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Small Commercial And Industrial Electricity Consumption In Las Cruces, New Mexico

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SMALL COMMERCIAL AND INDUSTRIAL ELECRICITY CONSUMPTION IN LAS CRUCES, NEW MEXICO

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by

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Abstract

Research examining small commercial and industrial electricity usage patterns have historically received less attention than residential electricity consumption patterns. This study examines electricity as an input to commercial and industrial production in Las Cruces, New Mexico using annual frequency data from 1978 to 2018. Those data examined include labor, per capita personal income, price measures for electricity and natural gas, and weather variables. The long-run and short-run elasticities of the data are then estimated using an autoregressive distributed lag model (ARDL). In the long run, CIS customers in Las Cruces respond to natural gas a complimentary good, and the derived-demand curve is found to be upward sloping. Real per capita income is also found to have a positive impact in the long-run, while weather impacts are found to be ambiguous in the long-run. In the short-run, CIS customers in Las Cruces treat natural gas a substitute, the derived-demand curve is found to be downward sloping, and weather extremes are found to be positive correlated with electricity usage.

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Chapter 1: Introduction

Las Cruces is the second largest metropolitan economy in the state of New Mexico. In spite of that, relatively few in-depth economic analyses have been completed for this region of the state. To date, commerce and energy in this vibrant and growing urban economy are among the various economic topics that have not been analyzed very extensively. El Paso Electric Company is the private sector public utility that generates, transmits, and distributes electricity in Las Cruces.

The objective of this study is to analyze electricity consumption as an input to production for small commercial and industrial (CIS) customers in Las Cruces. To achieve that goal, annual data are assembled for a variety of variables covering a period from 1978 to 2018. Those data include labor, per capita personal income, price measures for electricity and natural gas, and weather variables. In general, CIS electricity usage patterns are less well documented than residential consumption patterns. This study will help partially fill that gap in the applied economics literature.

Six chapters are included in the study with the next section providing an overview of related literature. Chapter 3 discusses model specification. Chapter 4 summarizes sample data used for the analysis. Chapter 5 reports empirical results outcomes. Chapter 6 provides a summary and potential future research efforts.

Chapter 2: Literature Review

Prior studies have shown personal income can affect both long-run and short-run CIS electricity usage. However, a wide variety of outcomes have been documented regarding those relationships. For Kuwait, when real GDP is used as a proxy for income, it does not reliably influence electricity demand in the short-run, but does affect it in the long-run (Eltony and Hajeeh, 1999). Similar results have been reported for South Africa (Amusa et al., 2009). Watson et al (1987) find an inverse relationship between income and CIS usage in a study of Rhode Island and Massachusetts. Along those lines, Allen and Fullerton (2019) record an inverse relationship between real per capita incomes and CIS usage in El Paso, Texas in the short-run. However, that effort reports an insignificant income impact for the long-run in El Paso.

Average prices are used for both own-price elasticity and cross-price elasticity estimation in this study. For electricity, EPEC charges a flat rate for winter and summer months in Las Cruces and scaled pricing schedules are not employed. Average price and marginal pricing have both been found acceptable to use by Fisher and Kaysen (1962). A study of residential electricity usage justified the use of average price of electricity over marginal price as customers tend to react to their bill as a whole and not consider marginal increase that may have been factored into it (Wilder and Willenborg, 1975; Ito, 2014). Average price has also historically been used and proven reliable in studies examining electricity consumption in the El Paso and Las Cruces service areas (Fullerton 1998; Fullerton et al., 2016; Allen and Fullerton, 2019).

The price of electricity (own-price) is used in most studies that analyze CIS electricity consumption. Results of these studies are somewhat mixed. In an early study for New South Wales, neither short-run nor long-run changes in electricity prices are found to impact CIS usage (Hawkins, 1975). That is contrary to what is found in Virginia where an inverse relationship is documented between the own-price of electricity and CIS electricity consumption (Murray et al., 1978). Consistent with the evidence for New South Wales, Amusa et al. (2009) finds that short-run and long-run changes in electricity prices do not affect CIS usage in South Africa. In contrast to those outcomes, an inverse relationship existing between own-price and service sector electricity consumption has been reported for Korea (Lim et al., 2014). Most recently, own-price variations are found to exercise insignificant impacts on CIS usage in the short-run in the geographically adjacent El Paso service area (Allen and Fullerton, 2019). Statistically reliable inverse own-price effects are registered in that study for CIS usage over the long-run.

The price of natural gas is also included in the analysis as natural gas is a viable alternative fuel source for production. In Virginia, estimates of long-run and short-run cross price elasticities for industrial and commercial customers are found to be responsive to variations in alternative fuel prices (Murrary,et al., 1978). Bernstein and Griffin (2006), however, report that the price of natural gas is statistically insignificant in the long-run as it is a more expensive alternative to electricity in much of the United States. Allen and Fullerton (2019) corroborate that finding for CIS customers in El Paso in the long-run. Surprisingly, cross-price elasticity estimates in that same study indicate that electricity and natural gas are complementary inputs, rather than substitutes, at least in the short-run.

Weather variables such as heating-degree days (HDD) and cooling-degree days (CDD) are used in empirical analysis to capture the impacts of cold and hot weather have on electricity consumption. Evidence of this has been documented for New Zealand where a strong positive relationship is found between increases in HDD and electricity usage (Fatai, et al., 2003). In the case of El Paso, CIS electricity consumption is not found to respond to HDD and CDD variations in statistically reliable manners over the long-run. In the short-run, CIS usage increased in notable manners whenever HDD or CDD increases occur in El Paso (Allen and Fullerton, 2019). That is a plausible outcome. Weather patterns can vary substantially in the short-run, but tend to remain fairly stable over the long-run.

A review of the theoretical model for CIS electricity demand is provided in the next section. That section also provides an overview of the estimation procedure employed by this study. The methodologies selected have been designed for, and applied to, the analysis of commercial and industrial electricity consumption in several recent studies (Amusa et al., 2009; Allen and Fullerton, 2018).

