price is used for the entire region, northern border gasoline prices are lower than those charged in the rest of the country as a means for reducing fuel tourism to the United States. This implies that gasoline prices in El Paso can respond to price changes specifically observed in Ciudad Juarez, but the converse does not hold. Thus, there is no danger of simultaneity arising from any fuel price feedback between the cities.

The economic importance of crude oil and gasoline has fostered a broad range of related literature. Recurring research topics along these lines include price asymmetries (Karrenbrock, 1991; Borenstein et al., 1997; Galeotti et al., 2003), Edgeworth cycles in gasoline markets (Eckert, 2002; Wang, 2009), and the impacts of regulation and tax incidence on gasoline prices (Rietveld and van Woudenberg, 2005; Bello and Contín-Pilart, 2012). Several studies also analyze the role of consumer behavior and the willingness of consumers to travel in response to cheaper substitutes (Banfi et al., 2005; Manuszak and Moul, 2009). Much of this research uses national or state data, but research at the metropolitan level is scarce. Efforts that examine cross-border interactions tend to compare neighboring countries rather than city pairs.

This article uses monthly data from 2001 to 2013 to analyze average gasoline prices. The development of a structural model for gasoline prices at the city level is complicated by the lack of consumption data (Eckert, 2011). The approach utilized should overcome this problem. A theoretical model and reduced form equation are developed to analyze price without consumption data. Parameter estimation is utilized to examine the various roles played by the variables incorporated in the analysis in long-run and short-run settings.

This paper proceeds as follows. Section 2 discusses the existing literature on retail gasoline prices. Section 3 discusses the data collected and hypothesized relationships between the explanatory variables and gasoline prices. Section 4 specifies a theoretical model and develops a reduced form equation. An error correction framework for the reduced form equation is also specified. Section 5 reviews empirical estimation results. Section 6 provides a brief summary of the empirical findings and implications.

2. Literature Review

A wide array of literature examines factors that influence gasoline prices. A substantial part of the research focuses on asymmetric price behavior. Pricing asymmetries occur when the lag time required for prices to react to changes in upstream prices is different for a price decrease than for a price increase. In the context of the gasoline industry, several studies document that gasoline prices generally respond more quickly to an increase in the price of crude oil than to a decrease, presumably because retailers attempt to capture larger profit margins as input prices go down (Borenstein et al., 1997; Chen et al., 2005; Davis, 2007; Grasso and Manera, 2007; Deltas, 2008). Other studies (Galeotti et al., 2003; Bachmeier and Griffin, 2003; Douglas, 2010; Angelopoulou and Gibson, 2010) argue there is little evidence of asymmetrical response to price shocks. Karrenbrock (1991) claims that although there is evidence of price asymmetry in response to wholesale price changes, consumers eventually do benefit from price decreases as fully as they do for increases.

A recently growing related area of research proposes that gasoline prices follow Edgeworth cycles (Eckert, 2002; Noel, 2007; Doyle et al., 2010; Zimmerman et al., 2013). Edgeworth price cycles, as described by Maskin and Tirole (1988), are characterized by a pattern of gradually falling prices followed by rapid hikes. Edgeworth cycles occur when prices oscillate due to the strategic behavior of firms rather than only due to changes in input prices or consumer demand. Competing firms begin by selling a product at a relatively high price, and each firm has an incentive to undercut its competitors by lowering the price. Firms continue to undercut each other during the 'price war phase' until prices fall to unsustainably low levels. In the subsequent 'relenting phase,' one firm will finally relent and increase its prices, leading other firms to follow suit and begin the cycle anew. Wang (2009) finds evidence that the behavior of retail gasoline prices is consistent with Edgeworth cycles, and that the larger firms tend to be the ones that first relent and increase their prices.

A variety of other factors also affect retail gasoline prices. Some studies look for upstream determinants by analyzing the response of retail prices to changes in wholesale prices (Karrenbrock, 1991; Tsuruta, 2008) or crude oil prices (Radchenko, 2005). Eckert and West (2004) present evidence that retail gasoline prices can vary between cities due to differences in market structures and the level of competition from 'maverick firms' that complicate tacit collusion among stations. Bello and Contín-Pilart (2012) specify a model for Spanish gasoline prices that posits regional gasoline prices as a function of taxes and numerous cost and demand variables that potentially contribute to gasoline price formation. The latter include weather, income, and demographics. Results indicate that regional price differences are mainly due to tax differences, while the other cost shifting and demand shifting determinants explain only a small portion of price differentiation.

