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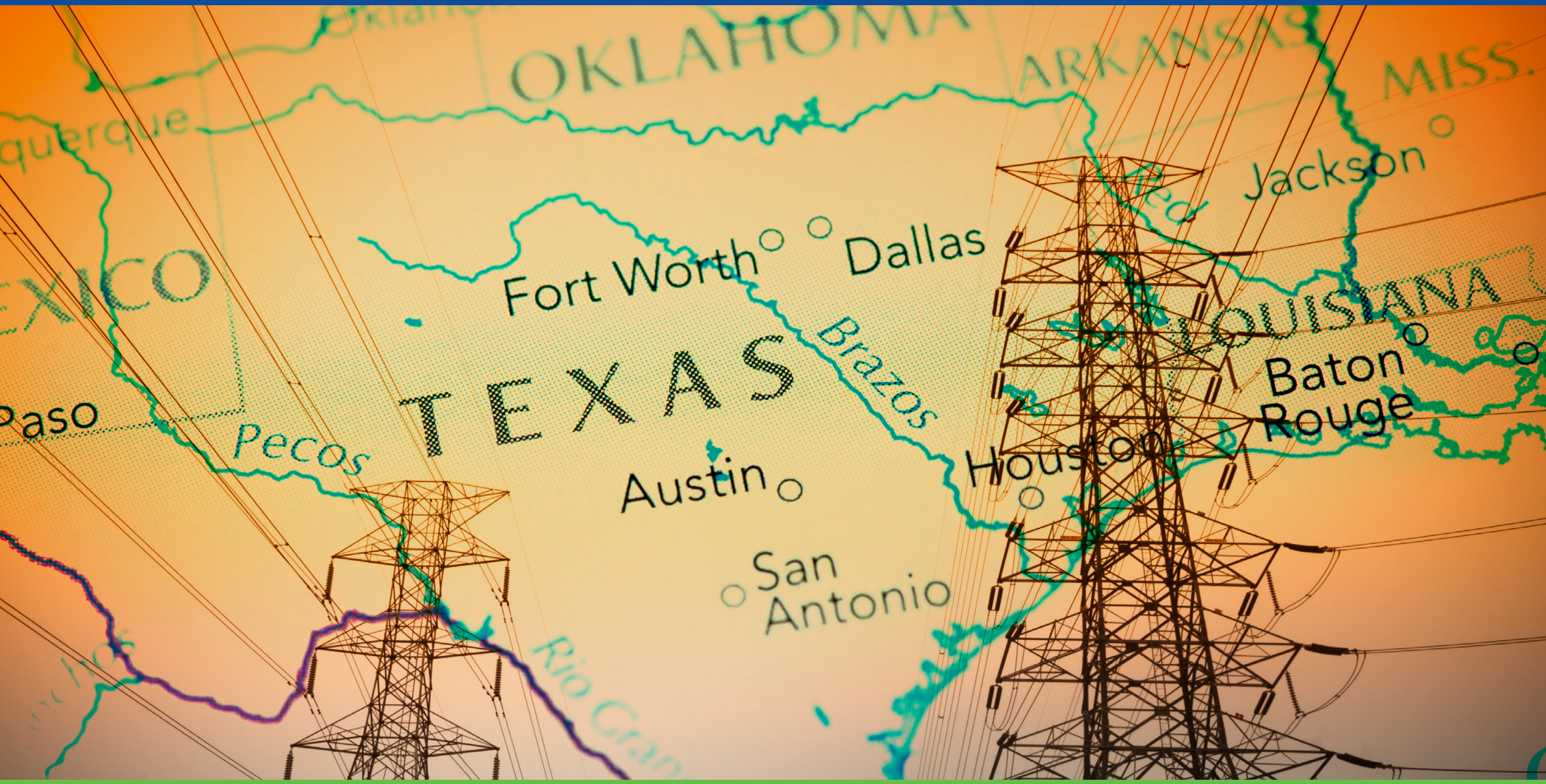

ELECTRICITY REFORM AND RETAIL PRICING IN TEXAS

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“Electricity Reform and Retail Pricing in Texas”

Abstract

Electricity market reforms have pursued two main goals, both aimed at increasing economic efficiency. The first is to make prices more reflective of costs so that consumers can make more efficient decisions about where and when to consume electricity. The second goal is to ensure that suppliers minimize the costs of supply. How successful has electricity market reform in Texas been with regard to achieving these goals? We focus on one aspect of this overall set of desired outcomes, namely whether movements in retail prices reflect wholesale market prices and whether reform has delivered cost reductions in the delivery of energy services by retailers. We find clear evidence that retail prices in competitive market areas better reflect wholesale prices and have moved favorably for consumers relative to wholesale prices. The same is not necessarily true for consumers in non-competitive market areas. This suggests that competitive retail markets have delivered cost reductions consistent with electricity service providers reducing their marginal costs. The effort that Texas undertook over a decade ago to introduce competition into the retail electricity supply thus appears to be yielding the benefits to consumers that were intended in competitive areas. Consumers in less competitive areas do not appear to have benefited as much.