Chapter 3: Theoretical Model

A derived input-demand function for Las Cruces CIS electricity consumption shown in Equation (1) is specified using economic and weather variables. Derived demand refers to the demand for electricity as an input factor as a result of the demand for the final product. Equation (1) is the first partial derivative with respect to the price of electricity of a profit function using a normalized quadratic specification. That underlying profit function is assumed to be the dual of a production function (Allen and Fullerton, 2018). This approach has been successfully utilized to empirically analyze CIS usage for the nearby metropolitan economy of El Paso, located 40 miles to the south in Texas (Allen and Fullerton, 2019). In Equation (1), *ln* stands for natural logarithm, *t* represents yearly time periods, *k* the number of lags, *CIS* is kilowatt hours (KWH) of electricity usage by small industrial and commercial firms in Las Cruces, *PE* is the real average price per KWH of electricity charged by EPEC in Las Cruces, *PG* is the average real price per hundred cubic feet (CCF) of natural gas sold to commercial consumers in New Mexico, *PL* is the average real wage and salary paid per worker in Las Cruces, *PQ1* is real total personal income in Las Cruces, *K* is the fixed capital stock in Las Cruces, *HDD* is Las Cruces heating degree days, *CDD* is Las Cruces cooling degree days, and *u* is a stochastic error term.

$$lnCIS_t = \alpha_0 + \alpha_1 lnCIS_{t-k} + \alpha_2 lnPE_{t-k} + \alpha_3 lnPG_{t-k} + \alpha_4 lnPL_{t-k} + \alpha_5 lnPQ1_{t-k} + \alpha_6 lnK_{t-k} + \alpha_7 lnHDD_{t-k} + \alpha_8 lnCDD_{t-k} + u_t \qquad (1)$$

The derived input demand function is used as the starting point for empirically specifying long-run and short-run models of CIS electricity usage. That is carried out within an autoregressive distributed lag (ARDL) framework because it allows analyzing both long-run and short-run dynamics (Fox and Kivanda, 1994). An augmented Dickey-Fuller (ADF) test is applied against the first difference of each variable in the series to ensure that integration of order 2 or higher is not present (Asteriou and Hall, 2016). If integration of order of 2 or higher exists, the ARDL approach cannot be utilized. A bounds test can be used to determine if a significant long-run relationship is present. In the ARDL specification shown in Equation (2), Δ represents the difference operator and *v* represents a random disturbance term. Short-run impacts are represented by coefficients β_1 through β_8, while β_9 through β_{16} capture long-run effects.

$$\Delta lnCIS_t = \beta_0 + \beta_1 \Delta lnCIS_{t-k} + \beta_2 \Delta lnPE_{t-k} + \beta_3 \Delta lnPG_{t-k} + \beta_4 \Delta lnPL_{t-k} + \beta_5 \Delta lnPQ1_{t-k} + \beta_6 \Delta lnK_{t-k} + \beta_7 \Delta lnHDD_{t-k} + \beta_8 \Delta lnCDD_{t-k} + \beta_9 lnCIS_{t-1} + \beta_{10} lnPE_{t-1} + \beta_{11} lnPG_{t-1} + \beta_{12} lnPL_{t-1} + \beta_{13} lnPQ1_{t-1} + \beta_{14} lnK_{t-1} + \beta_{15} lnHDD_{t-1} + \beta_{16} lnCDD_{t-1} + v_t \quad (2)$$

An F-test is utilized to test the null hypothesis that the variables are not cointegrated. H_0 : $\beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = \beta_{15} = \beta_{16} = 0$. If the F-statistic is greater than an upper bound cut-off limit at a selected significance level, the null hypothesis is rejected; conversely, if the F-statistic falls below a lower bound cut-off limit, the null cannot be rejected (Pesaran, et al., 2001). Because the number of sample observations is less than 80, bounds critical values estimated by Narayan (2005) are utilized for the cointegration test. If the null hypothesis of no cointegration is rejected, the Schwarz Information Criterion, or other similar procedures, is then used to determine the lag structure of the equation (Asteriou and Hall, 2016).

If cointegration is determined to exist, an error correction model (ECM) is then estimated. The ECM specification shown in Equation (3) includes a one-year lag of the error term, μ_{t-1}, from Equation (1). Because deviations from equilibrium cause subsequent period adjustments, the lagged error term regression coefficient, γ_9, is hypothesized to be negative and fall between 0 and -1. The magnitude of γ_9 measures the speed of adjustment for CIS KWH usage to return to equilibrium. The reciprocal of γ_9 provides an estimate of the time required for total error dissipation.

$$\Delta lnCIS_t = \gamma_0 + \gamma_1 \Delta lnCIS_{t-k} + \gamma_2 \Delta lnPE_{t-k} + \gamma_3 \Delta PG_{t-k} + \gamma_4 \Delta PL_{t-k} + \gamma_5 \Delta PQ1_{t-k} + \gamma_6 \Delta K_{t-k} + \gamma_7 \Delta HDD_{t-k} + \gamma_8 \Delta CDD_{t-k} + \gamma_9 u_{t-1} + w_t \qquad (3)$$

One advantage associated with ARDL estimation is that it provides short-run and long-run coefficient estimates. Equation (4) shows how the long-run parameter estimates are calculated. Those estimates are summarized along with the other modeling results in the empirical results section.

$$a_j = \sum_{i=0}^{p_j} \alpha_{ji} (1 - \sum_{i=1}^{q} \gamma_i) \qquad (4)$$

In the proposed framework, the own-price is hypothesized to be inversely correlated with CIS usage. The correlations between the other input prices and CIS consumption are ambiguous. If a particular factor is used as a substitute for electricity, the correlation will be positive. If an input serves as a complement to electricity, a negative correlation will result. For the income

(PQ1) and the weather (HDD and CDD) variables, positive correlations with CIS usage are anticipated.