There is evidence that taxes can play a major role in determining gasoline prices and, thus, in explaining price variation across countries and states. The existence of varying tax regimes across contiguous geographical regions creates an incentive for fuel tourism to emerge. Rietveld and van Woudenberg (2005) find that small countries in Europe try to capture this fuel tourism by setting gasoline taxes significantly lower than those of nearby countries. The city-states of Singapore and Hong Kong charge higher taxes than neighboring regions, but set regulatory restrictions that work as deterrents to fuel tourism. Banfi et al. (2005) investigate the impact of price differentials between Switzerland and its neighbors, concluding that about nine percent of Swiss gasoline sales stem from fuel tourism. Manuszak and Moul (2009) analyze data on Indiana and Illinois to measure the effect of different tax regimes on gasoline consumption. The spikes in prices along the borders of different tax regions point to the effects of consumers traveling to avoid higher tax areas.

Academic research on US-Mexico fuel tourism has tended to focus on the south side of the border. Haro and Ibarrola (1999) calculate the price elasticity of gasoline in the northern region to be less than unitary and confirm that U.S. gasoline acts as a substitute good for most of the border. Ibarra and Sortres (2008) explore the same issue and also conclude that the presence of a substitute good makes gasoline demand on Mexico's northern border much more sensitive to price changes than that of interior regions. Ayala and Gutiérrez (2004) analyze a sharp decrease in gasoline sales in northern Mexico from 1997 to 2000. Survey responses indicate that over a third of all polled families cross the border to purchase U.S. gasoline. U.S. gasoline is seen to act as a 'product hook' that greatly increases the probability Mexican consumers will make other purchases across the border that would otherwise occur in Mexico.

Fullerton et al. (2012) estimate the demand for gasoline in Ciudad Juarez as a function of employment, local gasoline prices, and the price of gasoline in El Paso. Results obtained indicate that cross-border prices have a net positive effect on sales in Ciudad Juarez, indicating that El Paso gasoline serves as a substitute good for the fuel sold on the south side of the international boundary. A natural extension of that study is to examine the retail gasoline market of El Paso. To date, very little research exists on retail automotive fuel markets on the north side of the U.S.-Mexico border. This study attempts to at least partially fill that void.

3. Data

Monthly frequency time series data from January 2001 to October 2013 are used to model gasoline prices in El Paso. Table 1 lists the name, definition, source, and units of measure for each variable employed in the analysis. Average regular gasoline prices at mid-month are available from GasBuddy.com. Although prices posted on this and similar sites are provided by voluntary spotters, Atkinson (2008) documents that data reported by these volunteers are generally accurate and finds no evidence of a systematic bias towards gasoline stations with unusually high or low prices. Although taxes can affect data consistency, the Texas gasoline tax has not varied during the sample period utilized.

A major determinant of any local retail gasoline price is the wholesale gasoline price. The wholesale price is the bulk acquisition price retailers pay for inventories. Wholesale price fluctuations will likely explain a large share of the total variation in El Paso gasoline prices. The portion of local gasoline prices left unexplained by national wholesale prices is presumably determined by variables reflecting local market conditions. Wholesale price data are obtained from the U.S. Energy Information Administration (EIA, 2014).

A number of studies document positive relationships between regional income levels and gasoline prices (Chouinard and Perloff, 2007; Hosken et al., 2008; Bello and Contín-Pilart, 2012). A similar pattern is expected to prevail in El Paso. Quarterly personal income estimates for El Paso are available from IHS Economics (Orozco, 2014). Monthly income per capita is interpolated using monthly employment data and then dividing over population (Friedman, 1962; Fernandez, 1981). Monthly employment data are available from the Bureau of Labor Statistics (BLS, 2014a). Population data are available from the Bureau of Economic Analysis (BEA, 2014). Income and all of the gasoline prices are adjusted for inflation to reflect 1982-1984 price levels using the consumer price index (BLS, 2014b). Quarterly income data are regressed on quarterly employment data as shown in Table 2. Moving average (MA) terms are included to account for serial correlation. The resulting equation is then used to estimate monthly personal income by using the historical observations for monthly employment in El Paso.

As mentioned above, cross-border price differentials tend to encourage fuel tourism. Ayala and Gutierrez (2004) report that a third of survey respondents in Ciudad Juarez cross the border for gasoline purchases. To determine whether fuel tourism affects El Paso gasoline prices, border crossings are included as an explanatory variable. If an increase in border crossings reflects an increase in fuel tourism from Mexico, then the variable is predicted to have a positive effect on price. However, if the increase in border crossings represents return trips by U.S. fuel tourists, the expected marginal effect is negative. Since it is not clear which of these scenarios is more likely to occur, no hypothesis is advanced regarding the effect of border crossings on the price of gasoline. Personal vehicle border crossing data are obtained from the Bureau of Transportation Statistics (BTS, 2014).

It may seem surprising that so many of the survey responses obtained by Ayala and Gutierrez (2004) indicate that the border is crossed specifically to make gasoline purchases. However, according to electronic mapping services and confirmed by author driving experiments, it takes less than 5 minutes to get to the nearest gasoline station in El Paso from any of the international bridges. All of the distances involved are less than 1.5 miles.

On the south side of the border, it can take up to 7 minutes to reach the nearest gasoline station in one case, but the distances are all less than 1.9 miles. Geographic distance and road network inconvenience are not obstacles to cross-border purchases of this homogeneous product.

