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Upward Sloping Demand for a Normal Good? Residential Electricity in Arkansas

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ABSTRACT

This study analyzes residential electricity demand in the state of Arkansas using an error-correction approach that examines both long-run and short-run dynamics. As in prior studies, results indicate that higher electricity prices reduce consumption in the long-run, but not in the short-run. With respect to variations in household income, residential electricity is treated as a normal good. The long-run income elasticity estimate is about twice as large as the short-run estimate. It is suggested that the muted short-run responses to price and income variables may reflect limited capacity to adjust the stock of electricity-consuming household devices over the short-term. More surprisingly, households are found to treat electricity as a normal good in the short-run, but have an upward sloping demand curve associated with it. The overall results suggest that increasing generating capacity in Arkansas will be feasible using the standard approach of incremental rate increases.

Keywords: Residential Electricity Consumption, Regional Economics, Business Economics
JEL Classifications: M21, Q4, R15

1. INTRODUCTION

Regional electricity consumption patterns vary substantially. Demand is affected by local economic and climatic conditions as well as by specific customer needs. Regional growth differences will cause geographic areas to face widely variant pressures to expand generation, transmission, and distribution capacities. Given those circumstances, econometric models of electricity demand can exhibit substantially different specification characteristics and/or parameter magnitudes between different locations within the same country (Bernstein and Griffin, 2006; Contreras et al., 2009). One region in the United States which has previously received relatively little attention in this regard is the state of Arkansas.

The objective of this study is to analyze residential electricity demand in Arkansas. To achieve that goal, per customer household electricity usage is modeled using an error-correction approach that has proven useful for other regions (Fullerton et al., 2012). Kilowatt hour (KWH) per customer demand is modeled using economic and climatic variables for a 44-year sample period covering 1970 through 2013. As an expanding regional economy whose energy consumption patterns have not been analyzed very extensively, a study of this nature for Arkansas may yield interesting insights that are useful to analysts and decision makers. Residential energy consumption is an area of ongoing research, in part, because of regionally heterogeneous economies, customer bases, and policies (Bastos et al., 2015; Cebula, 2012a).

The next section provides a brief overview of prior studies that analyze some aspects of electricity demand. Those studies cover various sample periods and geographical regions, and employ somewhat different empirical methodologies. Section three describes the theoretical framework and model used to carry out the econometric analysis for this effort. Section four summarizes empirical results obtained. A summary plus recommendations for future research comprise the conclusion of the paper.

2. LITERATURE REVIEW

Electricity prices vary across the United States by consumer category and geographical area (Bernstein and Griffin, 2006;

Kury, 2013). Because electricity cannot be stored, utility companies must plan ahead for usage fluctuations and forecasting major demand changes. Different consumer classes have variant consumption patterns and usually have to be modeled on a case-by-case basis. General consumption determinants include customer base sizes, usage requirements, electricity prices, budget constraints, substitute good prices, and weather conditions.

One of the first major studies of electricity demand in the United States is Fisher and Kaysen (1962). Short-run electricity consumption is modeled as a function of price, income and the stock of electric appliances. Relatively severe informational constraints are encountered with respect to electric appliance stock estimates. Following that effort, a large proportion of subsequent analyses deal with that ongoing difficulty by employing time series methods that allow analyzing dynamic properties of consumption even in the absence of potentially useful information on household capital stocks.

Silk and Joutz (1997) employ an error-correction model to analyze the residential electricity demand of the United States using data from 1949 to 1993. Indices of seasonal electricity appliances are developed to capture weather and appliance stock effects on demand. Short-run income and price elasticities are found to be similar in magnitude with opposite signs. Cooling degree day (*CDD*) coefficients are similar for both the short- and long-run, while heating degree day (*HDD*) coefficients are larger in the short-run.

Kamerschen and Porter (2004) analyzes residential, industrial, and total electricity demand in the United States from 1973 to 1998. Residential consumption is found to exhibit close to unitary own-price elasticity, with somewhat inelastic income elasticity, and fairly inelastic cross-price elasticity with respect to natural gas. Warm weather is found to affect residential usage substantially more than cool weather. Similar results, albeit with lower elasticities, are reported for household consumption from 1955 to 1996 in Taiwan by Holtedahl and Joutz (2004).

Bernstein and Griffin (2006) examine geographic differences in the demand for energy in the United States. The findings show that demand is relatively inelastic to changes in price. Surprisingly, for a normal good, 17 different states exhibit positive residential price elasticities. That unexpected outcome is attributed to regional declines in real electricity rates over the period covered by the study.