Las Cruces data limitations force the fixed capital stock variable to be dropped from the model. Omission of that variable may cause biased parameter estimates to result. Commercial sector electricity sales can, however, be modeled reliably without the inclusion of fixed capital stock sample data. Watson et al. (1987) analyze CIS consumption using several estimation approaches without fixed capital stock regressors. From a forecasting perspective, the most accurate results are generated by econometric equations that include variables for economic and weather conditions. Data constraints such as this one do increase the likelihood of serially correlated and heteroscedastic errors. Consequently, generalized least squares, or comparable parameter estimation procedures, that can handle those types of classical assumption violations will be required.

Chapter 4: Data

El Paso Electric Company (EPEC) is a regulated public utility that services residential, commercial, industrial, non-profit, and public sector customers within a 10,000 square mile region that extends from Van Horn, Texas to Hatch, New Mexico. Included in this service area are three major military installations located in Texas and New Mexico. The latter include Fort Bliss, White Sands Missile Range, and Holloman Air Force Base. EPEC has a combined generating capacity of 2,082 megawatts from nuclear, gas-fired, and solar generating sources. CIS customers represent approximately 10 percent of all retail accounts (EPEC, 2018a, b).

Data employed for this study are listed in Table 1. Also listed are variable descriptions, units of measure, and data sources. A total of ten variables are included in the data set. Summary statistics for the sample data are reported in Table 2. Statistics reported for each variable are mean, median, maximum, minimum, standard deviation, skewness, kurtosis, and coefficient of variation. Annual frequency data are collected for each of the series. The sample period is from 1978 to 2018. The software package utilized is EViews.

Table 1: Sample Data and Sources

Variable	Description	Source
CIS	CIS electricity consumption in kilowatt hours (KWH) per CIS customer billed by EPEC, obtained from EPEC Federal Energy Regulatory Commission Form No. 1, annual report of major electric utilities, licensees, and others.	EPEC FERC Form No. 1., Annual Report of Major Electric Utilities, Licensees, and Others
KWH	Las Cruces electricity consumption, measured in KWH sales	El Paso Electric
PE	Real EPEC Average Price per KWH of Electricity in U.S. Cents, Base Period 2009	EPEC FERC Form No. 1., Annual Report of Major Electric Utilities, Licensees, and Others
PG	Real Price per CCF of Natural Gas sold to New Mexico Commercial Consumers in U.S. Dollars, Base Period 2009	United States Energy Information Administration
PL	Real Las Cruces Wages and Salaries Paid per Worker in thousands of U.S. Dollars, Base Period 2009	UTEP Border Region Modeling Project
PQ1	Real Las Cruces Personal Income Per Capita in U.S. Dollars, Base Period 2009	UTEP Border Region Modeling Project
HDD	Las Cruces Heating Degree Days, Sum of Average Daily Temperatures under 65° Base	National Oceanic and Atmospheric Administration Northeast Regional Climate Center
CDD	Las Cruces Cooling Degree Days, Sum of Average Daily Temperatures over 65° Base	National Oceanic and Atmospheric Administration Northeast Regional Climate Center
PGDP	GDP Implicit Price Deflator, Base Period 2009	U.S. Bureau of Economic Analysis
PCE	Personal Consumption Expenditures Deflator, Base Period 2009	U.S. Bureau of Economic Analysis

Table 2: Summary Statistics

	CIS	PE	PG	PL
Mean	65,513	$12.04	$6.86	$23,597
Standard Deviation	4,804	$1.76	$1.81	$1,861
Coef. of Variation	0.07	0.15	0.26	0.08
Median	64,192	$11.94	$6.33	$23,379
Maximum	73,211	$16.28	$11.23	$26,810
Minimum	57,426	$8.51	$4.37	$20,764
Range	15,785	$7.77	$6.86	$6,045
Skewness	0.12	0.59	0.88	0.27
Kurtosis	1.77	3.66	2.86	1.69

	PQ1	CDD	HDD
Mean	$22,979	2,666	1,952
Standard Deviation	$4,855	290	233
Coef. of Variation	0.21	0.11	0.12
Median	$21,582	2,651	1,943
Maximum	$31,893	3,346	2,442
Minimum	$16,308	2,064	1,502
Range	$15,585	1,282	940
Skewness	0.27	0.09	0.18
Kurtosis	1.55	2.60	1.98

Note:
Sample Period is 1978-2018

The dependent variable, CIS, is calculated as yearly energy sales divided by the annual average number of customers. Data for billed KWH are from the EPE FERC Form No. 1 (EPEC, 2018c). As reported in Table 2, the average for CIS in Las Cruces is 65,513 KWH for the 1978 to 2018 sample period utilized. The standard deviation is 4,804 KWH. The sample minimum and maximum for CIS is 57,426 KWH and 73,211 KWH, respectively. A skewness coefficient of 0.12 reflects a relatively symmetric distribution. The kurtosis is 1.77, characteristic of a platykurtic distribution. In spite of the latter, coefficient of variation is 0.07 indicating that the tails of the distributions are fairly thin.

The CIS own-price, PE, is approximated by real average cents per KWH. An inverse relationship between the real price of electricity and CIS electricity consumption, especially over the long-run as CIS can adjust appliance stocks in favor of equipment that uses energy more efficiently. The average annual real price of electricity variable is calculated using annual EPEC energy sales and operating revenues obtained from EPEC FERC Form No. 1 from 1978 – 2018 then deflated using the personal consumption expenditure deflator (BEA, 2019).

During the sample period, the average real price of electricity is 12.04 cents per KWH with a standard deviation of 1.76 cents. The observations for PE range from a low 8.51 cents per KWH in 2018 to a high of 16.28 cents in 1983. A skewness of 0.59 indicates that the own-price data are somewhat positively skewed. As reported in Table 2, the kurtosis is 3.66, indicating a relatively thin-tailed distribution with a relatively high peak. That observation is confirmed by a coefficient of variation is 0.15.