With such short port-of-entry to nearest gasoline station driving distances on both sides of the border, it might be tempting to conclude that European style fuel tourism will be observed between the Borderplex economies. However, border wait times may cause the total volume of shopping trips to be much lower than geographic proximity implies (Clark, 1994; Fullerton, 2007). In 2013, for example, repeated hourly sampling for El Paso indicates that northbound border wait times averaged approximately 25 minutes per trip (CBP, 2013). That, in combination, with the relatively small volume of carrying capacity of most personal vehicle gasoline tanks, may cause benefits of cross-border gasoline purchases to be more diluted than in other regions of the world.

The Mexican equivalent to United States regular gasoline is Magna (in fact, the Magna sold in Ciudad Juarez and northern Mexico is refined in the United States). To further test whether fuel tourism affects El Paso gasoline prices, the price of Magna gasoline in Mexico is also included as a regressor. A positive relationship is expected to exist between the price of Magna in Ciudad Juarez and demand for the most readily available substitute good, U.S. regular gasoline. Increased demand for gasoline sold on the north side of the border is anticipated to result in higher prices. Thus, gasoline prices in Ciudad Juárez are hypothesized to have a positive impact on prices in El Paso.

Magna prices in nominal pesos are from the national statistics agency (INEGI, 2014). These data are originally expressed in pesos per liter. Those prices are converted into dollars per gallon by dividing those data by the peso/dollar exchange rate and then multiplying the results by 3.7854, the liter per gallon ratio. As with other border region products, the dollar price estimates for Magna gasoline are, of course, affected by currency market fluctuations (Fullerton et al., 2009).

Gasoline prices are generally lower during winter months, so it is often helpful to include seasonal variables in gasoline price equations (Borenstein et al., 1997; Chouinard and Perloff, 2007; Angelopoulou and Gibson, 2010). Local temperature data are from the National Climatic Data Center (NOAA, 2014). A positive correlation between temperature and gasoline prices is hypothesized.

Table 3 provides descriptive statistics for each of the variables. Northbound automobile border crossings varied considerably during the sample period, reaching a maximum of nearly 1.7 million per month immediately prior to the terrorist attacks of 11 September 2001 and oscillating over a wide range in subsequent years. All series exhibit fairly good degrees of variability, as measured by the ratio of the standard deviation to the mean. Highlighting the importance of analyzing local gasoline markets on a case by case basis, the retail gasoline price in El Paso, P, is more volatile than is the wholesale price, W.

Not surprisingly, a much lower degree of variability is observed for the Ciudad Juarez gasoline price series, CJ. Although gasoline prices are set at lower levels in northern regions of Mexico than in other regions of the country, Ciudad Juarez gasoline prices are not always lower than El Paso gasoline prices. As shown in Figure 1, Ciudad Juarez gasoline prices frequently exceeded those charged in El Paso prior to 2005 as well as during much of 2013. On average, the regular grade gasoline price in El Paso and the Magna gasoline price from across the river match each other very closely. The range for the price in El Paso, however, is much broader than what is observed in Ciudad Juarez for the sample period in question (Table 3).

Does border crossing traffic respond to gasoline price differentials between the two cities? There are many factors that can affect cross-border traffic flows (Fullerton, 2007), but Figure 2 shows that there is a positive correlation between northbound vehicle volumes across the international bridges and the magnitude of the inflation adjusted gasoline price gap between Ciudad Juarez and El Paso. The simple correlation coefficient between these two series is 0.382 and at least raises the possibility that some linkage may exist between these two variables within the Borderplex economy. Empirical evidence on whether or not statistically reliable relationships exist between cross-border traffic flows and El Paso retail gasoline prices are discussed below.

Wholesale prices account for supply and demand factors that affect gasoline prices at the national level, while local determinants primarily exercise demand effects. To incorporate all of these variables, a theoretical model is developed and an equilibrium specification is specified. Next, to account for both long-run and short-run influences, the static, reduced form equation is re-cast within an error-correction framework.

4. Theoretical model

The factors that influence supply and demand in gasoline markets are generally well understood (Dahl and Sterner, 1991; Bello and Contín-Pilart, 2012). Given equations for supply (Q_S) and demand (Q_D), it is possible to extract a reduced form equation for price (Pindyck and Rubinfeld, 1998). One advantage of this approach is that it does not require data on gasoline consumption, which are unavailable for El Paso during the sample period. Reduced form equations are common in the literature on gasoline prices (Vita, 2000; Chouinard and Perloff, 2007).