Dergiades and Tsouldfidis (2008) model aggregate household electricity demand in the United States using real per capita income, the real average residential price of electricity, *CDD*, *HDD*, the real average price of home heating oil, and the per capita stock of housing. A key assumption is that electricity using equipment will be linked to the stock of occupied dwelling units. Parameter estimation results support the hypothesized relationships for the various regressors in the long-run equilibrium and short-run error correction equations. Departures from the long-run equilibrium for residential electricity consumption are estimated to last approximately 2.75 years before fully dissipating.

Contreras et al. (2009) conduct an empirical analysis of residential usage across all 50 states and the District of Columbia using regional economic, demographic, and climatic data. Dummy variables are included for the nine regions defined by the United States Census Bureau. Estimation results indicate that residential electricity demand is price inelastic. Additionally, the parameter estimates indicate that residential electricity is an inferior good for the United States as a whole. The latter outcome means that increases in personal income will lead to decreases in household electricity usage. Higher incomes are potentially correlated with higher quality and more efficient home appliances, allowing residential electricity demand to decrease.

Fullerton et al. (2012) analyze residential electricity consumption in Seattle. Simultaneity between residential electricity consumption and the average price variable necessitates the employment of two-staged least squares estimation for the sample period in question. Variables used as instruments for the residential price per KWH are the national fixed asset price deflator for electric power structures in the United States and the national electricity price index. The long-run income elasticity estimate indicates that residential electricity in Seattle behaves as an inferior good. Not surprisingly, residential usage behaves as a normal good in the short-run when household appliance stocks are fixed.

Labandeira et al. (2012) examine electricity demand for cases when data are limited. Using a panel for regions in Spain, results indicate that residential consumption is more price elastic than commercial and industrial usage. Household consumption is also found to become more price inelastic as per capita incomes rise. The latter result may also be relevant to a region such as Arkansas where incomes have grown in recent decades.

Several recent studies (Atamturk and Zafar, 2012; Blazquez et al., 2013) highlight the numerous differences that occur in household electricity usage patterns between regions. Results in those studies emphasize the importance of conducting demand analyses on a region by region basis due to important variations in elasticities. Along those lines, Pourazarm and Cooray (2013), uncover evidence of circumstances that may result in substantial price insensitivity as regional economies develop and income performances improve. Similar evidence of fairly low price elasticities is also reported by Blazquez Gomez et al. (2013).

3. THEORETICAL MODEL

Numerous studies have shown that residential electricity demand is affected by its own price, substitute good prices, income, weather, and customer base size (Espey and Espey, 2004). In most, but not all, cases, per customer (or per capita demand) is modeled directly. When needed for planning purposes, aggregate usage for the region in question can be calculated by multiplying per customer consumption by the customer base (or by multiplying per capita usage by total population). Implicitly, the demand equation for per customer residential electricity consumption can be represented by the general function shown below.

$$KWHR = \mathrm{f}(P, Y, PG, CDD, HDD) \quad (1)$$

In Equation (1), *KWHR* represents per customer residential electricity consumption in kilowatt hours, *P* is the real residential electricity price, *Y* is real household income, *PG* is the real price of natural gas, and *CDD* and *HDD* are cooling and heating degree days, respectively.

The own price measure employed is the average price, calculated as total residential revenues divided by total residential KWH. This is in line with recent research regarding customer rate awareness (Bastos et al., 2015). It does, however, create a potential endogeneity issue for the per customer usage equation, because total KWH consumption appears in the numerator of the dependent variable and in the denominator of the own price regressor on the right-hand side of that equation. To test for potential simultaneity, the artificial regression procedure of Davidson and MacKinnon (1989) is employed. Two instrumental variables are used to carry out the endogeneity test: EST, the national fixed asset price deflator for electric power structures, and USP, the national residential electricity price in cents per KWH. EST is published by the Bureau of Economic Analysis (BEA, 2015a). USP is published by the Energy Information Agency (EIA, 2015).

