2014-01-01

A Long- and Short-Run Analysis of Electricity Demand in Ciudad Juarez

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Dedication

I lovingly dedicate this project to my wonderful husband Ryan who has been my greatest cheerleader throughout the process. He has always believed in me. His constant reassurance inspires me to push myself and take calculated risks.

To my amazing parents, Hortensia and Agustin, and my awesome sisters, Paola and Jessica, who have always been by my side loving me, encouraging me, and helping me spiritually and emotionally.

To my beautiful new family –the Stoltzfuses, the Gobbles, and the Hofackets– for embracing a new member in the group, and for wholeheartedly supporting me as a daughter, sister, and aunt.

Thank you all for your never-ending love, prayers, and encouragement. I love you!

A LONG- AND SHORT-RUN ANALYSIS OF ELECTRICITY DEMAND IN CIUDAD JUAREZ

by

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THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

Department of Economics and Finance

THE UNIVERSITY OF TEXAS AT EL PASO

May 2014

Acknowledgements

I would like to take this opportunity to convey my sincere gratitude to those who have, academically, made this project possible. Dr. Tom Fullerton has been an invaluable thesis supervisor. His sage advice, insightful criticism, and patient guidance aided in the writing of this thesis in innumerable ways. I would also like to thank thesis committee member and academic advisor Adam Walke for granting me his time and support as I progressed through my MSE degree and stumbled into uncharted graduation territories. I want to thank Dr. Heidi Taboada for dedicating her time to my project and offering her valuable feedback. Finally, I would like to thank the amazing faculty in the program, who unreservedly shared their minds, insights, and expertise on a regular basis.

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Chapter 1: Introduction

Empirical studies of electricity consumption have been conducted for many different regions of the world. This is not surprising because electric energy plays a central role in household, private sector, and public sector production functions. Although economic growth and appliance saturation are increasing electricity consumption in Mexico, there have been relatively few analyses of metropolitan electricity usage for that country.

To complete such a study, a data set is assembled for Ciudad Juarez, a large metropolitan economy near the border with the United States. Annual frequency data from 1990 to 2012 are utilized to develop an error correction framework that sheds light on short- and long-run consumption behavior in this metropolitan economy. The sample data include variables for consumption, price, weather, and economic conditions.

The study is organized as follows. Section 2 provides a literature review. Section 3 describes the data and methodology employed. Section 4 explains the empirical results obtained. Section 5 provides concluding remarks.

Chapter 2: Literature Review

To meet increasing regional electricity demand, large investments are required for generation, transmission, and distribution. These are important steps because electricity production costs increase exponentially as maximum generation capacity is reached (Albadi and El-Saadany, 2008). In Mexico, a federal government agency, Comisión Federal de Electricidad (CFE), produces, transmits, and distributes electricity throughout the country.

Information constraints generally make it difficult to gather marginal price data. Taylor (1975) argues that utilizing average prices constitutes a misspecification as marginal price constitutes the appropriate price variable for analyzing demand. That study acknowledges, however, that marginal price is often measured incorrectly, often leading to biased parameter estimates. Shin (1985) provides evidence that consumers do not respond to marginal prices but to ex-post average prices because electricity bills arrive at the end of each month. Consequently, average price is an appropriate measure. Fisher and Kaysen (1962) maintains that either price metric can be employed with no major repercussions on empirical results. Wills (1981) also provides empirical evidence that neglecting to utilize marginal prices does not significantly affect empirical outcomes.

Previous empirical work indicates that long-run own-price elasticities generally range between –0.4 and –2.25 (Espey and Espey, 2004). Because consumers can modify appliance stocks, almost all long-run price responsiveness is due to stock adjustments rather than utilization adjustments (Wills, 1981). Short-run own-price sensitivities are more inelastic, usually ranging between –0.2 and –0.4 (Fisher and Kaysen, 1962; Taylor, 1977; Dubin and McFadden, 1984; Marshall, 2010). There is also some evidence that own-price elasticity decreases as household income increases (Reiss and White, 2005). Price sensitivities also appear to be more inelastic in the summer than in the winter, probably reflecting a smaller substitution capacity for air conditioning equipment relative to heating devices (Filippini, 1999).

Income elasticity estimates appear to be affected by the type of data utilized. Estimates obtained with household data reveal income elasticities of 0.4 and below (Sheinbaum et al., 1996; Wills, 1981; Yoo et al., 2007). Estimates that utilize aggregate data oscillate between 0.5 and 1 (Galindo, 2005). Wilson (1971) and Roth (1981) provide empirical evidence that residential electricity is an "inferior good" whose consumption declines as income grows. These results conflict with most prior research (Espey and Espey, 2004). Wills (1981) corroborates these findings in a study that differentiates between the long run and the short run: in the short run, electricity is found to be a "weakly" normal good that becomes inferior in the long run. At least three subsequent studies confirm these outcomes also (Berndt and Samaniego, 1984; Contreras et al., 2009; Fullerton et al., 2012).