I. Introduction

Electricity markets in the United States have generally exhibited one of two types of market structures—often characterized as "regulated" versus "deregulated"—or a combination thereof.[1] The first extreme, a regulated vertically integrated utility, is the older, more traditional form of load-serving entity. In the past two decades, however, market reform has, to varying extents, unbundled the vertically integrated paradigm and facilitated entry by new firms, resulting in competition at the wholesale or retail level, or both. The more competitive structures can also retain varying degrees of price and service regulation, and different mechanisms for determining market prices. The introduction of reforms has varied regionally and over time, but the general tendency in the US since the 1990s has been a slow movement toward deregulated, competitive markets. In fact, according to the US Energy Information Administration (EIA), by 2015 over 20% of total US electricity sales came from retail power marketers or retail energy providers.

The Texas electricity market featured vertically integrated utilities until the passage of Senate Bill 7 in 1999, which allowed competition in the market.[2] Utilities were restructured or "unbundled" into retail energy providers, generators, and distribution and transmission

[1] The characterization of electricity markets as "deregulated" is an oversimplification. Electricity market reform generally increases the number of competing firms at the wholesale and retail levels by splitting formerly vertically integrated firms, and alters the rules of the market in order to facilitate entry and competition at the wholesale and retail levels. Thus, the change might be better characterized as a change in the market structure and regulatory apparatus away from the traditional vertically integrated regulated monopoly model of the past rather than an elimination of regulation altogether.

[2] Zarnikau (2005), Adib and Zarnikau (2006), and Zarnikau and Whitworth (2006) provide detailed overviews of the Texas electricity reform.

utility companies before consumer choice commenced 15 years ago, in January 2002.[3] In the five years that followed, transitory provisions such as mandated price caps or "price-to-beat" were established to incentivize market entry.

Today, "the ERCOT market is generally considered to be the most successful of the restructured electricity markets in North America" (Zarnikau 2011), with more retail competition than any other market in Canada and the US (DEFG 2015). Moreover, the Texas market is remarkable among deregulated markets for its customer participation. According to the 2017 Public Utility Commission of Texas draft report "Scope of Competition in Electric Markets in Texas," as of March 2016, 92% of all customers have exercised their right to choose an electricity provider (PUC 2017). The success is also evidenced by the fact that about 75% of all electricity sold in Texas is to retail choice consumers (ERCOT 2016).

The Texas experience is not universally accepted as a success. Notably, a recent study commissioned by the Texas Coalition for Affordable Power (TCAP 2016) claims that electricity deregulation in Texas has not delivered the intended outcome. In particular, the study notes among its major findings that Texans paid average residential rates that were 6.4% below the national average in the 10 years prior to deregulation but 8.5% higher in the 10 years following deregulation. The study also asserts that the "price-to-beat" mechanism failed, highlights the role of natural gas prices as a determining feature of electricity prices, and points to higher transmission and distribution costs as factors that have contributed to higher rates in Texas.

In this study, we find that residential rates in competitive and non-competitive areas of Texas have behaved in a manner that is consistent with economic theory. More specifically, residential rates in competitive areas are highly reflective of wholesale rates, which suggests that electricity providers are minimizing costs in meeting market demands. By contrast, residential rates in non-competitive areas do not generally reflect wholesale rates. Furthermore, we find a shrinking gap between residential rates and wholesale rates in competitive areas, which is consistent with improvements in firm and market efficiency. This also has not generally been the case in non-competitive areas.

Importantly, we also find that residential rates in areas with regional cooperatives tend to behave more similarly to those in competitive market areas. A possible explanation is that such cooperatives still must effectively compete with outside entities for market access. We elaborate more on this below, but the implication is that the introduction of market competition has spillover effects on some less competitive market areas.

We have also examined site-specific load and billing data for several large commercial consumers of electricity. This provides a more complete picture of the behavior of electricity rates in the state of Texas across competitive and non-competitive areas since market reforms began. The data reveal that commercial electricity consumers in non-

[3] Intelometry (2008) provides a detailed description of the utility unbundling and name history.