The implicit demand equation is Q_D=D(p,Y,CJ,BC,TEMP) and the implicit supply equation is Q_S=S(p,W). The supply and demand equations can be written in linear fashion as follows, along with the expected signs for each parameter shown parenthetically:

$$Q_D=\alpha_0+\alpha_1 p_t+\alpha_2 Y_t+\alpha_3 CJ_t+\alpha_4 BC_t+\alpha_5\, TEMP_t+e_t \quad \textbf{(1)}$$
(-) (+) (+) (?) (+)

$$Q_D=\beta_0+\beta_1\, p_t+\beta_2\, W_t+u_t \quad \textbf{(2)}$$
(+) (-)

The equilibrium price can be solved by equating supply and demand (Q_S=Q_D). Doing so with Equations (1) and (2) yields the expression for price shown in Equation (3):

$$\beta_1 p_t-\alpha_1 p_t=\alpha_0+\alpha_2\, Y_t+\alpha_3 CJ_t+\alpha_4\, BC_t+\alpha_5 TEMP_t+e_t-\beta_0-\beta_2 W_t-u_t$$

$$(\beta_1-\alpha_1)\, p_t=\alpha_0-\beta_0+\alpha_2 Y_t+\alpha_3 CJ_t+\alpha_4 BC_t+\alpha_5\, TEMP_t-\beta_2\, W_t+e_t-u_t$$

$$p_t=(\alpha_o-\beta_o)/(\beta_1-\alpha_1)+\alpha_2/(\beta_1-\alpha_1)Y_t+\alpha_3/(\beta_1-\alpha_1)CJ_t+\alpha_4/(\beta_1-\alpha_1)BC_t+\alpha_5/(\beta_1-\alpha_1)TEMP_t-\beta_2/(\beta_1-\alpha_1)W_t+(e_t-u_t)/(\beta_1-\alpha_1) \quad \textbf{(3)}$$

Equation (3) can be rewritten more compactly as:

$$p_t= \gamma_0+\gamma_1 Y_t+\gamma_2 CJ_t+\gamma_3 BC_t+\gamma_4 TEMP_t+\gamma_5 W_t+v_t \quad \textbf{(4)}$$

The expected signs of the parameters in Equation (4) can be ascertained by including the hypothesized sign of each parameter from Equations (1) and (2) in Equation (3). This yields four specific testable hypotheses:

$$\gamma_1>0,\gamma_2>0,\gamma_4>0,\gamma_5>0$$

Based on the assumptions made for Equations (1) and (2), the hypothesized signs for γ_1, γ_2, γ_4, and γ_5 will be positive. The expected sign of the remaining fifth slope coefficient, γ_3, is ambiguous. That is because a rise in border crossings may lead to either an increase or a decrease in local gasoline demand, depending on the direction of cross-border fuel tourism, as well as the relative magnitudes of the price elasticities of supply and demand.

Error correction models are commonly employed to estimate gasoline price equations because they can handle long-run price dynamics as well as short-run deviations from equilibrium (Borenstein et al., 1997; Bachmeier and Griffin, 2003; Radchenko, 2005; Grasso and Manera, 2007). The basic framework consists of two equations, a long-run cointegrating equation and a short-run error correction equation. The long-run equation is estimated using non-differenced variables. Within such an approach, Equation (4) represents the long-run cointegrating equation. If the residuals from Equation (4) are stationary, a cointegrating relationship has been found and the equation can be estimated in a statistically reliable fashion (Maddala and Kim, 1998).

The short-run error correction equation is estimated using first differences of the same variables included in the long-run equation plus a one-period lag of the long-run equation residual:

$$\Delta p_t=\pi_1+\pi_2\Delta Y_t+\pi_3\Delta CJ_t+\pi_4\Delta BC_t+\pi_5\Delta TEMP_t+\pi_6 \Delta W_t+\pi_7\hat{v}_{(t-1)}+w_t \quad (5)$$

In Equation (5), Δ is a difference operator, $\hat{v}_{(t-1)}$ are the lagged residuals from Equation (4), and w is a random error term. The coefficient π_7 represents the speed of adjustment to any deviation away from the long-run equilibrium price and, because it offsets prior period disequilibria, should be negative. The amount of time (in months) required for any disequilibria to fully dissipate is equal to $1/|\pi_7|$.

5. Empirical results

Table 4 lists the parameter estimates for Equation (4). All variables are logarithmically transformed prior to estimation. Consequently, the estimated coefficients can be interpreted as elasticities. A unit root test on the regression residuals indicates that gasoline prices are cointegrated with the explanatory variables. Residual autocorrelation is corrected by including a first order autoregressive (AR) term in the equation specification.

Real per capita income exerts a strong positive impact on retail gasoline prices in El Paso. As shown in Table 4, a ten percent increase in per capita income results in a 5.3 percent increase in gasoline prices. This aligns well with previously documented evidence that business cycle movements explain a large portion of long-run variation in gasoline prices (Kilian, 2009).