An error correction framework is applied to per customer consumption. The basic form for the long-run co-integration equation for electricity usage per household is shown in Equation (2). The hypothesized sign for each coefficient is shown in the parentheses below the equation. As in prior studies, residential electricity is expected to behave as normal good with a downward sloping demand curve. In Equation (2), *u* is a stochastic error term and t is an annual time index. Previous empirical efforts have indicated that serial correlation may occur with this specification (Fullerton et al., 2012).

$$\underset{}{KWHR_t} = \alpha_0 + \underset{(-)}{\alpha_1 P_t} + \underset{(+)}{\alpha_2 Y_t} + \underset{(+)}{\alpha_3 PG_t} + \underset{(+)}{\alpha_4 CDD_t} + \underset{(+)}{\alpha_5 HDD_t} + u_t \tag{2}$$

Natural gas is hypothesized to be used as a substitute good by households. Accordingly, the parameter for the natural gas price in Equation (2) is expected to be positive. Both weather variables are expected to be positively correlated with residential electricity consumption. As temperatures fluctuate above (or below) 65°F, the need for air conditioning (or heating) is likely to increase.

An error correction model is used to analyze short-run dynamics of residential electricity consumption per customer. The residuals from the long-run co-integrating equation are used to represent deviations from long-run equilibrium usage. The variables are differenced prior to estimation. In Equation (3), d is a difference operator. The numbers in parentheses represent the expected signs of the coefficients. The error correction coefficient, δ_6, is hypothesized to be negative because deviations from previous periods are expected to be offset in subsequent periods.

$$\begin{aligned} d(KWHR_t) = \delta_0 &+ \underset{(-)}{\delta_1 d(P_t)} + \underset{(+)}{\delta_2 d(Y_t)} + \underset{(+)}{\delta_3 d(PG_t)} + \underset{(+)}{\delta_4 d(CDD_t)} \\ &+ \underset{(+)}{\delta_5 d\mathrm{Ln}(HDD_t)} + \underset{(-)}{\delta_6 (u_{t-1})} + v_t \end{aligned} \tag{3}$$

4. EMPIRICAL ANALYSIS

Annual frequency data from 1970 to 2013 are used for the empirical analysis. The United States Energy Information Administration is the source for the Arkansas price and consumption data as well as the number of electricity customers from 1990 forward (EIA, 2015). Customer base data percent changes for the period from 1970 to 1990 are collected from Edison Electric Institute (EEI, 1995). The Edison Electric estimate of the customer base is slightly higher than the EIA estimate for the year 1990. In order to align the two sets of estimates, the Edison Electric rates of change for the years prior to 1990 are applied retroactively beginning with the 1990 EIA estimate. Total residential electricity usage in KWHs divided by the number of residential customers is used as the dependent variable.

CDD and *HDD* data are from the National Climatic Data Center (NCDC, 2013). Annual-frequency data on median household income are available from the US Census Bureau from 1984 to 2013 (USCB, 2015). Prior to 1984, median household income data are estimated using a standard regression methodology (Friedman, 1962). Per capita personal income data for Arkansas are used to approximate the 1970-1983 estimates of median household income (BEA, 2015b). Median household income, as well as both price measures, is deflated to 2009 prices by using the personal consumption expenditures price index. The latter is also known as the personal consumption expenditures deflator and those data are from the Bureau of Economic Analysis (BEA, 2015a). Table 1 lists all variables and data sources used in the used in the empirical analysis.

Table 1: Variables employed

Mnemonic	Description	Units	Source
KWHR	Arkansas residential electricity usage per customer account	KWH	EIA, EEI, and author calculations
P	Arkansas average residential electricity price, 2009 base year KWH	Real cents per	EIA and author calculations
Y	Arkansas real median household income, 2009 base year	Real dollars	US Census Bureau and author calculations
PG	Arkansas average residential natural gas price, 2009 base year	Real dollars per 1000 cubic feet	EIA
CDD	Cooling degree days, difference between daily average temperature and 65°F (when daily average temperature exceeds 65°F)	Number of degrees	NCDC
HDD	Heating degree days, difference between daily average temperature and 65°F (when daily average temperature is below 65°F)	Number of degrees	NCDC
USP	US residential average electricity price	Cents per KWH	EIA
EST	National fixed asset price deflator for electric power structures	Index, 2009=100	BEA

KWH: Kilowatt hours, EIA: United States Energy Information Administration, BEA: United States Bureau of Economic Analysis, NCDC: National Climatic Data Center, *HDD*: Heating degree days, *CDD*: Cooling degree days

As shown by the information contained in Table 2, the sample data exhibit good variability. Per customer residential electricity usage ranges from a low of 6802 KWH in 1970 to a high of 14,538 KWH in 2010. Real cents per KWH (base year 2009) records its lowest level of 8.20 cents in 2004 and peaks at 13.71 in 1983. Real household income (base year 2009) ranges from a low of $21,022 in 1970 to a high of 42,013 in 2007. The real price of natural gas per thousand cubic feet attains its lowest value of $3.36 in 1970 before ascending to $14.94 in 2006. Healthy value ranges are also observed for *HDD* and *CDD*, with a somewhat greater degree of variability exhibited by the warm weather temperatures.