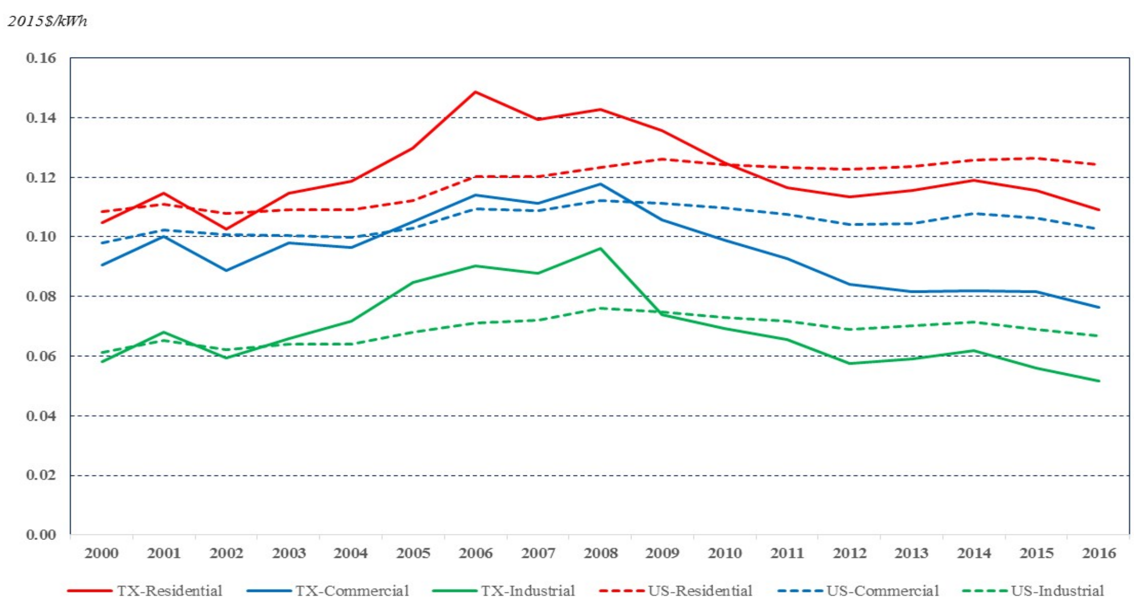
competitive areas generally pay higher rates than those in competitive areas. Commercial customers in non-competitive areas may thus be cross-subsidizing residential customers. Since commercial customers tend to have a lower price elasticity of demand, this may indicate that local load-serving entities in non-competitive areas are engaging in more price discrimination. However, if the cross-subsidies become large relative to the costs of onsite generation, such as the falling cost of (subsidized) solar power, commercial customers may install their own generating capabilities. In that case, residential rates may be forced to adjust upward so that the utility can cover its costs.

In Section II we provide background information on the Texas electricity market and reforms and discuss some relevant literature. Section III discusses the data and methodologies used in the analysis, while Section IV presents the results and explores their implications. Section V examines commercial sector electricity rates, before we summarize our conclusions in Section VI.

II. Background and Literature

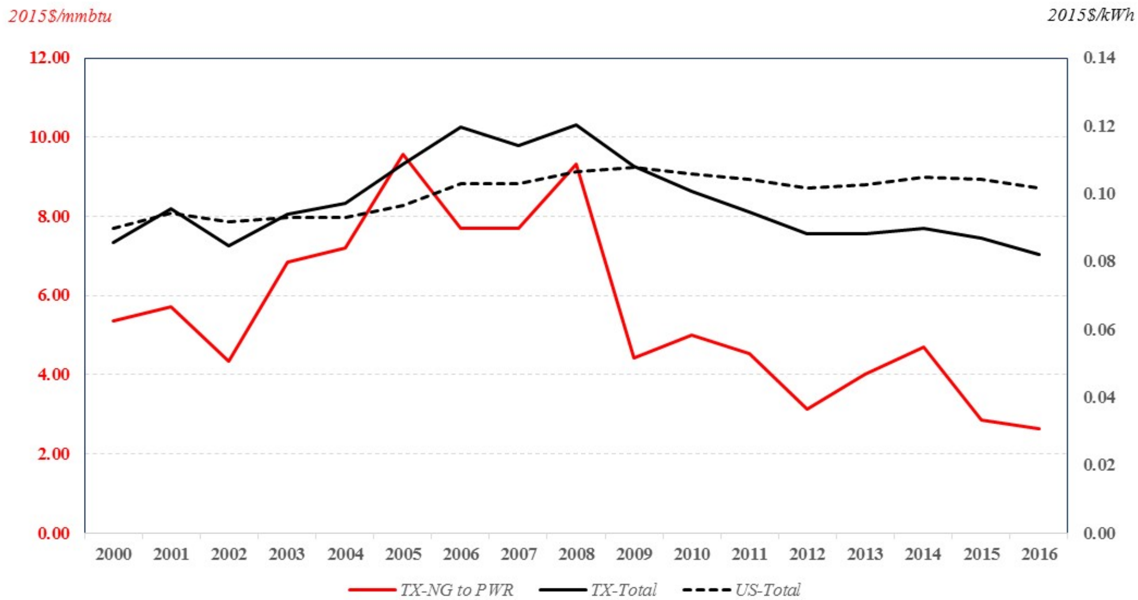
Texas consumers have historically enjoyed low retail electricity rates relative to national prices. An exception is the period from 2002 to 2010, when natural gas prices increased significantly before declining with the shale revolution. Notwithstanding volatility in energy markets, average electricity rates in Texas since 2000 across all sectors have been, on average, \$0.003/kWh lower than national rates (Energy Information Administration 2016), with variation across time and across major consuming sectors (Figure 1).