A complete demand function must capture substitute good effects. Natural gas has been utilized in numerous studies as the primary substitute for electricity. Cross-price elasticity estimates between these two goods tend to range between 0 and 0.25, indicating limited substitutability between them (Roth, 1981). Because natural gas is becoming a more popular energy source for cooking and heating in Mexico (Rosas-Flores and Gálvez, 2010), the substitution effect may be more pronounced in Ciudad Juarez.

Electricity demand is also affected by climatic conditions. The impacts of changes in weather conditions on electricity loads can be substantial (Fullerton et al., 2012; EPE, 2013). Commonly used variables include heating degree days and cooling degree days, which measure daily mean temperatures below and above, respectively, 65°F. These proxies are then able to capture the climate effects that shape heating and cooling requirements.

Residential electricity in Mexico is primarily used for lighting and appliance operation, cooking and heating are mainly carried out with liquid petroleum gas and natural gas (Berndt and Samaniego, 1984; Sheinbaum et al., 1996). Electricity for lighting and other appliances is the fastest growing category of energy usage in Mexico (Rosas-Flores and Gálvez, 2010).

Electricity tariffs in Mexico are set by the CFE and consist of two rate schedules per region. There is a normal service tariff and a lower tariff. The latter is applied during the six hottest months of the year (CFE, 2013). There is a special higher tariff per region applied to those customers who consume electricity above a specific threshold. For Ciudad Juarez, this threshold is 1,000 kilowatt-hours (KWH) per month (CFE, 2013).

Ciudad Juarez has a population of 1.3 million people. Total usage reached 4,105 gigawatt-hours (GWH) in 2012 (INEGI, 2013), yielding revenues of $5.57 billion pesos. From 1988 to 2012, electricity consumption has grown at an average of 5.1% per year. In spite of substantial growth, an econometric analysis of per customer usage and customer base growth for this urban economy has not previously been completed.

Chapter 3: Theoretical Model

Electricity itself does not generate utility for consumers; it indirectly contributes as an input for activities that do provide utility to individuals (Taylor, 1975). These processes require investments in durable goods. For that reason, it is helpful to differentiate between short- and long-run demand. In the short run, stocks of goods are fixed and the relevant decision is with respect to intensity of use. In the long run, consumers can modify durable good stocks.

$$\underset{}{Ln(D_t)} = \alpha_0 + \underset{(-)}{\alpha_1 Ln(P_t)} + \underset{(+)}{\alpha_2 Ln(Y_t)} + \underset{(+)}{\alpha_3 Ln(PNG_t)} + \underset{(+)}{\alpha_4 Ln(CDD_t)} + \underset{(+)}{\alpha_5 Ln(HDD_t)} + u_t \qquad \textbf{(1)}$$

Equation (1) is known as the cointegration equation. It represents the long run equilibrium when consumers can optimally adjust electric appliance stocks. Electricity demand per consumer (D) is modeled as a function of average price (P), income per capita (Y), the price of natural gas as a substitute good (PNG), and weather conditions measured by cooling degree days (CDD) and heating degree days (HDD). The data are transformed using natural logarithms, so the α_k parameters represent demand elasticities. The expected signs for the coefficients are included parenthetically below each explanatory variable.

Increases in average price are assumed to decrease electricity consumption. The income coefficient is expected to be positive, classifying electricity in Ciudad Juarez as a normal good. If electricity and natural gas are substitutes, increases in the price of the latter should lead to increases in electricity usage. The magnitude of this parameter will indicate the degree of substitutability between the two. Both weather variables are predicted to be positive because as temperatures rise above or fall beyond the 65°F baseline, the intensity of use of cooling or heating appliances increases.

Equation (2) represents short-run electricity demand. All data are differenced once and an error correction term is included. This regressor is a one-period lag of the residuals from

Equation (1). The coefficient estimated for it measures the speed at which short-run departures return to long-run equilibrium. It is, accordingly, expected to be negative because deviations from equilibrium will be followed by compensating adjustments in subsequent periods.

$$dLn(D_t) = \beta_0 + \underset{(-)}{\beta_1 dLn(P_t)} + \underset{(+)}{\beta_2 dLn(Y_t)} + \underset{(+)}{\beta_3 dLn(PNG_t)} + \underset{(+)}{\beta_4 dLn(CDD_t)} + \underset{(+)}{\beta_5 dLn(HDD_t)} + \underset{(-)}{\beta_6 u_{t-1}} + v_t \quad \textbf{(2)}$$

Customer base growth requires electric utilities to invest in system expansions. Consequently, this study also models the number of electricity customers in Ciudad Juarez. Equation (3) presents the long-run cointegration equation.

$$Ln(EC_t) = \gamma_0 + \underset{(+)}{\gamma_1 Ln(POP_t)} + \underset{(+)}{\gamma_2 Ln(EMP_t)} + e_t \quad \textbf{(3)}$$

As in Fullerton et al. (2012), demographic and economic trends are assumed to drive customer base growth. The specification above includes population (POP) and employment (EMP) as the explanatory variables for electricity customers (EC). Both regressors are expected to be partially correlated with the number of customers.