The coefficient for the Ciudad Juarez gasoline price is positive as hypothesized. However, the coefficient is statistically insignificant, implying that gasoline prices in El Paso and Ciudad Juarez are, at most, weakly related in the long-run. This is similar to evidence reported in Leal et al. (2009) that indicates that the impacts of cross-border purchases on regional automotive fuel markets in Spain are muted in the long-run, but statistically significant in the short-run. One reason for this outcome may be that gasoline prices in northern Mexico generally move in tandem with U.S. wholesale gasoline prices, albeit with deviations that last for relatively short periods of time. Over the long-run, multicollinearity between the two gasoline price regressors may explain the insignificance of Ciudad Juarez gasoline as an explanatory variable. When wholesale prices are omitted from the regression, the parameter estimated for Ciudad Juarez gasoline prices becomes statistically significant.

When border automobile crossings increase by ten percent, El Paso gasoline prices decline by 0.8 percent. The negative sign indicates that border commuters purchase more gasoline in Ciudad Juarez than in El Paso. That result is in contrast with outcomes obtained by Fullerton et al. (2012) that document negligible impacts of bridge crossings on Ciudad Juarez gasoline demand.

The coefficient for temperature in Table 4 is also positive but fails to satisfy the significance criterion. The statistical insignificance of this coefficient in a long-run regression equation may be explained in part by the seasonal nature of ambient monthly temperatures. Chouinard and Perloff (2007) show that weather conditions play an important role in explaining short-term fluctuations in retail gasoline prices but explain little of the long-term trends in prices.

Wholesale prices exert significant and strong effects on long-run retail gasoline price variations in El Paso. A ten percent increase in wholesale prices leads El Paso retail gasoline prices to increase by 7.7 percent. This coefficient is similar in magnitude to previously published estimates of the relationship between wholesale and retail gasoline prices (Deltas, 2008). The fact that the estimated parameter for the wholesale price is only 0.77 in Table 4 highlights the importance of taking into account local economic conditions and weather patterns when modeling metropolitan retail gasoline prices.

Table 5 summarizes the estimation results for the short-run error-correction equation. Real per capita personal income affects El Paso gasoline prices in a direct manner. Other things equal, a ten percent increase in per capita income is associated with a 3.14 percent rise in prices at the pump.

The price of Magna gasoline in Ciudad Juarez is a statistically significant predictor, at the 10-percent level, of the price for regular gasoline sold in El Paso in the short-term. A ten percent increase in gasoline price in Juarez would lead to an increase of 1.5 percent in El Paso gasoline prices. On the surface, the inelasticity of retail prices relative to what is charged south-of-the-border indicates that the Magna grade of gasoline is a highly imperfect substitute for regular gasoline in El Paso. A more plausible explanation is that ongoing difficulties in traversing the international boundary over the course of the sample period weaken the relationship that would otherwise exist between these two price series in neighboring metropolitan economies (Fullerton, 2007; Walke and Fullerton, 2014).

As shown in Table 5, the impact of northbound bridge crossings on short-run motor fuel price movements is not measurably different from zero. Average monthly temperature has a positive and significant effect on short-run gasoline price fluctuations. As noted by Lin et al. (1985), warmer temperatures may increase the likelihood of engaging in outdoor activities, including driving, and increased use of motor vehicles in warmer periods is likely to exert upward pressure on prices. A one percent increase in temperature leads to a 0.07 percent increase in prices. In other words, a seasonal increase from the approximate sample mean of 65 degrees to 80 degrees will lead to an 2 cent rise in the real price of gasoline (1982-84 = 100) from the sample mean of US$1.15 per gallon to US$1.17.

Not surprisingly, wholesale price changes also play prominent roles in determining short-run retail gasoline price variations. A ten percent increase in real wholesale prices increases El Paso retail gasoline prices by 4.3 percent. This outcome closely matches results reported in Polemis (2012).

The coefficient for the error correction term is negative as hypothesized. Its coefficient is -0.56 which means that any short-run deviation from the long-term equilibrium fully dissipates in less than two months. Most of the previous literature on this topic indicates that, after a shock, gasoline prices in other markets also return to long-run equilibria in a matter of months (Asplund et al., 2000; Kaufman and Laskowski, 2005).

Good in-sample model fits do always guarantee accurate out-of-sample simulation results. In this case, however, the modeling results summarized in Tables 4 and 5 perform well relative to random walk and random walk with drift forecasting benchmarks (Fullerton et al., 2015). The out-of-sample gasoline price simulations are conducted for forecast periods with step lengths of up to twelve months. The error correction model forecasts outperform the comparative benchmarks at nearly every step-length, a good performance by many gasoline price model standards (Bopp and Neri, 1978; Anderson et al., 2011).

One final observation with respect to the absence of a stronger short-run link between the pump price of gasoline and border crossings is in order. As shown by Png and Rietman (1994), some customers tend to avoid crowded gasoline stations and pay higher prices if time can be saved. If large numbers of customers from Mexico wish to avoid service station congestion in El Paso, it will tend to dilute the downward impact on gasoline prices that would otherwise be observed. At present, gasoline price dispersion data have not been assembled for El Paso, so it difficult to assess this possibility. That prospect raises interesting questions for future study.