The average annual real price of natural gas per 1000 cubic feet, PG, is used to capture the impacts of a substitute production input for CIS. It is hypothesized that the average annual real price of natural gas will exert a positive impact on CIS electricity consumption in the long-run as CIS customers seek cheaper energy alternatives in production to maintain a lower cost compared to electricity. In the short-run, it is also hypothesized to have a positive, but potentially insignificant, impact as switching to alternative inputs is generally difficult and requires relatively long periods of time to complete. Annual frequency data from 1978 to 2018 of the price of natural gas sold to New Mexico commercial customers are from the United States Energy Information Administration (EIA, 2018) and deflated to 2009 constant dollar equivalents using the U.S. GDP Implicit Price Deflator (BEA, 2019).

In Table 2, the sample mean for the average annual real price of natural gas (CCF) sold to CIS customers in Las Cruces is \$6.86 with a standard deviation of \$1.81. The minimum and maximum average annual real price of natural gas for this period is \$4.37 and \$11.23, respectively. A skewness coefficient of 0.88 for PG indicates a slight skew to the right. The kurtosis is 2.86, indicating a largely mesokurtic distribution. The coefficient of variation is 0.26 is indicative of a relatively low-variance distribution.

Las Cruces real wage and salary disbursements per worker is used to capture the impacts of changes in the price of labor, PL, on CIS electricity consumption. If the labor input is used in a complementary manner with electricity, real wage and salary disbursements will be inversely correlated with CIS electricity consumption. If labor and electricity are substitutes, then a positive coefficient will result. Annual frequency data on wage and salary disbursements and total employment in Las Cruces from 1978 – 2018 are used to calculate nominal wages and salaries paid per worker. That variable is then converted to 2009 real dollars using Personal Consumption Expenditure deflator (BEA, 2019).

In Table 2, the average for real wages and salaries paid per worker, PL, is \$23,597 per year, with a standard deviation of \$1,861. The minimum and maximum average Las Cruces real wages and salaries paid per worker for this period is \$20,764 and \$26,810, respectively. A skewness of 0.27 indicates a slight skew to the right, but a relatively symmetric distribution. The kurtosis is 1.69, implying that the sample data may be distributed in a platykurtic manner. However, the coefficient of variation is 0.08 is indicative of a low-variance distribution.

Real per capita Las Cruces personal income is used to represent the price of output, PQ1, for deriving the input demand function from the underlying profit function. It is hypothesized that increases in real personal income will have a significant positive effect on CIS electricity consumption in the long-run as CIS will increase production of goods and services as a response to increases in demand due to increases in personal income. The short-run impact is hypothesized to be positive, but of a smaller magnitude, as other factors take influence CIS may not permit it to instantaneously respond to increases demand in the short-run. Nominal personal income for Las Cruces are converted to real constant dollar values using the United States personal consumption expenditures deflator (BEA, 2020; Fullerton and Fullerton, 2020).

The sample average for real personal income per capita in Las Cruces is \$22,979 with a standard deviation of \$4,855. A skewness statistic of 0.27 indicates a slight skew to the right but still a relatively symmetric distribution for PQ1. Although the kurtosis is 1.55, the coefficient of variation is 0.21, indicative of a low-variance and light-tailed distribution.

The sample includes two weather variables, Las Cruces cooling degree days (CDD) and heating degree days (HDD). CDD is calculated as the number of degrees the average temperature is above 65 degrees Fahrenheit during a given day. HDD is measured as the number of degrees the average temperature is below 65 degrees Fahrenheit during a given day. CDD and HDD are both hypothesized to be positively correlated with CIS electricity consumption. Ambient climate conditions will cause CIS businesses to increase/decrease indoor electricity usage to maintain comfortable environmental conditions for employees and customers. Annual data on HDD and CDD from 1978 – 2018 are from the National Oceanic and Atmospheric Administration Northeast Regional Climate Center (NOAA, 2018).

Average annual HDD is 1,952 with a standard deviation of 233. The minimum and maximum annual HDD for this period is a minimum of 1,502 and a maximum of 2,442. A skewness of 0.18 indicates a slight skew to the right but still a relatively symmetric distribution for HDD. The kurtosis of HDD is -1.02, indicating a left-tailed platykurtic distribution. The coefficient of variation for HDD are 0.12 indicative of a low-variance distribution.

Average annual CDD is 2,666, with a standard deviation of 290. The minimum and maximum annual CDD for this period is minimum of 2,064 and a maximum of 3,346. A skewness of 0.09 indicates a light skew to the right but still relatively symmetric distribution for CDD. The kurtosis of CDD is -0.40 indicating a left-tailed platykurtic distribution. The coefficient of variation for CDD is 0.11 indicative of a low-variance distribution.

Chapter 5: Empirical Results

Unit root tests, summarized in Table 3, are performed prior to parameter estimation. The results indicate that all of the sample variables are integrated of an order of I(0) or I(1), which allows the ARDL method to be utilized. A maximum of two lags of the dependent variable and four of the independent variables are selected using the Akaike Information Criterion. That results in an ARDL (2,1,2,4,0,1,3) model specification. The Breusch-Godfrey serial correlation LM test, summarized in Table 4, fails to reject the null hypothesis of no serial correlation in the residuals. The Breusch-Pagan-Godfrey heteroscedasticity test, summarized in Table 5, fails to reject the null hypothesis that heteroscedasticity is not present in the residuals.