Because KWHs consumed appears on both sides of the equation, it is important to test for potential simultaneity prior to parameter estimation. To examine this possibility, an artificial regression test is used (Davidson and MacKinnon, 1989). To carry out that test for endogeneity between the average price explanatory variable and the KWH per customer dependent variable, two instrumental variables are employed. Those variables are the national residential electricity price in cents per KWH and the national fixed asset price deflator for electric power structures. The null hypothesis tested is that the average price variable is not correlated with the error term of the long-run equation. The null hypothesis fails to be rejected, implying that ordinary least squares parameter estimates will be unbiased even though the average price variable is employed as a regressor.

Table 2: Descriptive statistics

Variable	*KWHR*	*P*	*Y*	*PG*	*HDD*	*CDD*
Mean	11,188	10.54	32,293	8.24	3,366	1,848
Median	11,191	10.38	33,281	7.76	3,374	1,802
Maximum	14,538	13.71	42,013	14.94	3,960	3,464
Minimum	6,802	8.20	21,022	3.36	2,725	1,397
Standard deviation	1,854	1.60	5,564	3.28	294	324
Skewness	−0.33	0.33	−0.28	0.34	−0.09	2.95
Kurtosis	2.65	1.89	2.00	2.44	2.60	16.79
Observations	44	44	44	44	44	44

Units of measure listed in Table 1, *HDD*: Heating degree days, *CDD*: Cooling degree days

Table 3 summarizes estimation results for the long-run co-integrating equation for per customer residential electricity usage. Similar to prior studies of regional electricity demand, serial correlation is present in the residuals (Fullerton et al., 2012). The latter problem is resolved by expanding the specification to allow for a first-order moving average error process (Pagan, 1974). All of the estimated coefficients, with exception of the natural gas parameter, are statistically significant at the 5% level. Table 4 shows elasticities of demand estimated with respect to each of the explanatory variables. The estimates are calculated by multiplying the coefficients in Tables 3 and 5 by the mean values of the corresponding independent variables and dividing by the mean of the dependent variable.

The estimated long-run income elasticity is 0.646. This estimate is somewhat lower than the 0.92 median reported by Espey and Espey (2004), and is also lower than estimates reported in other studies such as Houthakker (1980). Notwithstanding its relatively low value, the fact that the income elasticity estimate is positive indicates that residential electricity behaves as a normal good in the long-run. Recent evidence reported for many regions of the United States finds that households sometimes treat electricity as an inferior good (Contreras et al., 2009; Fullerton et al., 2012). However, this does not seem to be the case in the long-run for Arkansas residential usage during the sample period in question. Rising incomes plus an increasing prevalence of electric appliances for communication and entertainment purposes in Arkansas households potentially contribute to the positive income parameter estimate.

The own-price elasticity estimate for residential electricity is −0.201 and the corresponding coefficient in Table 3 is statistically significant. The negative sign of the coefficient suggests that higher electricity rates may help achieve conservation targets to some extent (Cebula, 2012a). However, the magnitude of the long-term price elasticity estimate is relatively small compared to the majority of estimates reported in surveys of previous research

Table 3: Per customer residential electricity demand long-run co-integrating equation

Dependent variable: *KWHR*				
Method: Non-linear least squares (ARMAX)				
Sample: 1970-2013				
Included observations: 44				
Convergence achieved after 6 iterations				
Variable	**Coefficient**	**Standard error**	**t-statistic**	**P**
Constant	−801.1972	2336.592	−0.342891	0.7336
Y	0.223767	0.051350	4.357706	0.0001
P	−213.4986	97.52420	−2.189186	0.0350
PG	91.82670	83.52555	1.099385	0.2787
CDD	1.109860	0.274230	4.047182	0.0003
HDD	1.247027	0.350305	3.559836	0.0010
MA (1)	0.410537	0.160178	2.562997	0.0146
R^2	0.902747	Mean dependent variable	11188.45	
Adjusted R^2	0.886976	Standard deviation dependent variable	1854.233	
Standard error of regression	623.3745	Akaike information criterion	15.85728	
Sum squared residual	14378044	Schwarz info. criterion	16.14113	
Log likelihood	−341.8601	Hannan–Quinn information criterion	15.96254	
F-statistic	57.24184	P (F-statistic)	0.000000	
Durbin–Watson statistics	1.676754	Inverted MA roots	−0.41000	