Equation (4) represents the short-run error correction equation. The third regressor is a one-period lag of the residuals from Equation (3). Its coefficient quantifies the speed of adjustment subsequent to any disequilibrium shocks.

$$dLn(EC_t) = \delta_0 + \underset{(+)}{\delta_1 dLn(POP_t)} + \underset{(+)}{\delta_2 dLn(EMP_t)} + \underset{(-)}{\delta_3 e_{t-1}} + f_t \quad \textbf{(4)}$$

Annual data from 1990 to 2012 are employed in the study. Consumption data include total electricity consumption and total electricity customers in Cuidad Juarez (GWH and number of meters, respectively). These data are obtained from the national statistics agency (INEGI, 2013). The real price variable is average revenue per KWH divided by the consumer price index. To account for income effects, a real per capita disposable income variable is included. This series uses national disposable income data obtained from the Organization for Economic Cooperation and Development (OECD, 2013). These estimates are transformed into metropolitan data by multiplying them by the ratio of Ciudad Juarez employment to Mexico employment.

The real price of natural gas in the area is included to capture substitution effects. These data are obtained from the national petroleum company (PEMEX, 2013). Mexican households typically utilize electricity to power air conditioning and heating appliances. Weather affecting electricity consumption is measured using CDD and HDD. These series are constructed using data obtained from the national weather service (SMN, 2013) by subtracting the base of 65°F from the average daily temperature. The resulting positive numbers for each year were added to obtain each yearly CDD figure; the absolute values of the negative results were added in the same way to form the HDD series. The population and total employment variables are obtained from the national statistics agency (INEGI, 2013) and the social security institute (IMSS, 2013), respectively. All the price and income variables are deflated using the Mexican consumer price index to express them in real 2010 pesos. Table 1 summarizes this information.

Table 1 – Variable Definitions

Variable	**Definition**
D	Electricity demand per consumer, kilowatt-hours
P	Price per kilowatt-hour, real 2010 Mexican pesos
Y	Disposable income per capita, real 2010 Mexican pesos
PNG	Price of natural gas, real 2010 Mexican pesos per kilo
CDD	Cooling degree days, base temperature = 65°F
HDD	Heating degree days, base temperature = 65°F
EC	Total electricity customers, number of accounts
POP	Population
EMP	Total employment covered by IMSS
IV1	CFE total electricity generation capacity, million kilowatts
IV2	Yearly inflation, consumer price index, percentage

Chapter 4: Empirical Results

Endogeneity represents a potential concern for this model as one of the exogenous variables, P, is jointly determined with the endogenous variable D in Equation (1). This occurs due to the manner in which these variables are calculated: D = KWH/POP and P = revenue/KWH. A model that exhibits endogeneity yields biased and inconsistent OLS parameter estimates, so alternative procedures must be utilized. To examine whether endogeneity exists between P and D, a two-step artificial regression test is performed (MacKinnon, 1992). This test will verify whether bi-directional causality exists between the average real price, P, and per customer demand, D.

To implement the two-step artificial regression test, instrumental variables (IVs) correlated with the average price of electricity must be identified. These variables are meant to isolate the regressor's variation components that are not likely to be affected by the dependent variable D. For this specification, the instrumental variables selected are yearly inflation in Mexico (as measured by the consumer price index), and CFE total generation capacity. The results of the two-step artificial regression test indicate that endogeneity is present. To obtain unbiased and consistent parameter estimates, fitted values of the average real price variable must be obtained via the IV vector.

$$P_t = \varepsilon_0 + \varepsilon_1 IV1_t + \varepsilon_2 IV2_t + w_t \quad \textbf{(5)}$$

Once Equation (5) is estimated, the fitted values for the average price (PF) are calculated by subtracting the residuals w_t from the original P variable. PF then becomes the real average price measure utilized for estimating the long-run cointegration equation. Equation (6) depicts the modified long-run demand model.

$$Ln(D_t) = \alpha_0 + \alpha_1 Ln(PF_t) + \alpha_2 Ln(Y_t) + \alpha_3 Ln(PNG_t) + \alpha_4 Ln(CDD_t) + \alpha_5 Ln(HDD_t) + u_t \quad \textbf{(6)}$$

Table 2 displays the estimation results for Equation (6). The coefficient of determination and computed F-statistic indicate a good model fit and all of the coefficient estimates exhibit the expected signs. The Durbin-Watson test for serial correlation is inconclusive. However, an autocorrelation function analysis of the residuals and Q-statistic reveal that serial correlation is not present in the residuals.