Table 3: Unit root test results

Variable	**Augmented Dickey-Fuller Test Statistic**	**Prob.**
Δ LNCIS(-1)	-3.0942	0.0038
Δ LNPE(-1)	-4.4708	0.0001
Δ LNPG(-1)	-6.3466	0.0000
Δ LNPL(-1)	-5.9577	0.0000
Δ LNPQ1(-1)	-5.3625	0.0000
Δ LNHDD (-1)	-9.6258	0.0000
Δ LNCDD (-1)	-8.8602	0.0000

Notes:
Sample Period is 1978-2018.
Null hypothesis tested is $H_0: b_1 = b_2 = \cdots = b_j = 0$
Results obtained indicate that the differenced time series variables are stationary.

Exclusion of the capital stock variable, K, in Equation (2) modifies that expression to the one that appears in Equation (5) below. It is used for the diagnostic tests summarized in Tables 4 through 6. Empirically, following the Watson et al. (1987) approach means that any β_1 and β_8 coefficients estimated for lags of CIS in Equation (5) are likely to be larger than if lags of K were included as shown in Equation (2).

$$\Delta lnCIS_t = \beta_0 + \beta_1 \Delta lnCIS_{t-k} + \beta_2 \Delta lnPE_{t-k} + \beta_3 \Delta PG_{t-k} + \beta_4 \Delta PL_{t-k} + \beta_5 \Delta PQ1_{t-k} + \beta_6 \Delta HDD_{t-k} + \beta_7 \Delta CDD_{t-k} + \beta_8 lnCIS_{t-1} + \beta_9 lnPE_{t-1} + \beta_{10} lnPG_{t-1} + \beta_{11} lnPL_{t-1} + \beta_{12} lnPQ1_{t-1} + \beta_{13} lnHDD_{t-1} + \beta_{14} lnCDD_{t-1} + v_t \tag{5}$$

In spite of the exclusion of the lags of K in Equation (5), no evidence of serial correlation is uncovered in Table 4 and no evidence of heteroscedasticity is unveiled in Table 5. The F-statistic, shown in Table 6, for $H_0 = \beta_8 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = 0$, is 6.10. This is greater than the 1% critical value, indicating cointegration. The long-term stability of the parameters are tested using CUSUM and CUSUMSQ tests. Results of these tests are summarized in Figure 1 and Figure 2 and show stability with no statistics surpassing the 5-percent bounds. The coefficients estimated for the long-run model are shown in Table 7.

Table 4: Serial correlation test results

Breusch-Godfrey serial correlation LM test			
F Statistic	3.1780	Prob. F(2, 15)	0.0707

Notes:
Sample Period is 1978-2018.
Null hypothesis tested is $H_0: \rho_1 = \rho_2 = \cdots = \rho_j = 0$
Failure to reject the null hypothesis indicates that serial correlation is not present.

Table 5: Heteroscedasticity test results

Heteroskedasticity test: Breusch-Pagan-Godfrey			
F Statistic	0.9616	Prob.. F(19, 17)	0.5360

Notes:
Sample Period is 1978-2018.
Null hypothesis tested is $H_0: \sigma_1 = \sigma_2 = \cdots \sigma_j = \sigma$
Failure to reject the null hypothesis indicates that heteroscedasticity is not present.

Table 6: ARDL Bounds test results

F Statistic	6.1090	Lower Bound (0)	2.88
Significance	1%	Upper Bound (1)	3.99

Notes:
Sample Period is 1978-2018.
Null hypothesis tested is $H_0 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = 0$
Results obtained indicate cointegration.

In Table 7, the estimated coefficient for PE, the own-price real EPEC average price per KWH, is statistically significant at the 10-percent level. The hypothesized long-run inverse relationship is not supported. It indicates that a 1-percent increase in the KWH price is associated with a CIS consumption increase of 0.27 percent. Some studies have documented upward sloping demand curves for electricity (Fullerton et al., 2016). This result runs counter, however, to what is reported for CIS demand in nearby El Paso by Allen and Fullerton (2019) and for commercial firms nationally by Contreras et al. (2011). It also runs counter to what is reported for residential customers in Las Cruces by Fullerton and Mejia (2020).

The estimated long-run coefficient measured for real price of natural gas in Table 7 is statistically insignificant. Similar to the El Paso CIS result in Allen and Fullerton (2019), the PG parameter is negative. That indicates that CIS customers use natural gas and electricity as complements in Las Cruces. The small size of the natural gas price parameter magnitude suggests that, as down the road in El Paso, natural gas appears to be a weak complement to CIS electricity in this metropolitan economy.

The long-run parameter estimate for real Las Cruces wages paid per worker, PL, in Table 7 is negative and satisfies the significance criterion. Because it is less than zero, it implies that labor and electricity are complementary inputs as employed by CIS firms in this urban economy. The coefficient magnitude implies that a 1-percent increase in real Las Cruces wages paid per worker will cause CIS electricity usage to decline by 0.91 percent. That result is opposite of what is reported for long-run CIS usage in El Paso (Allen and Fullerton, 2019).