Figure 1. Real US and Texas Electricity Rates by Sector, 2000-2016



Source: Energy Information Administration

Figure 2. Real Electricity Rates and Natural Gas Prices in Texas, 2000-2016



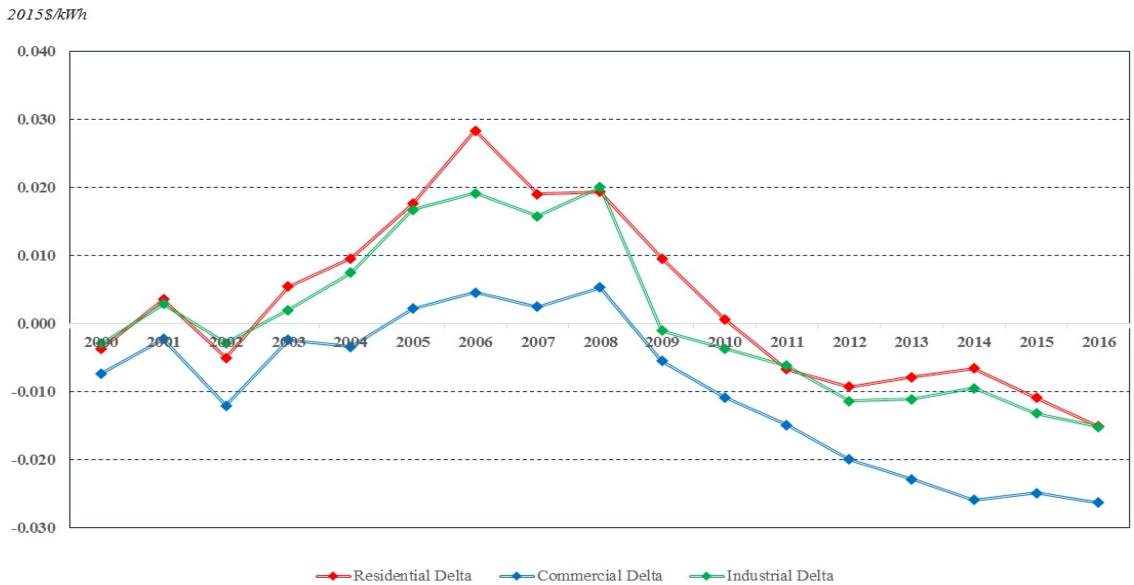
Source: Energy Information Administration

Over the same period, 2000-2016, the residential sector in Texas has averaged $0.003/kWh above national rates, while the commercial sector has averaged $0.010/kWh below the national average. The industrial sector average has kept virtual parity with the national rate.

Figure 2 shows that, for every sector, the temporal variation in Texas electricity prices is tied to movements in the price of natural gas. This reflects the fact that natural gas plants most often provide marginal generation in Texas. Across the nation, while there is considerable variation in regulatory regimes, there is also variation in the marginal fuel. This latter point is salient when comparing the movement of rates across time and across sectors. Indeed, when one considers the trends before and after 2008, when domestic natural gas prices peaked, simple averages comparing Texas relative to the rest of the US can be misleading. In fact, from 2009-2016 residential sector rates in Texas have averaged $0.006/kWh below national rates, commercial sector rates have averaged $0.019/kWh below national rates, and industrial sector rates have averaged $0.009/kWh below national rates. Moreover, in 2016, the discount for Texas consumers dipped to $0.015/kWh, $0.026/kWh, and $0.015/kWh in the residential, commercial, and industrial sectors, respectively. Thus, the discount for consumers in Texas has expanded over the last decade.