The price elasticity, –0.510, lies toward the lower range of long-run price elasticities reported in prior studies (Espey and Espey, 2004). This implies that there is relatively limited utilization adjustment to price changes in Ciudad Juarez. The result also indicates, however, that raising revenues for infrastructure investment should be feasible for CFE.

The income elasticity in this study is positive and slightly more inelastic than what is discussed in other studies. The income coefficient in Table 2 indicates that electricity is a normal good in Ciudad Juarez. This result implies that as income increases, so does demand and confirms the outcomes documented in a number of prior studies (Espey and Espey, 2004; Labandeira et al., 2006). The parameter estimate obtained for income is, however, lower than what has been reported in many of those earlier efforts (Jaunky, 2007).

The cross-price elasticity coefficient is negative and very close to zero, –0.164, indicating that natural gas is a weak complement to electricity. This may be attributable to the different ways in which these fuels are employed. Electricity is mainly used for lighting and small appliance operation, while natural gas is primarily utilized for cooking and heating.

The coefficient estimates for the weather variables CDD and HDD are not significant at the 5-percent level. McCloskey and Ziliak (1996) underscores the importance of considering the "economic significance" of a result. In this sense, the parameter magnitudes for CDD and HDD in Table 2 are economically plausible, as well as their positive relationship with consumption: as temperature rises above or falls below the base, the utilization of cooling and heating devices becomes more intensive.

Table 2 – Estimates for Electricity Demand per Consumer Long-Run Cointegration Equation

Dependent Variable: LOG(D)
Method: Two-Stage Least Squares
Sample (adjusted): 1990 2012
Included observations: 23 after adjustments
Instrument specification: LOG(Y) LOG(PNG) LOG(CDD) LOG(HDD) LOG(IV1) LOG(IV2)
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1.342267	2.998346	0.447669	0.6600
LOG(P)	-0.510439	0.102639	-4.973144	0.0001
LOG(Y)	0.425599	0.193110	2.203921	0.0416
LOG(PNG)	-0.163634	0.027982	-5.847810	0.0000
LOG(CDD)	0.149925	0.126417	1.185949	0.2520
LOG(HDD)	0.114097	0.148287	0.769436	0.4522

R-squared	0.927422	Mean dependent var	7.752004
Adjusted R-squared	0.906076	S.D. dependent var	0.182123
S.E. of regression	0.055815	Sum squared resid	0.052961
F-statistic	44.84120	Durbin-Watson stat	1.420691
Prob(F-statistic)	0.000000	Second-Stage SSR	0.031231
J-statistic	0.815224	Instrument rank	7
Prob(J-statistic)	0.366580		

Table 3 summarizes the estimation results for the short-run error correction equation. The short-run own-price sensitivity is –0.297, which stands around the middle of the –0.2 to –0.4 range that prior studies report (Fisher and Kaysen, 1962; Taylor, 1977; Dubin and McFadden, 1984; Marshall, 2010). The coefficient does not, however, satisfy the 5-percent significance criterion.

The short-run income elasticity in Ciudad Juarez indicates that electricity is a normal good. However, the result of 0.253 is substantially lower than estimates reported in previous research utilizing aggregate data (Galindo, 2005). The estimate is not exceptionally low. Wills (1981) finds that in the short run, electricity is a "weakly" normal good with an income elasticity of 0.05 in Massachusetts. Ultimately, this result implies that income variations do not affect short-run electricity consumption very noticeably in Ciudad Juarez.

The short-run coefficient for PNG is negative. This suggests that electricity and natural gas are complements in the short run. The coefficient estimate is quite small, –0.037, indicating a limited complementary relationship between the two. This interpretation is supported by the fact that this estimate is not significant at the 5-percent level.

The CDD coefficient indicates limited short-run warm weather effects on electricity demand in Ciudad Juarez. Moreover, the estimate is not significant at the 5-percent level. This result is unusual as temperature for this city rises well above 90°F from April to October of any typical year (SMN, 2013). In places with predominantly warm weather, a more intensive use of cooling devices during spring and summer months typically represents an important factor of short-run electricity demand.

The parameter estimate for HDD is very small and statistically insignificant. Fullerton et al. (2012) states that this regressor is better utilized to analyze markets with generally cooler weather. In Ciudad Juarez, utilization adjustments due to cold temperatures do not appear to constitute a significant factor in determining short-run electricity demand.

As hypothesized, the error correction term is negative. Its magnitude is –0.153, indicating that short-run deviations from the long-term consumption equilibrium will require 6.529 years to fully dissipate. This result is similar to those reported in other research (Fullerton et al., 2012).