6. Conclusion

The border metropolitan economies of El Paso and Ciudad Juarez are physically adjacent to each other and consumers from both cities make cross-border gasoline purchases. Because regular gasoline is a fairly homogeneous product, the behavior of border region retail gasoline prices provides at least some insight to the degree of economic integration that exists between neighboring metropolitan economies along the border between the United States and Mexico. To shed some light on this possibility, a model is specified and estimated for monthly El Paso retail gasoline price movements.

Estimation results corroborate much of what has been recorded for other regional gasoline markets. In particular, wholesale gasoline prices play prominent roles in determining both long-run and short-run retail fuel price fluctuations in El Paso. Beyond that, real per capita income and the volume of northbound automobile border crossings are found to reliably influence long-term gasoline price movements. In the short-run, real income, cross-border gasoline price changes in Ciudad Juarez, and outdoor temperatures are all found to affect El Paso gasoline prices in statistically significant manners. Deviations from the long-term equilibrium price are also found to be corrected in less than 60 days.

The long-term cointegration and short-term error correction results both indicate that El Paso gasoline prices react in very inelastic manners to variations in their south-of-the-border retail counterparts. That Magna gasoline prices are found to exercise only limited influence on monthly regular grade gasoline price fluctuations in El Paso should not be interpreted as evidence that consumers treat these products as highly imperfect substitutes. More than likely, given the close proximity of gasoline stations to the ports of entry on both sides of the river, it is an indication of how effectively the international boundary limits regional economic integration between these Borderplex neighbors.

From that perspective, it is difficult to argue that these two metropolitan economies are very highly integrated. Whether this is also the case for other border metropolitan economies has not been widely investigated. More research on this topic for areas such as Brownsville - Matamoros, McAllen - Reynosa, Laredo - Nuevo Laredo, Calexico - Mexicali, and San Diego - Tijuana appears warranted. Results obtained herein indicate that the international boundary still represents, in the case of retail gasoline in this region, a substantial barrier to cross-border trade for a homogeneous product.

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Table 1
Variables

Variable Name	Definition	Units	Source
P	El Paso real gasoline price	Dollars/gallon	GasBuddy.com and author calculations
Y	El Paso real personal income per capita	Dollars	IHS Economics and author calculations
CJ	Real price of Ciudad Juarez Magna gasoline	Dollars/gallon	INEGI and author calculations
BC	Total number of northbound personal vehicles crossing the border	Personal vehicles	BTS
TEMP	Average monthly temperature in El Paso region	Fahrenheit	NOAA
W	USA real wholesale gasoline price	Dollars/gallon	EIA

Notes:
Nominal data are converted to real values using the USA consumer price index, 1982-1984 = 100.
Magna peso prices per liter are converted to dollar per gallon by dividing by the corresponding nominal peso per dollar exchange rate and multiplying by the liter per gallon ratio, 3.7854.

Table 2
Personal income regression analysis

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-27905.37	4121.899	-6.770028	0.0000
EMP	172.4001	15.32835	11.24714	0.0000
MA(1)	0.737385	0.082233	8.967012	0.0000
MA(2)	0.728665	0.085425	8.529881	0.0000
R-squared	0.951201	Mean dependent variable	18294.01	
Adjusted R-squared	0.948386	S.D. dependent variable	2463.095	
S.E. of regression	559.5848	Akaike information criterion	15.56102	
Sum of squared residuals	16283029	Schwarz criterion	15.70568	
Log likelihood	-431.7085	Hannan-Quinn criterion	15.61710	
F-statistic	337.8659	Durbin-Watson statistic	1.930722	
Probability (F-statistic)	0.000000			
Inverted MA Roots	-.37-.77i	-.37+.77i		

Notes:
Dependent Variable: Income
Method: Least Squares
Sample: 2000Q1 – 2013Q4
Included observations: 56
Convergence achieved after 10 iterations
MA Backcast: 1999Q3 – 1999Q4

Table 3
Summary statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
P	1.15	0.31	0.60	1.80
Y	24,192	1,135	21,522	27,011
CJ	1.16	0.13	0.82	1.49
BC	1,071,208	223,845	688,921	1,695,692
TEMP	65.4	13.15	42.0	85.7
W	0.91	0.31	0.33	1.56

Notes:
For each variable there are 154 monthly observations, January 2001 – October 2013.