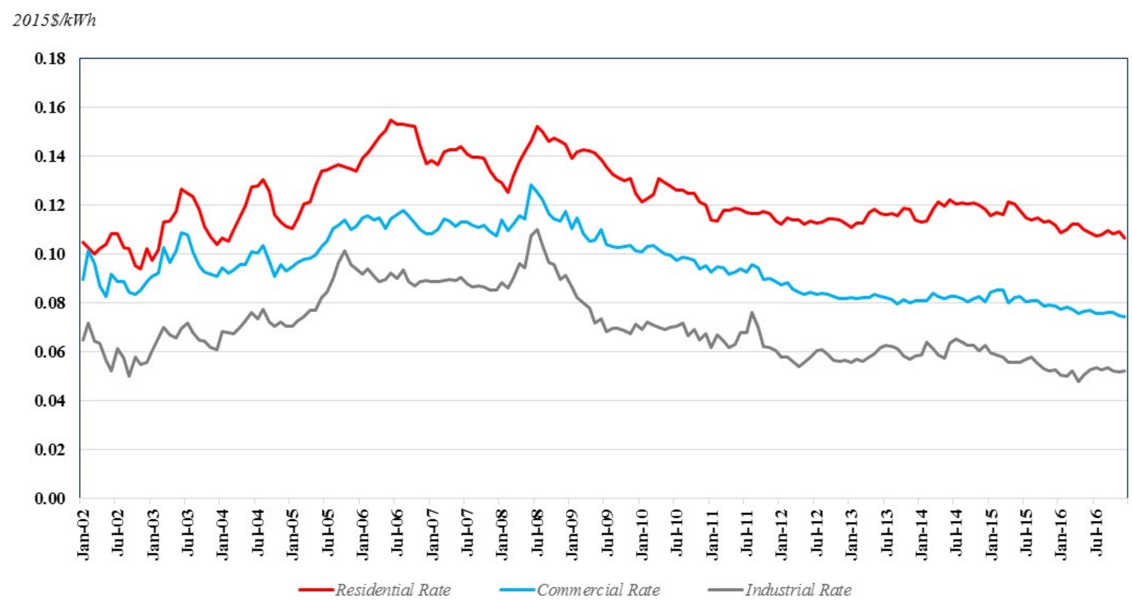
Figure 3 also shows that the differences between the US and Texas in residential and industrial electricity rates are quite different from the difference in commercial rates. Since only 20% of US electricity sales came from retail power marketers or retail energy providers as of 2015, the rate discrepancies are likely correlated to market structure. We return to this issue below.

Figure 3. Electricity Rate Differences–Texas Minus US, 2000-2016



Source: Energy Information Administration

Figure 4. Real Average Monthly Electricity Rates by Sector in Texas, Jan. 2002–Dec. 2016



Source: Energy Information Administration

Figure 4 graphs the inflation-adjusted (real) average retail rates across sectors in Texas by month. It shows that monthly rates to industrial and commercial consumers fell from the beginning of the sample to the end, while the residential rate is virtually flat. Rates generally increased from 2002 through 2006 before peaking in 2008, then declined thereafter. It is important to note electricity rates in real terms because the purchasing power of a dollar changed over the sample period for consumers and firms alike. Nominal price data examined over limited windows of time can give quite a different impression to the trends displayed in Figure 4. Such analyses have led to the observation that retail rates have increased faster in consumer choice areas compared to non-competitive market areas, with concomitant erroneous conclusions about the impact of competition in the marketplace.

There is extensive research examining the impact of deregulation and market restructuring on electricity rates. "Most studies conclude that there have been some efficiency gains [from restructuring of the electricity industry], but the subject of whether retail prices have fallen has been contentious" (Blumsack, Lave, and Apt 2008). Texas has been cited as an example with mixed post-restructuring results. As noted above, retail prices generally trended up more rapidly in competitive market areas than in non-competitive market areas from 2002 through 2006. Subsequently, retail rates tended to converge toward wholesale rates, indicating that competition was providing benefits by stimulating efficiency gains. To tease out the effects of restructuring per se, one needs to allow for other factors impacting prices in the Texas market at the same time.

Lower prices are the key benefit expected from market restructuring, but other intrinsic and extrinsic benefits are important when analyzing a policy. Previous studies have quantified some of the Texas-specific effects of market restructuring.[4] For instance, deregulation of the market resulted in increased diversity in generation mix (see, for example, Zarnikau 2011), achieved energy efficiency goals (see Zarnikau, Isser, and Martin 2015), and augmented a variety of value-added products and services (see Rai and Zarnikau 2016). Other benefits include increased consumer choice, innovative new products and services, customizable rates,[5] environmental benefits from increased renewable growth, and general market efficiency gains from competition.

A recent study conducted by the Texas Coalition for Affordable Power (TCAP 2016) shows that customers in areas exempt from deregulation have on average enjoyed lower residential rates compared to those in deregulated areas. The study also quantifies the hypothetical savings customers in deregulated areas would have enjoyed had they paid the average rates of regulated areas during the same period. Although the simplistic but objective finding that retail rates have on average been lower in regulated areas is an accurate observation, it ignores the path of prices over time and, thus, fails to identify the

[4] For an extensive list of consumer choice attributes see Goett, Hudson, and Train (2000) and for benefits and costs resulting from retail competition see Bae, et al. (2014) and Christensen Associates Energy Consulting LLC (2016).

[5] A complete list of retail energy providers, plans, and rates are available at the PUC website at www.powertochoose.com.

dynamic effects of the market reform in Texas. In particular, the study makes no attempt to assess whether rates were lower in the areas that remained regulated before the reforms were introduced, and how those rates have changed through time.

The tendency to measure the success of market restructuring in terms of retail rates may result from the tendency of policymakers and politicians to focus on the hoped-for outcomes from introducing competition as being most salient to voters. To examine this policy objective, Woo and Zarnikau (2009) develop a theoretical economic model to show that rate reduction following deregulation depends on post-reform marginal costs being below average costs. Besides pointing out post-reform failures in Ontario, California and other North American markets, the authors also note that the prerequisite assumption about the relationship between marginal and average costs has failed in Texas, specifically citing increasing natural gas prices.