Because the overall diagnostics shown in Table 3 are not very strong, the results should be interpreted with some caution. In particular, the computed F-statistic is fairly low. The aspects of short-term consumption included in this study are difficult to assess at this point in time

Table 3 – Estimates for Electricity Demand per Consumer Short-Run Error Correction Equation

Dependent Variable: DLOG(D)
Method: Two-Stage Least Squares
Sample (adjusted): 1991 2012
Included observations: 22 after adjustments
Instrument specification: DLOG(Y) DLOG(PNG) DLOG(CDD) DLOG(HDD) E(-1) DLOG(IV1) DLOG(IV2)
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.024431	0.014804	1.650335	0.1197
DLOG(P)	-0.297125	0.302276	-0.982959	0.3412
DLOG(Y)	0.252855	0.128449	1.968520	0.0678
DLOG(PNG)	-0.036580	0.094617	-0.386608	0.7045
DLOG(CDD)	0.089192	0.066199	1.347330	0.1979
DLOG(HDD)	0.118632	0.083508	1.420601	0.1759
U(-1)	-0.153090	0.374391	-0.408904	0.6884

R-squared	0.471248	Mean dependent var	0.024854
Adjusted R-squared	0.259748	S.D. dependent var	0.041600
S.E. of regression	0.035792	Sum squared resid	0.019216
F-statistic	2.506804	Durbin-Watson stat	1.413556
Prob(F-statistic)	0.069695	Second-Stage SSR	0.017074
J-statistic	1.917636	Instrument rank	8
Prob(J-statistic)	0.166117		

In order to maintain adequate generation, transmission, and distribution capacity, CFE needs to monitor the customer base in Ciudad Juarez. Equation (3) models the metropolitan customer base as a function of population and employment. The estimation results are shown in Table 4. At first glance, these estimation results exhibit desirable statistical characteristics. However, the Durbin-Watson statistic reveals that positive, first-order serial correlation is present.

Table 4 – Initial Estimates for Customer Base Long-Run Equation

Dependent Variable: LOG(EC)
Method: Least Squares
Sample (adjusted): 1990 2012
Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-7.865177	1.051729	-7.478328	0.0000
LOG(POP)	2.226555	0.153911	14.46654	0.0000
LOG(EMP)	0.837562	0.145038	5.774796	0.0000

R-squared	0.952919	Mean dependent var	12.62320
Adjusted R-squared	0.948211	S.D. dependent var	0.281597
S.E. of regression	0.064083	Akaike info criterion	-2.536154
Sum squared resid	0.082134	Schwarz criterion	-2.388046
Log likelihood	32.16577	Hannan-Quinn criter.	-2.498905
F-statistic	202.4018	Durbin-Watson stat	0.664333
Prob(F-statistic)	0.000000		

Serial correlation is sometimes caused by omitted variables. Therefore, the specification in Table 5 adds real disposable income as an additional economic variable. The Durbin-Watson statistic for that specification yields inconclusive results regarding the presence of serial correlation. An analysis of the residuals correlogram and Q-statistics, not shown below, reveals that serial correlation is not a problem for this augmented specification. All coefficient estimates in Table 5 are significant at the 5-percent level. All regressors display the expected positive signs: as population, employment, and income increase, new electricity accounts also expand in this northern metropolitan economy. These results corroborate and extend those obtained for municipal water demand in Ciudad Juarez (Fullerton et al., 2006).

Of particular interest is the coefficient estimate for population due to its magnitude. Immigration into the city not only creates new households, but also fosters the establishment of new businesses, schools, recreation centers, churches, etc. These, of course, for the most part represent new customer accounts in CFE's records. Moreover, the creation of the maquiladora industry in the late 1960s in Ciudad Juarez caused a large number of people from different areas in Mexico to migrate to the area in a short period of time. Since then, a deficit in coverage emerged, leaving about 14 percent of the population with no access to electricity. Substantial government investments have been closing this gap, especially during the late 1990s and early 2000s. CFE suggests that this phenomenon may be reflected in the large coefficient estimate for population in this equation.

Table 5 – Estimates for Revised Customer Base Long-Run Cointegration Equation

Dependent Variable: LOG(EC)
Method: Least Squares
Sample (adjusted): 1990 2012
Included observations: 23 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-14.15447	1.222652	-11.57686	0.0000
LOG(POP)	2.326938	0.094167	24.71088	0.0000
LOG(EMP)	1.282342	0.114444	11.20493	0.0000
LOG(Y)	0.944264	0.157024	6.013499	0.0000

R-squared	0.983784	Mean dependent var	12.62320
Adjusted R-squared	0.981223	S.D. dependent var	0.281597
S.E. of regression	0.038587	Akaike info criterion	-3.515035
Sum squared resid	0.028290	Schwarz criterion	-3.317558
Log likelihood	44.42291	Hannan-Quinn criter.	-3.465370
F-statistic	384.2182	Durbin-Watson stat	1.044798
Prob(F-statistic)	0.000000		

The short-run error correction estimates for the customer base are shown in Table 6. Even though the signs of the coefficient estimates are all positive, only the constant term is statistically significant at the 5-percent level. This implies that short-run changes in the customer base related to demographic or economic indicators are not statistically precise. The positive constant term implies that the number of electricity accounts in Ciudad Juarez is increasing steadily at 3.264 percent per year. The error correction term is less than zero, and indicates that short-run deviations from the long-run equilibrium customer base will dissipate in 10.811 years. That is a fairly long adjustment period and may reflect the extended catch-up game that CFE is forced to play throughout Mexico due to resource limitations. Similar constraints also affect water utilities in Mexico (Fullerton et al., 2006).