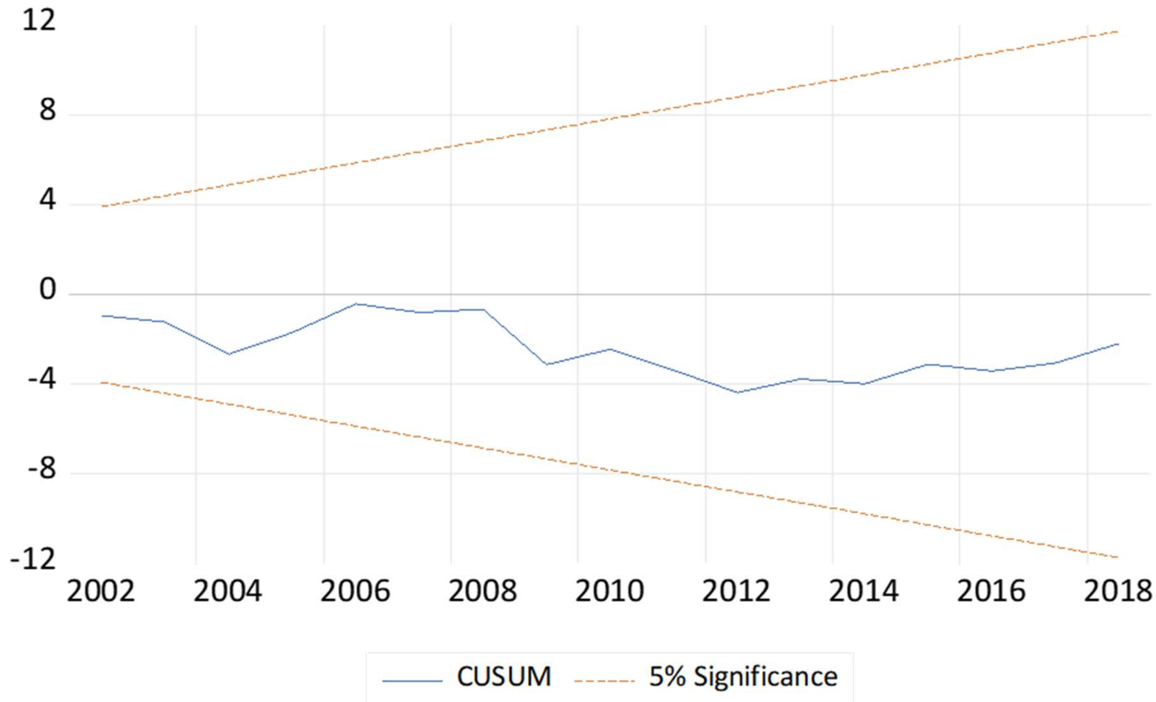

Figure 1: CUSUM Results for CIS Electricity Consumption

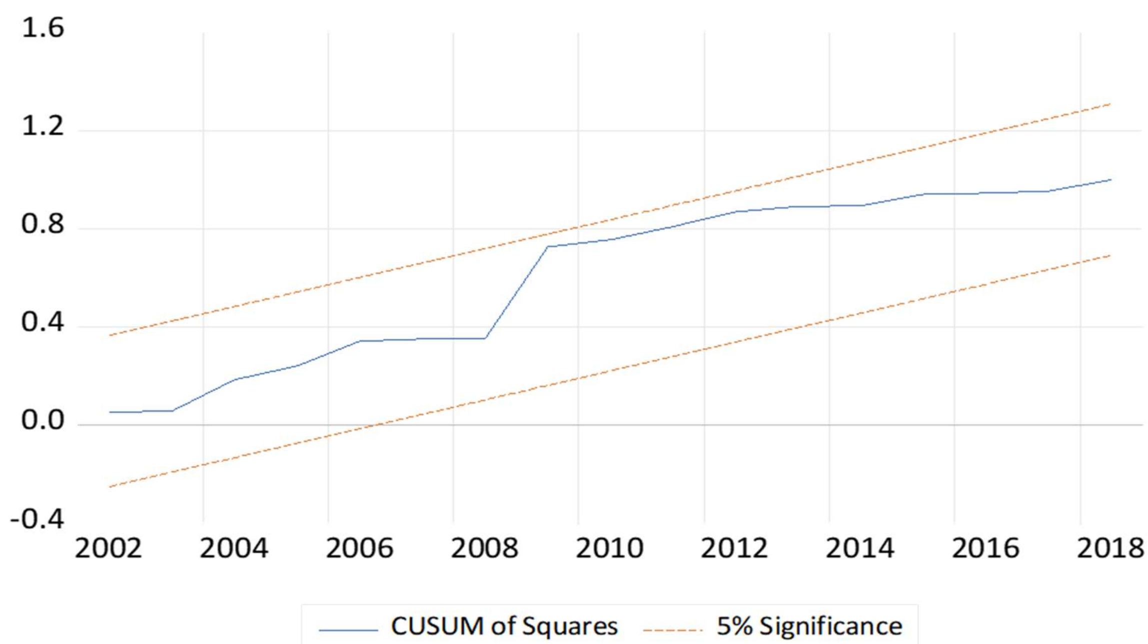

Figure 2: CUSUM of Squares Results for CIS Electricity Consumptiom

The real Las Cruces personal income per capita, PQ1, parameter estimate in Table 7 exhibits the hypothesized positive sign but does not satisfy the 5-percent significance criterion. The estimated long-run coefficient shows an inelastic response and can be interpreted as a 1-percent increase in real Las Cruces personal income per capita will increase CIS electricity consumption by 0.27 percent. This is expected as an increase in real personal income is associated with greater consumption of good and services.

Table 7: Long-run coefficient estimates

Variable	Coefficient	Std. Error	T-Stat	Prob.
LNPE	0.2743	0.1611	1.702	0.0978
LNPG	-0.0394	0.0658	-0.599	0.5534
LNPL	-0.9189	0.2610	-3.519	0.0013
LNPQ1	0.2773	0.1461	1.898	0.0663
LNHDD	-0.2162	0.1113	-1.942	0.0605
LNCDD	0.0660	0.1167	0.566	0.5749
C	18.1577	2.5989	6.987	0.0000

R-squared	0.5191	Mean dependent var	11.0873
Adjusted R-squared	0.4343	S.D. dependent var	0.0732
S.E. of regression	0.0551	Akaike info criterion	-2.804
Sum squared resid	0.1032	Schwarz criterion	-2.512
Log likelihood	64.490	Hannan-Quinn criter.	-2.698
F-statistic	6.119	Durbin-Watson stat	0.396
Prob(F-statistic)	0.0002		

Notes:
Sample Period is 1978-2018.

The two weather variables heating degree days, HDD, and cooling degree days, CDD, are both hypothesized to be positively correlated with CIS electricity consumption. In Table 7, only the long-run coefficient estimated for cooling degree days supports this hypothesis, albeit with a somewhat large standard error attached to it. The result indicates that a 1-percent increase in cooling degree days will increase CIS electricity consumption by 0.06 percent. The long-run coefficient estimated for heating degree days implies that an inverse and insignificant relationship exists between CDD and CIS electricity consumption.