Borenstein and Bushnell (2015) showed that natural gas prices have had a stronger effect on electricity rates in the US than restructuring efforts. Moreover, rates in restructured markets are dictated by marginal generation costs rather than average costs, and natural gas generators often are the marginal suppliers. By contrast, "cost-of-service" regulation tends to result in prices that reflect average costs, reducing the impact of natural gas prices and wholesale prices on retail rates. Thus, as markets continue to become more competitive, the price of electricity may be expected to move more with the natural gas price. On the other hand, other factors such as policies that internalize environmental costs and promote renewable integration may also take greater precedence over time.[6] While these factors will play out predominantly in wholesale markets, their impacts are relevant for retail price formation. Furthermore, how they manifest in retail prices will depend on market structure, in particular because wholesale prices in a competitive market reflect the marginal generation source, whatever it may be. Given the fact that natural gas is the fuel at the margin in the competitive wholesale market in Texas (ERCOT 2016), we implicitly account for natural gas price movements by including wholesale prices in the analysis.

In this study, we use 15+ years of monthly data to explore the evolving effects of market reform in Texas since January 2002. Over that time, ERCOT has progressed from a market transitioning to competition to one that is now relatively mature. Retail consumers have had ample opportunity to fully internalize the potential benefits of choice in provider. In addition, competition has expanded market depth and promoted firm-level efforts to lower costs through innovation and technology adoption.

Importantly, studies estimating post-reform electricity prices must account for price movements that resulted from multiple or phased regulatory interventions. In Texas, for example, it is possible that the periods from 2002 to 2005 and 2005 to 2007 could be impacted by market features such as a customer choice default to regulated rates and the "price-to-beat" program, respectively. Kang and Zarnikau (2009) prudently acknowledge

[6] For more information on the impact of the growth of renewables on electricity prices, please refer to Pfund and Chhabra (2015) and Tra (2016).

these effects. Specifically, by analyzing prices in Texas following the removal of the "price-to-beat" retail price caps they show that prices declined even though natural gas prices remained high during their study period.

This study uses Texas electricity price data across competitive and non-competitive market areas to focus on competitive retail electricity markets. Papers using a related approach include Joskow (2000) and Hortaçsu, et al. (2015). Similar to Borenstein and Bushnell (2015), we also examine post-reform price trends.

A note on price-taking (competitive) retail electricity providers

Consider a firm that sells electricity, q_j, to consumers in sector j at a price, p_j, and is a price-taker. It can generate its own power,[7] q_o, or purchase power in the wholesale market, q_w, to meet its customer service obligations. It will pay a price in the wholesale market given as p_w and a transfer price to its own generators given as p_o. The firm also pays for transmission and distribution, given as $\tau(q)$, where total cost is dependent on the total amount of power it sells, q. In addition, the firm must cover all other costs of operations, denoted $w(q)$. This includes items such as labor and is also positively related to total electricity sales. Finally, the firm will seek to maximize profits from all electricity sales.

Hence, we can formulate this firm's problem as

$$\max_{q_j} \sum_{j=1}^{n} p_j q_j - \left(p_w q_w + p_o q_o + \tau(q) + w(q)\right)$$

subject to

$$q = \sum_{j=1}^{n} q_j = q_w + q_o$$

$$q_j, q_w, q_o, \tau, w \geq 0$$

Noting that $q_w = \sum_{j=1}^{n} q_j - q_o$, we can find our first order necessary conditions for an interior

maximum as

$$\frac{\partial \pi}{\partial q_j} = p_j - p_w - \frac{\partial \tau}{\partial q_j} - \frac{\partial w}{\partial q_j} = 0 \quad \forall \quad j$$

[7] While many of the firms supplying retail electricity in Texas do not generate their own power—indeed separating these functions is a key part of the reform process—some vertically integrated firms remain.

and

$$\frac{\partial \pi}{\partial q_o} = -p_w + p_o = 0.$$

Notice, this implies

$$p_j = p_w + \frac{\partial \tau}{\partial q_j} + \frac{\partial w}{\partial q_j} \quad \text{and} \quad p_w = p_o.$$

In other words, the firm will set the retail price equal to the price of power purchased in the wholesale market plus the marginal cost of operations. Moreover, it will balance delivery between its own generation sources and the wholesale market such that the price at the margin will be the same across generation sources. If the firm does not own any generation resources, then the problem simplifies to one in which $q = q_w$. Similarly, if the firm does not purchase power from the wholesale market, we have $q = q_o$.[8]

The above example illustrates that for the price-taking firm in a competitive retail market, the retail price to consumers in sector j, p_j, is a markup over the wholesale price, p_w.