HDD: Heating degree days, *CDD*: Cooling degree days by Espey and Espey (2004) and Labandeira et al. (2012). The inelastic relationship between price and demand reported in Table 4 indicates that moderate electricity rate hikes will have limited impacts on per-customer demand and will tend to increase utility revenues, other things equal.

Changes in the price of the main substitute good, natural gas, have even more subdued long-run effects on demand per customer. The cross-price elasticity shown in Table 4 is 0.068. The small magnitude of the coefficient implies that residential natural gas is a highly imperfect substitute good for residential electricity in Arkansas. Further underscoring that point, the computed t-statistic shown in Table 3 does not satisfy the 5% significance criterion. The influence of variations in natural gas prices on residential electricity usage may be rather small because of constraints on potential fuel switching (Silk and Joutz, 1997). Digital video recorders, flat screen televisions, personal computers, and other household appliances can only be operated using electrical power sources. This outcome corroborates similar results reported in other studies (Bernstein and Griffin, 2006; Contreras et al., 2009).

Table 3 further indicates that both climate variables, *CDD* and *HDD*, are positively correlated with residential electricity consumption. Both of the parameters estimated for the weather variables are statistically different from zero at the 5% level. The coefficients fall within the inelastic range indicated by prior studies (Silk and Joutz, 1997; Filippini, 1999; Cebula, 2012b). The results imply that a 1% increase in annual *CDD* increases residential electricity consumption by 0.183% while a 1% increment in *HDD* raises consumption by 0.375%.

Table 4: Elasticity estimates

Elasticity of demand with respect	Long-run	Short-run
Y	0.646	0.311
P	−0.201	0.168
PG	0.068	−0.092
CDD	0.183	0.156
HDD	0.375	0.251

HDD: Heating degree days, *CDD*: Cooling degree days

Table 5 reports the coefficient estimates for the short-run error correction model for per customer residential electricity demand. The error correction term is a one-period lag of the long-run equation residuals. As noted in Holtedahl and Joutz (2004), that series represents deviations in electricity consumption from its long-run equilibrium. First differences of the explanatory variables from the long-run equation are used as regressors in the short-run equation.

The constant term is positive and statistically significant. For a dependent variable that is differenced prior to estimation, this implies that a portion of the growth in per customer residential electricity usage has occurred in a highly reliable manner over the course of the four decade sample period. The presence of statistically significant deterministic component that is greater than zero is similar to what is reported for Seattle (Fullerton et al., 2012), but the rate of growth for Arkansas shown in Table 4 is much higher.

Not surprisingly, the short-run elasticities shown in Table 4 are almost always smaller in magnitude than those reported in the long-run. Those outcomes are similar to what has been previously documented for residential electricity (Dergiades and Tsoulfidis, 2008). Although many of the parameters in Table 5 exhibit the respective signs hypothesized for them, the slope coefficients for the price variables in the sample do not satisfy the 5% significance criterion. The latter implies that short-run household usage patterns contain a fairly high amount of uncertainty with respect to price responses.

The real per capita income coefficient is positive in Table 5, indicating that residential electricity is also treated as a normal good in the short-run in Arkansas. This parameter indicates that a one percent increase in real per capita income will lead to an increase of 0.311% in per customer consumption. The magnitude

Table 5: Per customer residential electricity demand short-run error correction equation

Dependent variable: d (*KWHR*)				
Method: Least squares				
Sample (adjusted): 1971-2013				
Included observations: 43 after adjustments				
Variable	**Coefficient**	**Standard error**	**t-statistic**	**P**
Constant	145.9132	71.67507	2.035759	0.0492
d (*Y*)	0.107851	0.046864	2.301355	0.0273
d (*P*)	178.5334	185.0156	0.964964	0.3410
d (*PG*)	−124.2872	91.82530	−1.353518	0.1843
d (*CDD*)	0.945253	0.151432	6.242101	0.0000
d (*HDD*)	0.833219	0.207486	4.015795	0.0003
RESIDLR (−1)	−0.558461	0.124859	−4.472726	0.0001
R^2	0.631113	Mean dependent variable		158.0710
Adjusted R^2	0.569632	Standard deviation dependent variable		680.4832
Standard error of regression	446.4134	Akaike information criterion		15.18827
Sum squared residual	7174259	Schwarz information criterion		15.47498
Log likelihood	−319.5478	Hannan–Quinn information criterion		15.29400
F-statistic	10.26516	P (F-statistic)		0.000001
Durbin–Watson statistics	2.239070			