Results for the short-run error correction model are shown in Table 8. The short-run real own-price elasticity is -0.11 and satisfies the 5-percent significance criterion. The sum of the estimated short-run natural gas real price coefficients is 0.026. The parameter magnitude and positive sign confirm that, during the short-run, natural gas serves as an imperfect substitute for electricity among CIS firms in Las Cruces. The sum of the estimated coefficient for real Las Cruces wages is 0.625 and indicates that labor and electricity are substitutes in the short-run. These results share similarities with those reported for commercial electricity demand in other regions (Cebula, 2013; Eltony and Hajeeh, 1999; Inglesi-Lotz and Blignaut, 2011).

Coefficients estimated for the HDD and CDD weather variables are both hypothesized to be greater than zero and exert statistically reliable impacts on CIS electricity consumption in the short-run. The outcomes in Table 8 support these hypotheses. The HDD parameter estimate is 0.022 and indicates that cool weather leads to a slight uptick in CIS electricity usage in Las Cruces. The sum of the CDD coefficient estimates is 0.190. While the latter still falls within the inelastic range, it implies that CIS electricity consumption is fairly responsive to warm weather in this metropolitan economy. Both results are comparable in magnitude to those reported for nearby El Paso (Allen and Fullerton, 2019).

Table 8: Error Correction Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNCIS(-1))	-0.3594	0.1343	-2.675	0.0160
D(LNPE)	-0.1104	0.0268	-4.116	0.0007
D(LNPG)	0.0067	0.0086	0.780	0.4459
D(LNPG(-1))	0.0202	0.0074	2.725	0.0144
D(LNPL)	0.0957	0.0690	1.387	0.1833
D(LNPL(-1))	0.1566	0.0586	2.670	0.0162
D(LNPL(-2))	0.2095	0.0635	3.295	0.0043
D(LNPL(-3))	0.1879	0.0777	2.418	0.0271
D(LNHDD)	0.0219	0.0126	1.734	0.1010
D(LNCDD)	0.0406	0.0133	3.046	0.0073
D(LNCDD(-1))	0.1062	0.0214	4.958	0.0001
D(LNCDD(-2))	0.0431	0.0160	2.685	0.0157
CointEq(-1)	-0.0377	0.0045	-8.306	0.0000

R-squared	0.8936	Mean dependent var	-0.0024
Adjusted R-squared	0.8405	S.D. dependent var	0.0159
S.E. of regression	0.0063	Akaike info criterion	-7.003
Sum squared resid	0.0009	Schwarz criterion	-6.437
Log likelihood	142.54	Hannan-Quinn criter.	-6.803
Durbin-Watson stat	2.377		

Notes:
Sample Period is 1978-2018.

The error correction parameter estimate in Table 8 is -0.038 and negative as hypothesized. This indicates deviations from the long-run equilibrium dissipate very slowly at a rate of less than 4 percent per year. At that rate, it will take a little more than 26.5 years for any departures from equilibrium to fully disappear. That is substantially longer than the 2.5 year period required for full dissipation for CIS usage in El Paso (Allen and Fullerton, 2019). It is also much longer than what is required for equilibrium re-attainment by residential electricity consumption in Las Cruces itself (Fullerton and Mejia, 2020).

Chapter 6: Conclusion

Research that analyzes small commercial and industrial electricity usage patterns are less commonly documented than are residential electricity consumption patterns. This study helps partially fill this gap by analyzing electricity as an input to commercial and industrial production in Las Cruces, New Mexico. Annual data are gathered for a variety of variables covering a 1978 to 2018 sample period. Empirical analysis is completed using an autoregressive dynamic lag error correction methodology.

Many of the results obtained run counter to what is reported in a similar study of commercial and industrial electricity demand in El Paso, Texas. Natural gas is found to be a complementary good in the long-run and a substitute good in the short-run. In the long-run, the derived-demand curve is found to be upward sloping, while it is downward sloping in the short-run. Similar results are also documented for labor. For real per capita income, no impact is uncovered in the short-run, but a positive impact is documented for the long-run. Ambiguous outcomes are uncovered for the impact of weather on small commercial and industrial usage in the long-run. In the short-run, those effects are decidedly positive as hypothesized.

One constraint encountered for this study is the absence of capital stock estimates for the Las Cruces metropolitan economy. If capital stock estimates become available for this region, it would be useful to examine whether the results obtained in this effort are corroborated. Additional research analyzing commercial and industrial electricity demand for other regions would also be helpful. At this juncture, substantial differences seem to characterize small commercial and industrial usage between different geographic areas. Additional research will help confirm exactly how substantial those differences truly are.

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Data Appendix

Table 9: Annual Data

Year	CIS	PE	PQ2	PQ1	PG	PL
1978	60,247	11.59	$1.349	$16,715.03	$5.32	$22,708
1979	60,571	12.09	$1.514	$16,529.53	$5.65	$22,077
1980	61,701	13.42	$1.681	$16,307.83	$6.60	$21,820
1981	62,833	15.27	$1.862	$16,901.00	$6.99	$22,063
1982	63,283	15.41	$2.077	$17,126.13	$8.60	$21,933
1983	62,713	16.28	$2.227	$17,846.37	$8.96	$22,263
1984	62,878	16.04	$2.244	$18,082.09	$8.94	$21,980
1985	62,918	15.20	$2.263	$18,477.98	$10.15	$21,906
1986	63,903	13.32	$2.309	$18,888.39	$7.48	$22,090
1987	64,192	12.15	$2.378	$18,873.41	$6.63	$21,727
1988	66,976	12.14	$2.448	$18,386.83	$5.34	$20,762
1989	67,577	12.55	$2.568	$19,119.31	$5.78	$20,866
1990	67,397	12.30	$2.719	$19,191.63	$6.63	$21,359
1991	67,892	12.23	$2.854	$19,264.05	$6.02	$21,109
1992	68,662	13.10	$3.039	$19,811.67	$4.76	$21,945
1993	69,849	12.65	$3.307	$19,795.19	$5.97	$22,220
1994	72,622	12.44	$3.423	$19,609.73	$5.98	$22,404