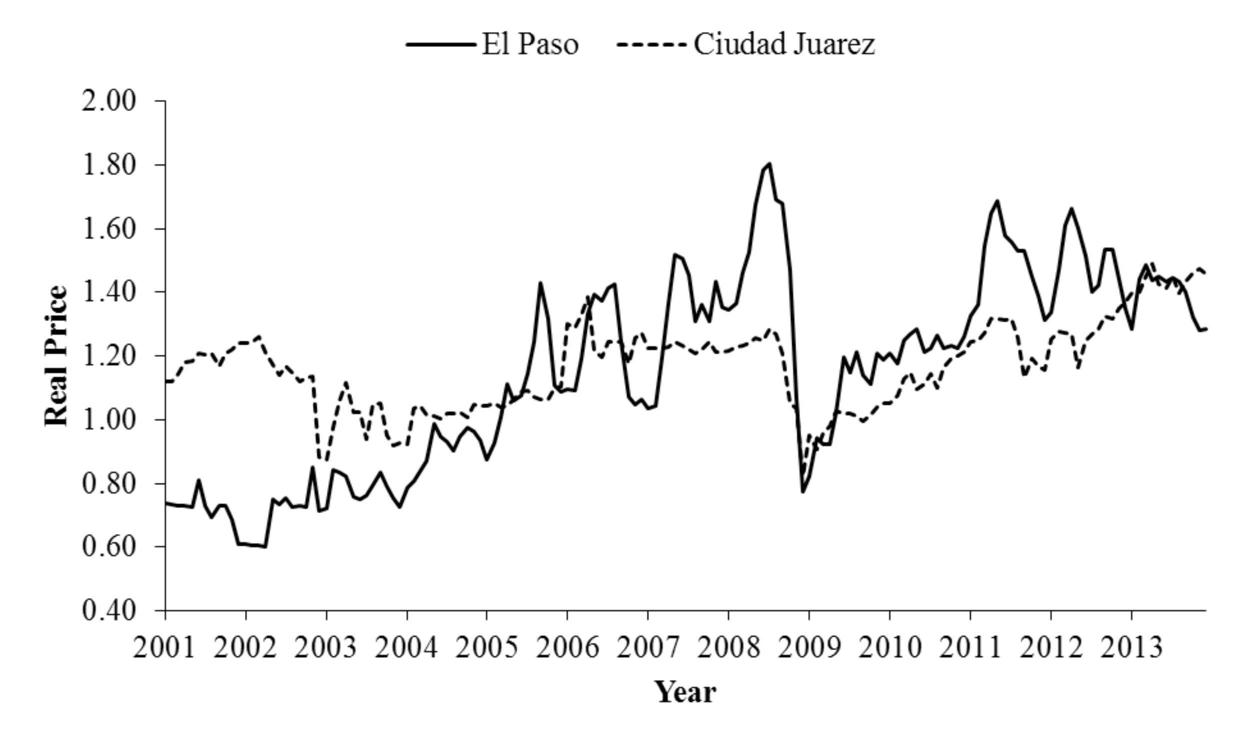

Figure 1. El Paso and Ciudad Juarez Real Gasoline Prices

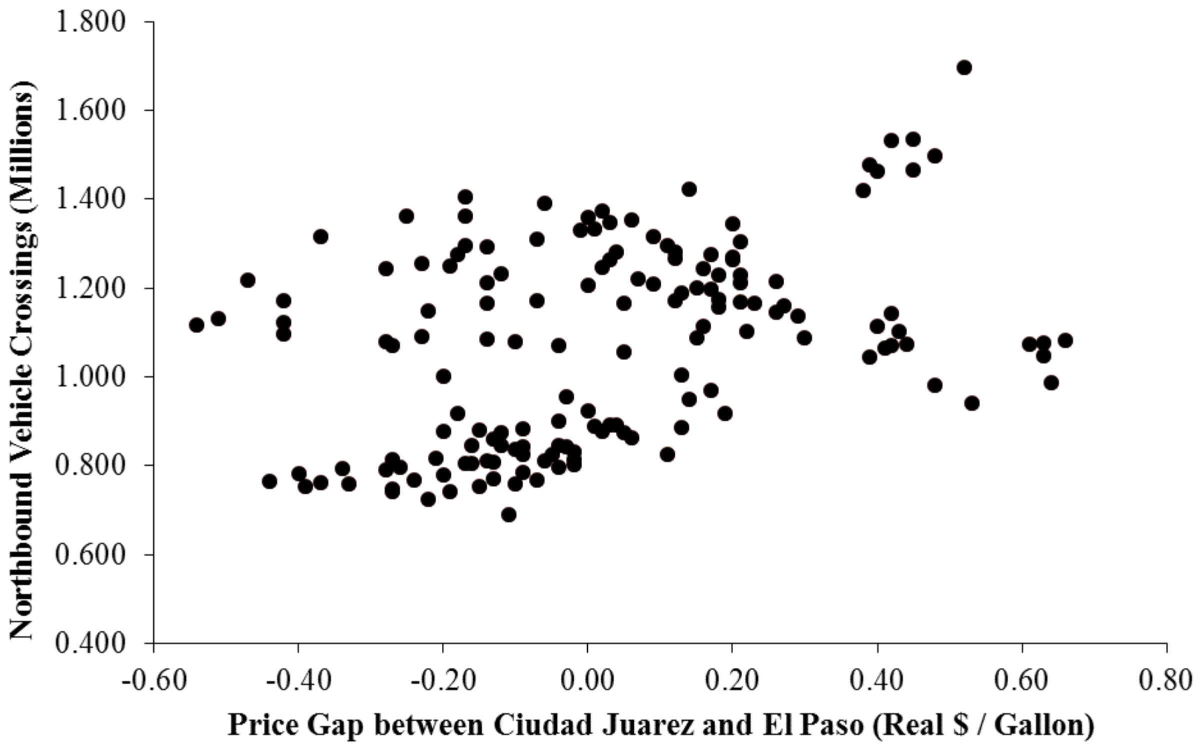

Figure 2. Northbound Vehicle Crossings vs. Ciudad Juarez – El Paso Gasoline Price Gap