Table 6 – Estimates for Customer Base Short-Run Error Correction Equation

Dependent Variable: D(LOG(EC))
Method: Least Squares
Sample (adjusted): 1991 2012
Included observations: 22 after adjustments

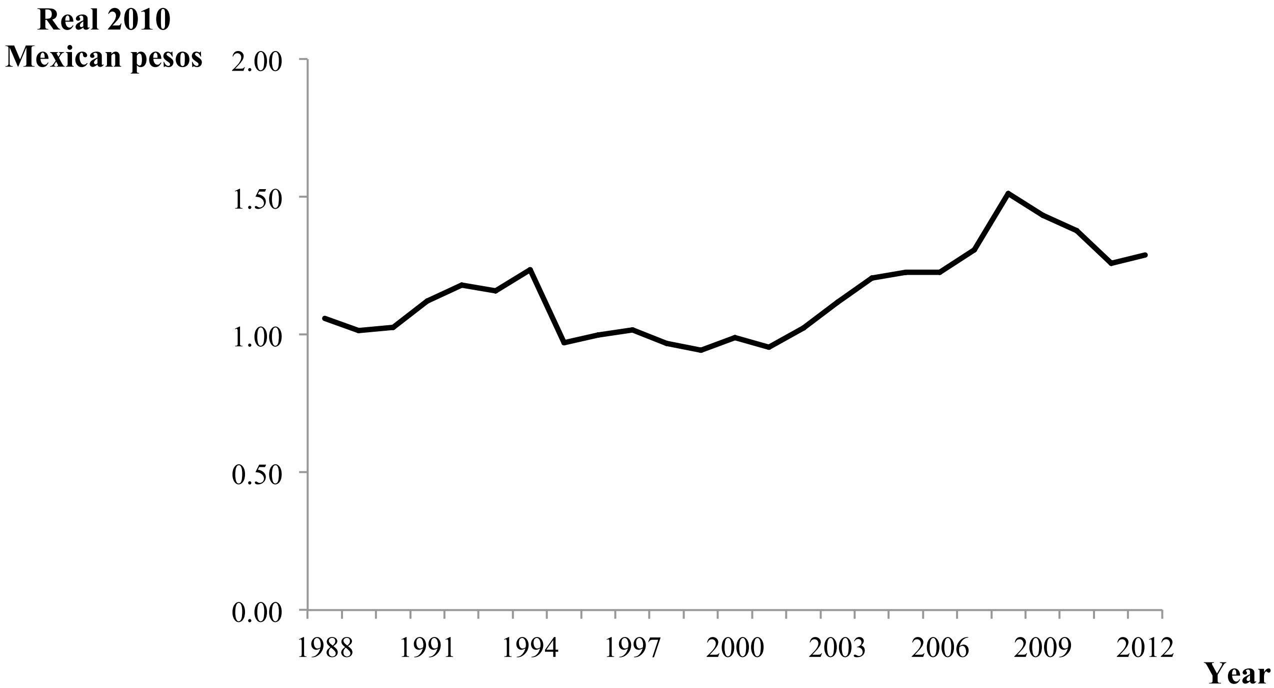
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.032643	0.007042	4.635537	0.0002
D(LOG(POP))	0.431350	0.311061	1.386705	0.1834
D(LOG(EMP))	0.285999	0.192803	1.483375	0.1563
D(LOG(Y))	0.214751	0.155451	1.381471	0.1850
E(-1)	-0.092490	0.162551	-0.568991	0.5768

R-squared	0.123549	Mean dependent var	0.038567
Adjusted R-squared	-0.082675	S.D. dependent var	0.019772
S.E. of regression	0.020573	Akaike info criterion	-4.732976
Sum squared resid	0.007195	Schwarz criterion	-4.485012
Log likelihood	57.06274	Hannan-Quinn criter.	-4.674563
F-statistic	0.599102	Durbin-Watson stat	2.083303
Prob(F-statistic)	0.668304		

These results have several policy implications. Table 2 shows that the own-price elasticity of electricity in Ciudad Juarez is –0.510. That implies that at least a portion of the CFE revenue limitations can be overcome by using rate increases. That would also reinforce usage efficiency objectives. In a market where electricity is a normal good, and where there is no close substitute, energy conservation efforts will have to involve rate increases. However, as shown in

Figure 1, the average real price per KWH has remained fairly constant during the last 25 years. Because usage is rate inelastic, meeting ambitious conservation goals would probably also require publicity campaigns to raise environmental awareness (Olmstead and Stavins, 2009; Renwick and Green, 2000). In the absence of rate increases, per capita electricity consumption in Ciudad Juarez is likely to continue to increase and grid coverage in the greater metropolitan area will remain substantially incomplete.