The markup in the example above is given as $\frac{\partial \tau}{\partial q_j} + \frac{\partial w}{\partial q_j}$, which is a function of all distribution and operating costs the firm faces. Importantly, the firm may be able to lower its costs through reducing labor costs or transmission and distribution costs, although such investments are not explicit in this example. Such changes would lower the markup over time.

If the firm is not a price-taker or attempts to redistribute costs across consuming sectors, it may deviate from the example above. An example of this may be if the firm redistributes costs from sector j to sector k in order to satisfy a competing objective—perhaps by placing greater value on the surplus of residential consumers (and voters) than on the surplus of other customers.[9] The result would be a reduction in the markup for consumers in sector j with a compensating increase in the markup for consumers in sector k. Empirically, this would create a confounding effect for identifying the markup through time and could even mask the relevance of the wholesale price of power for retail rates in sector j.

[8] For the firms in our analysis from the state of Texas, the latter case is never true. Since our focus is the retail market, we ignore the choice of generation in this paper and assume that firms take wholesale prices as given.

[9] An example of this is seen in Hartley and Medlock (2008). They noted that competing objectives for state-owned enterprises (SOEs) interfered with a revenue-efficient outcome. Although SOEs were still assumed to be maximizing an objective, that objective included factors other than profit as a result of political influence.

In addition, in non-competitive areas where the incumbent utility holds a monopoly position, rate-making may be based on an entirely different model, such as cost-of-service. In such cases, an annual revenue target can be modeled as the sum of

- a regulated return on undepreciated capital, plus
- depreciation expenses, plus
- operating expenses such as labor, maintenance, and fuel, plus
- tax liabilities.

Price is then determined by effectively allocating revenue requirements across customers. In these cases, the vertically integrated structure of the utility can render the above model of a price-taking firm invalid because retail pricing is also dependent on the activities of the utility in the generation of electricity. By guaranteeing a rate of return on expended capital, the utility can be incentivized to expand its generation portfolio and roll its purchases from the wholesale market into its rate base. This would distort the influence of the wholesale price on the retail price, reduce the firm's incentive to improve efficiency, and encourage it to expand its rate base. If true, we would not see evidence of cost reductions over time, a point to which we return below.

III. Data and Methodology

The data used in the empirical analysis are taken from ERCOT, the Texas Public Utilities Commission, the US Bureau of Labor Statistics, the US Energy Information Administration, and the US Federal Reserve. We also have collected data under confidentiality from commercial consumers of power with facilities across the state of Texas in both non-competitive and competitive zones. All pricing and cost data are in real 2015$, using the US Consumer Price Index as a deflator.

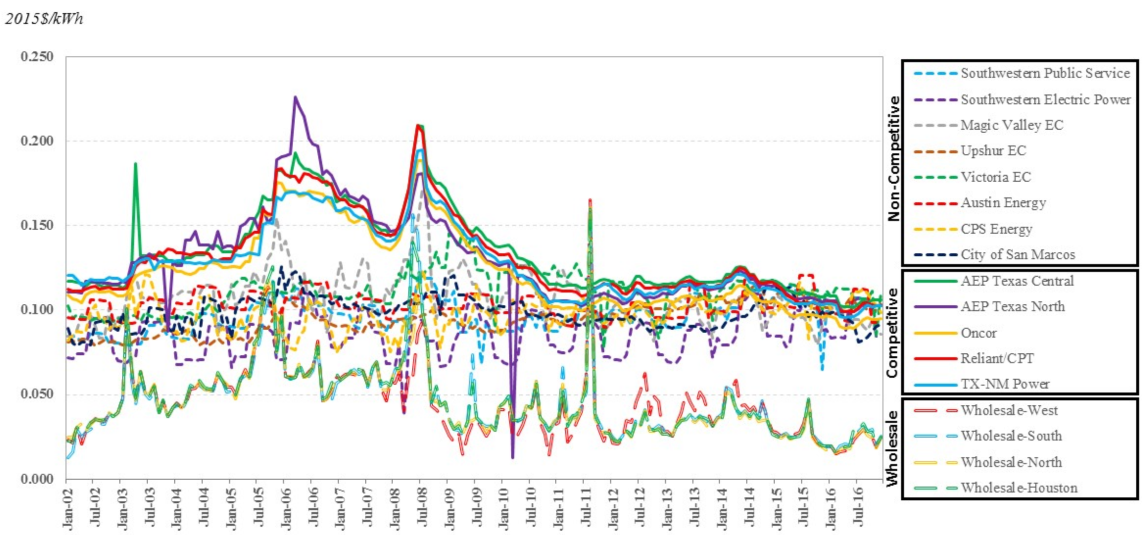
The monthly Electric Utility Bill Comparison published by the Rate Regulation Division of the Public Utility Commission of Texas (PUC 2017) gives aggregated residential electricity bill data for competitive and non-competitive areas for the years 2002 through 2016. The billing data for each residential customer grouping (at 500kWh and 1000kWh, respectively) was normalized by the load classification. This provides an effective average rate for electricity to each customer group, which is plotted in Figures 5 and 6 for the 1000kWh customer group.[10] These data are used throughout the analysis. Importantly, the rates, constructed in this manner, should be viewed as representative because the actual load in the different customer categories may not be exactly 500kWh or 1000kWh. Moreover, the billing data include non-commodity costs, such as fees for various services. Unfortunately, individual customer data is not available.