Table 4
Long-run cointegration equation for El Paso gasoline prices

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.235505	1.919573	-2.206483	0.0289
LOG(Y)	0.528075	0.173829	3.037890	0.0028
LOG(CJ)	0.088629	0.070823	1.251417	0.2128
LOG(BC)	-0.083034	0.039347	-2.110299	0.0365
LOG(TEMP)	0.026956	0.034731	0.776140	0.4389
LOG(W)	0.768189	0.034694	22.14201	0.0000
AR(1)	0.532095	0.072961	7.292833	0.0000
R-squared	0.969961	Mean dependent variable	0.099979	
Adjusted R-squared	0.968726	S.D. dependent variable	0.287549	
S.E. of regression	0.050851	Akaike info criterion	-3.075146	
Sum of squared residuals	0.377536	Schwarz criterion	-2.936499	
Log likelihood	242.2487	Hannan-Quinn criterion	-3.018825	
F-statistic	785.7133	Durbin-Watson statistic	1.827881	
Probability (F-statistic)	0.000000			
Inverted AR Roots	.53			

Notes:
Dependent Variable: Income
Method: Least Squares
Sample: 2000Q1 – 2013Q4
Included observations: 56
Convergence achieved after 10 iterations
MA Backcast: 1999Q3 – 1999Q4

Table 5
Short-run error-correction equation for El Paso gasoline prices

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001552	0.003955	0.392375	0.6954
DLOG(Y)	0.313965	0.170640	1.839919	0.0678
DLOG(CJ)	0.146059	0.083419	1.750908	0.0821
DLOG(BC)	-0.034506	0.055802	-0.618364	0.5373
DLOG(TEMP)	0.077175	0.037172	2.076187	0.0396
DLOG(W)	0.433449	0.055958	7.746012	0.0000
RES(-1)	-0.558710	0.086196	-6.481865	0.0000
R-squared	0.617736	Mean dependent variable	0.003880	
Adjusted R-squared	0.601918	S.D. dependent variable	0.077031	
S.E. of regression	0.048602	Akaike info criterion	-3.165358	
Sum of squared residuals	0.342508	Schwarz criterion	-3.026100	
Log likelihood	247.5672	Hannan-Quinn criterion	-3.108787	
F-statistic	39.05311	Durbin-Watson statistic	1.673368	
Probability (F-statistic)	0.000000			

Notes:
Dependent Variable: LOG(PRICE)
Method: Least Squares
Sample (adjusted): 2001M03 2013M10
Included observations: 152 after adjustments

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The authors of this publication are UTEP Professor & Trade in the Americas Chair Tom Fullerton and UTEP Associate Economist Adam Walke. Dr. Fullerton holds degrees from UTEP, Iowa State University, Wharton School of Finance at the University of Pennsylvania, and University of Florida. Prior experience includes positions as Economist in the Executive Office of the Governor of Idaho, International Economist in the Latin America Service of Wharton Econometrics, and Senior Economist at the Bureau of Economic and Business Research at the University of Florida. Adam Walke holds an M.S. in Economics from UTEP and has published research on energy economics, mass transit demand, and cross-border regional growth patterns.

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The authors of this publication are UTEP Professor & Trade in the Americas Chair Tom Fullerton and former UTEP Associate Economist Angel Molina. Dr. Fullerton holds degrees from UTEP, Iowa State University, Wharton School of Finance at the University of Pennsylvania, and University of Florida. Prior experience includes positions as Economist in the Executive Office of the Governor of Idaho, International Economist in the Latin America Service of Wharton Econometrics, and Senior Economist at the Bureau of Economic and Business Research at the University of Florida. Angel Molina holds an M.S. Economics degree from UTEP and has conducted econometric research on international bridge traffic, peso exchange rate fluctuations, and cross-border economic growth patterns.

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Professor Barraza is an award winning economist who has taught at several universities in Mexico and has published in academic research journals in Mexico, Europe, and the United States. Dr. Barraza currently serves as Research Provost at UACJ. Professor Fullerton has authored econometric studies published in academic research journals of North America, Europe, South America, Asia, Africa, and Australia. Dr. Fullerton has delivered economics lectures in Canada, Colombia, Ecuador, Finland, Germany, Japan, Korea, Mexico, the United Kingdom, the United States, and Venezuela.

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