Figure 1 – Historical Average Price per KWH



Income has grown steadily in Ciudad Juarez, placing additional upward pressures on electricity demand. The results in Table 2 indicate that electricity is a normal good in this city. When per capita income increases by 1 percent, electricity usage swells by 0.426 percent. Ongoing income expansion will likely force the CFE to invest in additional generation, transmission, and distribution capacities for this dynamic urban economy where electricity is a normal good (Fullerton and Walke, 2013).

Table 2 reveals that a 1 percent increase in CDD in Ciudad Juarez increases per customer electricity consumption by 0.150 percent. This creates at least some concern as climate change in northern Mexico may lead to longer, warmer, and drier springs and summers (Polley et al., 2013). Such developments would likely cause electricity customers in the area to use cooling appliances more intensively for longer periods of time. The need to increase electricity generation capacity may intensify if climate change becomes a long-term issue that substantially increases electricity demand in Ciudad Juarez.

CFE faces additional pressure from the expanding customer base in Ciudad Juarez. Table 5 sheds light on the long-run forces behind this growth: all of the explanatory variables affect the city's customer base in a positive manner. The population coefficient indicates that a 1 percent increase in population precipitates 2.327 percent growth in electricity accounts. The parameter estimate for employment in Table 5 indicates a 1.282 percent increase in electricity accounts following a 1 percent employment increase. Both population and employment are expected to grow in coming years (Fullerton and Walke, 2013).

Finally, as noted above, income in Ciudad Juarez is on an upward trajectory. This not only affects electricity consumption, it also affects the consumer base. CFE is likely to face fairly intense pressure to rapidly extend the distribution network as a consequence of these changes.

Chapter 5: Conclusion

This study analyzes electricity demand in Ciudad Juarez. The explanatory variables for this study include the average real price of electricity, real income, the real price of natural gas, and heating and cooling degree days. Error correction models are estimated for per customer electricity consumption and for the customer base. A two-step artificial regression reveals that endogeneity exists in the per customer consumption equation. Fitted price values obtained using two instrumental variables substitute for the original average price variable in the long- and short-run demand equations.

In both demand equations, all of the coefficient estimates exhibit the expected signs except for the price of natural gas. A coefficient that is less than zero for the cross price variable indicates that electricity and natural gas are complements in this market. In both the long and the short run, the cross-price elasticity between these goods is very close to zero, implying that natural gas is a weak complement to electricity in this urban economy.

The long-run own-price elasticity is –0.510. That estimate is comparable to those reported in prior studies. In the short run, the own-price elasticity estimate is –0.297, which stands within the range of estimates previously reported. However, the parameter is not significant at the 5-percent level, indicating that price variations do not exercise reliable effects on electricity demand in Ciudad Juarez in the short run.

None of the variable coefficients in the short-run equation for per customer usage is statistically significant at the 5-percent level. This indicates that short-run consumption adjustments are difficult to assess with this study. Further insight may be gathered through a seasonal analysis of the market (i.e. utilizing monthly data).

With respect to the customer base, population, employment, and income exercise positive and statistically significant impacts on the demand for electricity hook-ups. This outcome is consistent with previous public utility research for Ciudad Juarez. In the short run, changes in the customer base are very pronounced and deterministic in nature.

The CFE faces substantial pressure to expand local generation, transmission, and distribution capacity. Because the real price of electricity has remained fairly flat over the last 25 years, there is at least some flexibility for rate increases that exceed the rate of inflation in Ciudad Juarez. The price inelasticity of demand means that any rate increases will be net revenue generators and those resources can be used for grid expansion. Better usage efficiency will probably require public awareness campaigns.

These results are interesting and align well with prior international research. Whether these outcomes are unique to Ciudad Juarez is unknown at this juncture. Additional research for other metropolitan economies in Mexico and Latin America appears warranted.