HDD: Heating degree days, *CDD*: Cooling degree days of the income coefficient obtained corroborates the inelastic estimates listed in other studies. Espey and Espey (2004) survey short-run income elasticity estimates that average approximately 0.28. Silk and Joutz (1997) report a short-run income elasticity of 0.38 that is estimated using national data and satisfies the 5% criterion. Some studies such as Dergiades and Tsoulfidis (2008) obtain statistically significant short-run income elasticity estimates that are even lower than what is documented here for Arkansas.

The own-price elasticity is 0.168, implying that short-run residential electricity demand in Arkansas is upward sloping. For a normal good, that is very unusual and this result runs counter to what has generally been documented in prior studies. It should further be noted that the electricity price coefficient in Table 5 is not statistically different from zero. If, however, the own-price coefficient sign is correct, there are at least two plausible explanations for this surprising outcome.

There is some relatively recent research that finds empirical evidence of upward sloping electricity demand curves (Bernstein and Griffin, 2006). How can that occur for a normal good? As noted by Vandermeulen (1972), this unexpected outcome can be observed when the income effect exceeds the substitution effect. An upward sloping demand curve for a product with a positive income coefficient is no the exclusive realm of residential electricity. Fullerton et al. (2015) report a similar circumstance for gasoline × consumption in Mexico. Interestingly, the latter study also employs a data sample that invovles fairly strong income growth while prices for the good in question are regulated by a central authority.

Of course, the impact of price changes on household electricity demand occur gradually over the long-run. In the short-run, the stock of electricity-consuming devices is fixed. Consequently, the impact of a price change tends to be fairly muted when appliance stocks are not yet replaced with newer, more efficient ones (Taylor, 1975). From that perspective, the own-price coefficient in Table 5 would then, rightfully, be regarded as statistically indistinguishable from zero.

The short-run cross-price elasticity of natural gas is −0.092, but the estimated regression parameter does not satisfy the 5% significance criterion. Garcia-Cerruti (2000) and Pourazarm and Cooray (2013) also obtain negative coefficients on natural gas variables in electricity demand equations, implying that electricity and natural gas sometimes behave as complements. A negative cross-price elasticity is possible if consumers respond to an increase in natural gas prices by reducing the share of income spent on energy costs and using all appliances less intensively. However, the statistical insignificance of the cross-price parameter estimate suggests that the short-run impacts of natural gas prices on electricity usage are not very reliable during the sample period analyzed. That notwithstanding, there may be little reason to expect a high degree of substitution between electricity use and natural gas use in the short-run since switching from one energy source to the other generally requires altering the household capital stock and is, therefore, a long-run decision (Taylor, 1975).

Parameters estimated for the climate variables, *CDD* and *HDD*, are both greater than zero in Table 5. Both coefficients are also statistically significant, implying that residential electricity usage in Arkansas reacts in fairly consistent manners to temperature variations in the short-run. The magnitudes of the elasticities in Table 4 further indicate that short-run household electricity consumption in Arkansas is somewhat more sensitive to cold weather than to warmer temperatures.

The error-correction parameter result shown in Table 5 corroborates evidence reported in earlier studies. The estimated coefficient is −0.558 and statistically significant. This result implies that 56% of the consumption adjustment to any prior period disequilibrium occurs within 12 months of the shock. Approximately 1.79 years are required for complete adjustment. That is less time than what is reported for Seattle by Fullerton et al. (2012) and what is estimated for the United States by Dergiades and Tsoulfidis (2008), but is not so quick as to seem unrealistic.

5. DISCUSSION

The average price for residential electricity in Arkansas has consistently failed to keep pace with inflation from 1983 forward. Similarly, KWH usage per customer has consistently moved upward over the course of the entire 1970-2013 period for which complete data are available. Against this historical backdrop, if needed, there is ample room for electric rate increases in most, if not all, of the 22 service areas regulated by the Arkansas Public Service Commission. This is also likely to be the case for the municipally owned electric utilities that are not regulated by the state agency (APSC, 2013). While fuel charges may not rise very much, that may not be the case for generation, transmission, and distribution costs. Should those costs increase, covering them should be feasible.