1995	72,074	11.94	\$3.726	\$20,491.20	\$4.97	\$22,257
1996	71,225	12.06	\$3.786	\$20,392.95	\$4.37	\$22,326
1997	71,572	12.11	\$3.977	\$20,645.66	\$5.65	\$22,932
1998	72,180	11.71	\$4.131	\$21,582.18	\$5.12	\$23,784
1999	72,235	11.40	\$4.310	\$21,632.20	\$4.72	\$23,683
2000	73,211	11.62	\$4.317	\$22,162.20	\$5.98	\$23,872
2001	72,989	11.93	\$4.540	\$24,255.59	\$7.15	\$22,975
2002	71,709	11.85	\$4.760	\$24,950.79	\$5.59	\$23,966
2003	70,447	11.34	\$5.113	\$25,596.49	\$7.94	\$24,476
2004	68,850	11.60	\$5.522	\$26,379.27	\$8.97	\$24,644
2005	67,365	12.62	\$5.734	\$27,392.92	\$10.12	\$24,917
2006	66,264	11.83	\$5.787	\$27,344.73	\$11.23	\$25,115
2007	64,810	11.75	\$5.871	\$27,840.20	\$10.32	\$25,264
2008	63,063	12.27	\$6.024	\$27,854.92	\$10.47	\$26,043
2009	62,469	10.57	\$6.268	\$28,575.65	\$7.52	\$26,738
2010	62,829	10.86	\$6.379	\$28,845.24	\$7.38	\$26,924
2011	62,473	11.02	\$6.251	\$28,693.71	\$6.76	\$26,086
2012	61,308	9.84	\$5.965	\$28,690.33	\$6.00	\$26,031
2013	60,489	9.99	\$5.787	\$27,303.65	\$6.33	\$25,615
2014	59,542	10.07	\$5.869	\$28,052.25	\$7.23	\$25,686
2015	59,243	9.32	\$6.005	\$29,585.46	\$5.74	\$25,972
2016	58,601	9.54	\$6.009	\$29,654.09	\$5.10	\$25,718

2017	57,428	9.54	$6.170	$31,390.17	$5.81	$26,195
2018	57,426	8.51	$6.211	$31,893.13	$4.80	$26,321

Notes:

CIS; CIS Energy per Customer sales in kilowatt hours (KWH), obtained from EPEC FERC Form No. 1., Annual Report of Major Electric Utilities, Licensees, and Others.

PE; Real EPEC Average Price per KWH of Electricity in U.S. Cents, Base Period 2009 = 1, obtained from EPEC FERC Form No. 1., Annual Report of Major Electric Utilities, Licensees, and Others.

PQ2; Real Las Cruces Metropolitan Product in billions of U.S. Dollars, Base Period 2009 = 1, obtained from UTEP Border Region Modeling Project.

PQ1; Real Las Cruces Personal Income Per Capita in U.S. Dollars, Base Period 2009 = 1, obtained from UTEP Border Region Modeling Project.

PG; Real Price per CCF of Natural Gas sold to New Mexico Commercial Consumers in U.S. Dollars, Base Period 2009 = 1, obtained from United States Energy Information Administration.

PL; Real Las Cruces Wages and Salaries Paid per Worker in thousands of U.S. Dollars, Base Period 2009 = 1, obtained from UTEP Border Region Modeling Project.

Data Appendix

Table 9: Annual Data (Continued)

Year	CDD[i]	HDD[ii]
1978	3,029	1,795
1979	3,346	1,502
1980	3,100	1,762
1981	2,717	1,742
1982	3,024	1,685
1983	3,069	1,723
1984	3,029	1,806
1985	3,008	1,649
1986	2,683	1,765
1987	3,072	1,662
1988	2,799	1,715
1989	2,606	2,072
1990	2,788	1,943
1991	2,862	1,616
1992	2,943	1,786
1993	2,657	1,876
1994	2,535	2,200

1995	2,299	1,839
1996	2,185	1,841
1997	2,335	1,979
1998	2,461	1,813
1999	2,209	1,727
2000	2,409	2,231
2001	2,653	2,181
2002	2,636	2,185
2003	2,471	2,275
2004	2,714	1,826
2005	2,610	2,068
2006	2,538	1,954
2007	2,623	2,021
2008	2,641	1,737
2009	2,651	2,090
2010	2,873	2,081
2011	2,795	2,362
2012	2,446	2,209
2013	2,840	2,134
2014	2,380	2,075
2015	2,564	2,227
2016	2,247	2,234

2017	2,064	2,189
2018	2,378	2,442

Notes:

CDD; Las Cruces Cooling Degree Days, obtained from NOAA Northeast Regional Climate Center.

HDD; Las Cruces Heating Degree Days, obtained from NOAA Northeast Regional Climate Center.

Vita

Andrew T. Yurachek grew up in St. Peters, Missouri. He moved to El Paso, Texas in 2010 after enlisting in the United States Army as an infantryman where he served for 3 years, including one tour in Iraq. Upon receiving an honorable discharge in 2013, he enrolled at the University of Texas at El Paso and graduated with a Bachelor in Business Administration in Economics in 2017. While an undergraduate, he served 3 years in the Texas Army National Guard. He accepted a graduate internship with the YMCA of El Paso Shift Initiative after enrolling in the Master of Science in Economics program. While enrolled in the M.S. Economics program, he joined the Power Marketing Department of El Paso Electric Company as a Real-Time Energy Trader.

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