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Appendix I: Variables Electricity Demand Equations

Year	Electricity Demand per Consumer	Real Price per KWH	Real Disposable Income per Capita	Real Price of Natural Gas	Cooling Degree Days	Heating Degree Days
Units	Kilowatt Hours	Real 2010 Mexican pesos		Real 2010 Mexican pesos per kilo	Base temperature = 65°F	
1990	1,731.123	1.027	64,212.570	73.878	2,254	2,509
1991	1,824.289	1.122	62,392.677	56.065	1,931	2,560
1992	1,900.679	1.180	60,924.894	48.243	2,500	2,496
1993	1,883.181	1.159	59,210.701	42.087	2,653	2,249
1994	1,822.336	1.235	63,478.240	38.808	3,061	2,105
1995	1,856.397	0.969	61,844.126	29.856	2,390	1,956
1996	1,959.541	0.998	60,982.847	23.040	2,589	2,389
1997	2,044.643	1.017	64,523.983	20.030	2,467	2,756
1998	2,164.006	0.968	67,968.236	16.676	2,493	2,542
1999	2,216.749	0.943	70,285.438	12.597	2,268	2,214
2000	2,444.889	0.989	79,628.836	10.546	2,694	2,399
2001	2,456.099	0.954	73,013.602	9.626	2,679	2,496
2002	2,489.485	1.024	68,021.791	9.984	2,752	2,481
2003	2,451.851	1.117	70,026.730	9.751	2,716	2,251
2004	2,495.534	1.204	71,506.752	9.554	2,361	2,565
2005	2,730.090	1.226	75,272.929	9.326	2,567	2,197
2006	2,845.225	1.227	79,663.633	9.335	2,494	2,042
2007	2,871.121	1.309	81,307.234	9.615	2,593	2,306
2008	2,663.671	1.513	69,429.952	10.130	2,298	2,207
2009	2,683.857	1.434	61,814.109	9.825	2,792	2,165
2010	2,780.027	1.376	67,321.305	9.475	2,787	2,293
2011	3,041.199	1.258	69,139.635	9.918	3,167	2,422
2012	2,990.827	1.290	69,400.002	9.903	2,958	2,019

Appendix II: Instrumental Variables

Year	CFE Total Electricity Generation Capacity	Yearly Inflation
Units	Million Kilowatts	Percentage, Mexican Consumer Price Index
1990	28.235	29.930
1991	30.317	18.790
1992	30.756	11.940
1993	32.323	8.010
1994	35.374	7.050
1995	36.130	51.970
1996	37.904	27.700
1997	38.402	15.720
1998	38.599	18.610
1999	39.048	12.320
2000	40.251	8.960
2001	42.422	4.400
2002	45.697	5.700
2003	49.693	3.980
2004	52.255	5.190
2005	52.492	3.330
2006	55.347	4.050
2007	57.834	3.760
2008	58.239	6.530
2009	59.628	3.570
2010	62.225	4.400
2011	61.512	3.820
2012	60.421	3.570

Appendix III: Variables Customer Base Equations

Year	Total Electricity Customers	Population	IMSS Total Employment	Real Disposable Income per Capita
Units	Number of accounts			Real 2010 Mexican pesos
1990	192,400	798,499	215,364	64,212.570
1991	202,900	818,346	213,482	62,392.677
1992	212,446	840,989	216,935	60,924.894
1993	220,500	879,788	225,545	59,210.701
1994	223,156	942,278	248,279	63,478.240
1995	237,607	1’011,786	272,863	61,844.126
1996	236,071	1’060,322	286,510	60,982.847
1997	246,871	1’109,906	320,684	64,523.983
1998	258,914	1’159,765	346,888	67,968.236
1999	271,562	1’205,574	370,204	70,285.438
2000	290,646	1’218,817	395,349	79,628.836
2001	309,432	1’220,480	367,078	73,013.602
2002	327,019	1’217,416	337,250	68,021.791
2003	340,857	1’242,859	337,337	70,026.730
2004	358,993	1’269,468	333,366	71,506.752
2005	372,728	1’310,302	357,338	75,272.929
2006	387,303	1’334,864	369,258	79,663.633
2007	404,137	1’359,787	372,438	81,307.234
2008	415,585	1’389,102	322,737	69,429.952
2009	421,366	1’377,849	302,365	61,814.109
2010	423,334	1’332,131	312,920	67,321.305
2011	442,942	1’352,180	313,994	69,139.635
2012	449,464	1’372,530	335,806	69,400.002

Vita

Ericka Mendez-Carrillo was born in Ciudad Delicias, Chihuahua, Mexico, and was raised in Chihuahua City. After completing her high school studies at Prepa Tec de Monterrey Campus Chihuahua in May 2004, she started a BBA in Economics at Tec de Monterrey Campus Chihuahua. In August 2005 she transferred to the University of Texas at El Paso to continue her undergraduate education. She received the degrees of Bachelor of Business Administration in Economics and Finance in May 2009. During the following years she worked for local organizations in El Paso, TX in the areas of management and finance. Seeking a career shift into economics, she enrolled in the MS Economics program at the University of Texas at El Paso in August 2011, becoming the recipient of the James Foundation Graduate Scholarship in 2013. She is currently employed as a research assistant by the University of Texas at El Paso and is expecting to start a career in economic research upon graduation.

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