The results also indicate that long-run household electricity consumption increases in response to income gains. As one of the best performing regional economies in North America, household income growth in Arkansas is projected to easily exceed the rate of inflation in the United States at least through 2018 (Garg, 2014). Given that, residential electricity usage in fast growing regions such as Little Rock, Fayetteville, and other areas may force loads to increase more rapidly than in other regions of the United States. Because of demographic and economic expansion, pressures to increase generation, transmission, and distribution capacities are likely to be experienced in several service areas throughout the state.

Weather extremes may become more prevalent as a consequence of climate change. For example, data from the last 50 years indicate that prevailing temperatures have increased to record levels, especially from 2000 forward (Arndt et al., 2010). Should these patterns continue the outcomes in Tables 3 and 5 imply that additional investment in generating capacities will be required across Arkansas. The latter is because both summer and winter peak energy requirements are likely to increase more rapidly than total usage in the various service areas. If keeping pace with peak demands forces investing in underutilized generation capacity, rates will be forced upwards much more rapidly than has been the case in recent decades.

With respect to the short-run upward sloping demand curve indicated by Table 5, a practical observation is in order. The positive own-price elasticity is associated with a 30-year period during which electricity rates in Arkansas failed to keep pace with inflation. From a practical perspective, that circumstance is not likely to repeat itself over an extended period. That is especially true in a growing regional economy where eventual investment in new generating capacity is likely.

6. CONCLUSION

This study analyzes residential electricity demand in Arkansas. The analysis is carried out within a dynamic framework that employs a long-run co-integrating equation and a short-run error correction equation. Explanatory variables utilized include real median household income, a statewide average real residential electricity price, *HDD*, *CDD*, and a statewide real residential natural gas price.

Both of the estimated equations indicate that changes in median household income positively impact electricity demand. Over the long-run, as consumers buy new appliances, entertainment equipment, and larger houses, increased lighting, heating, and cooling requirements are likely to occur. Thus, rising incomes will likely exert pressure to increase electricity generation capacity in some areas of Arkansas.

The signs of both long-run price coefficients are in line with theoretical expectations. Although a somewhat smaller response is reported than what has been documented for other regions, the results suggest that lower real electricity rates tend to increase electricity consumption. Thus, the decline in real electricity prices since 1983 seems to have contributed to higher electricity consumption in Arkansas.

In contrast to the long-run results, the signs of both short-run price coefficients are opposite those expected based on economic theory. The own-price coefficient estimate is positive while the natural gas price coefficient is negative. Both parameter estimates are statistically indistinguishable from zero, suggesting that price has little discernible impact on electricity demand in the short-run for the sample considered. Substituting an alternative energy source for electricity typically requires changing the household appliance stock, which generally occurs as a result of long-term decision-making. Thus, it is not surprising that natural prices do not exert a strong effect on demand in the short-run. Even if the short-run demand curve for residential electricity is upward sloping, it does not seem likely that this remain the case if real electricity rates start to rise.

The error correction framework provides a convenient approach for examining the factors that affect demand over both the long-run and the short-run. While the outcomes documented for Arkansas in this study indicate that usage habits may differ from commonly held perceptions, it is not clear to what extent these results generalize to other regions. Replication using residential electricity usage data for other regional economies appears warranted.

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REFERENCES

APSC. (2013), Electric Section. Little Rock, AR: Arkansas Public Service Commission.

Arndt, D.S., Baringer, M.O., Johnson, M.E.R. (2010), State of the climate in 2009. Bulletin of the American Meteorological Society, 91(7), S1-S224.

Atamturk, N., Zafar, M. (2012), Electricity Use and Income: A Review. Sacramento, CA: Public Utilities Commission State of California.

Bastos, P., Castro, L., Cristia, J., Scartasini, C. (2015), Does energy consumption respond to price shocks? Journal of Industrial Economics, 63, 249-278.

BEA. (2015a), National Income and Product Accounts. U.S. Washington, DC: Bureau of Economic Analysis.

BEA. (2015b), Regional Data. U.S. Washington, DC: Bureau of Economic Analysis.

Bernstein, M.A., Griffin, J. (2006), Regional Differences in the Price-Elasticity of Demand for Energy. Golden, CO: National Renewable Energy Laboratory.

Blazquez, Gomez, L.M., Filippini, M., Heimsch, F. (2013), Regional impact of changes in disposable income on Spanish electricity demand: A spatial econometric analysis. Energy Economics, 40(S1), S58-S66.

Blazquez, L., Boogen, N., Filippini, M. (2013), Residential electgricity demand in Spain: New evidence using aggregate data. Energy Economics, 36, 648-657.

Cebula, R.J. (2012a), U.S. Residential Electricity Consumption: The effect of states' pursuit of energy efficiency policies. Applied Economics Letters, 19, 1499-1503.

Cebula, R.J. (2012b), Recent evidence on residential electricity consumption determinants: A panel two stage least square analysis, 2002-2005. Journal of Economics & Finance, 36, 925-936.

Contreras, S., Smith, W.D., Roth, T.P., Fullerton, T.M., Jr. (2009), Regional evidence regarding U.S. residential electricity consumption. Empirical Economics Letters, 8, 821-232.

Davidson, R., MacKinnon, J.G. (1989), Testing for consistency using artificial regressions. Econometric Theory, 5, 363-384.

Dergiades, T., Tsoulfidis, L. (2008), Estimating residential demand for electricity in the United States, 1965-2006. Energy Economics, 30, 2722-2730.

EEI. (1995), Historical Statistics of the Electric Utility Industry Through 1992. Washington, DC: Edison Electric Institute.

EIA. (2015), State Profile and Energy Estimates. U.S. Washington, DC: Energy Infomrmation Administration.

Espey, J.A., Espey, M. (2004), Turning on the lights: A meta analysis of residential electricity demand elasticities. Journal of Agricultural & Applied Economics, 36, 65-81.

Filippini, M. (1999), Swiss residential demand for electricity. Applied Economics Letters, 6, 533-538.

Fisher, F.M., Kaysen, C. (1962), A Study in Econometrics: The Demand for Electricity in the United States. Amsterdam, NE: North-Holland Publishing Company.

Friedman, M. (1962), Interpolation of time series by related series. Journal of the American Statistical Association, 57, 729-757.

Fullerton, T.M., Jr., Juarez, D.A., Walke, A.G. (2012), Residential electricity consumption in Seattle. Energy Economics, 34, 1693-1699.

Fullerton, T.M., Jr., Ibarra Salazar, J.A., Elizalde, M. (2015), Microeconomic gasoline consumption anomalies in Mexico: 1997-2007. Asian Economic & Financial Review, 5, 709-722.

Garcia-Cerrutti, L.M. (2000), Estimating elasticities of residential energy demand from panel county data using dynamic random variables models with heteroskedastic and correlated error terms. Resource and Energy Economics, 22, 355-366.

Garg, A. (2014), Arkansas. IHS Global Insight US Markets State Economies South. p41-50.

Holtedahl, P., Joutz, F.L. (2004), Residential electricity demand in Taiwan. Energy Economics, 26, 201-224.

Houthakker, H.S. (1980), Residential electricity revisited. Energy Journal, 1, 29-41.

Kamerschen, D.R., Porter, D.V. (2004), The demand for residential, industrial, and total electricity, 1973-1998. Energy Economics, 26, 87-100.

Kury, T.J. (2013), Price effects of independent transmission system operators in the United States electricity market. Journal of Regulatory Economics, 43, 147-167.

Labandeira, X., Labeaga, J.M., Lopez-Otero, X. (2012), Estimation of elasticity price of electricity with incomplete information. Energy Economics, 34, 627-633.

NCDC. (2013), Land-Based Station Data. Washington, DC: National Oceanic and Atmospheric Administration.

Pagan, A.R. (1974), A generalised approach to the treatment of autocorrelation. Australian Economic Papers, 13, 260-280.

Pourazarm, E., Cooray, A. (2013), Estimating and forecasting residential electricity demand in Iran. Economic Modelling, 35, 546-558.

Silk, J.I., Joutz, F.L. (1997), Short and long-run elasticities in US residential demand: A co-integration approach. Energy Economics, 19, 493-513.

Taylor, L.D. (1975), The demand for electricity: A survey. Bell Journal of Economics, 6, 74-110.

USCB. (2015), Median Household Income by State: 1984 to 2013. Washington, DC: U.S. Census Bureau.

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