The data considered in this study are from eight non-competitive market areas—Southwestern Public Service (SWPS), Southwestern Electric Power (SWEP), Magic Valley EC, Upshur EC, Victoria EC, Austin Energy, CPS Energy, the City of San Marcos—and five

[10] Note that renormalizing the bills by a constant does not alter the conclusions of the statistical analysis.

competitive market areas—AEP Texas Central, AEP Texas South, Oncor, Reliant/CenterPoint, and Texas-New Mexico Power. In the non-competitive market areas, SWPS and SWEP are investor-owned utilities; Magic Valley EC, Upshur EC, and Victoria EC are electricity cooperatives; and Austin Energy, CPS Energy, and the City of San Marcos are municipally-owned utilities.[11] To construct a complete time series in the competitive areas, the reported data series were merged to allow for ownership changes over time. Specifically, the data for TXU was linked with data for Oncor as of May 2007; data for Reliant was linked to data for CenterPoint; Central Power and Light was linked with AEP Texas Central; and West Texas Utilities was linked with AEP Texas North as of July 2006. The resulting time series are presented graphically in Figures 5 (monthly) and 6 (annual averages), together with four zonal wholesale price series.

Figure 5: Monthly Residential Electricity Rates (1000kWh load, 2015$) and Wholesale Electricity Prices (2015$), Jan. 2002-Dec. 2016



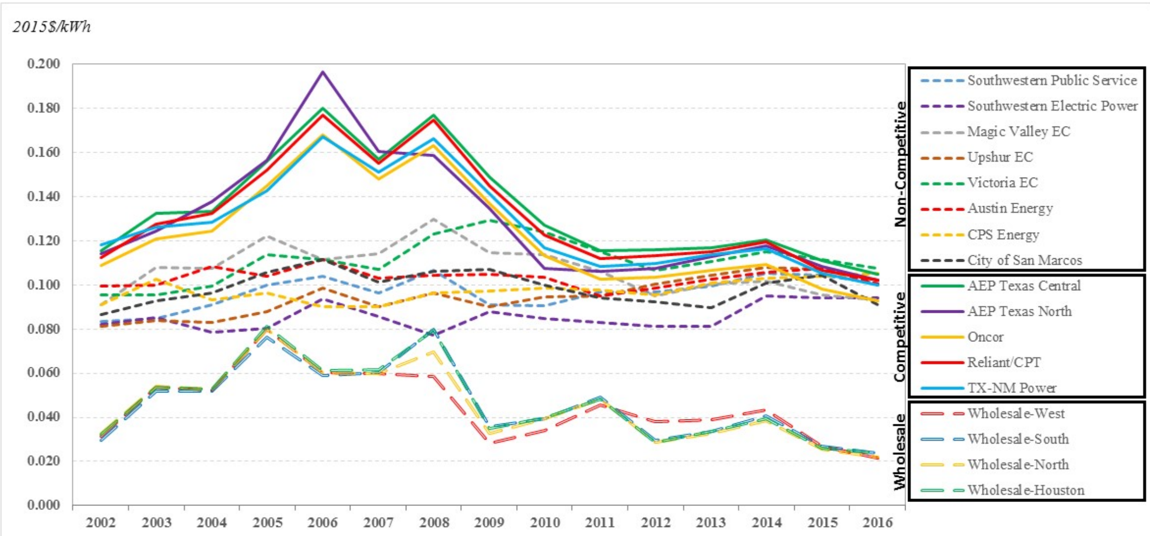
Data Sources: Nominal data collected from the Texas PUC and ERCOT and converted to real 2015$ using the US Consumer Price Index from the US Federal Reserve Database.

The ERCOT wholesale electricity price from the beginning of January 2002 through the end of November 2010 is reported as zonal 15-minute prices and obtained from the Balancing Market Prices for Energy and Resource archived datasets of the Electric Reliability Council of Texas. ERCOT wholesale prices from the beginning of December 2010 until the end of December 2016 are reported as nodal hourly day-ahead market prices and are obtained from the Day-Ahead Market Information portal of the Electric

[11] While there are more non-competitive market areas than those included in this analysis, the time series data are incomplete. Notably, Pedernales EC, one of the largest electricity cooperatives in the nation, is not included in this analysis for this reason. We also opted to use data for those areas that lie within ERCOT so that the wholesale prices remain relevant for the retail pricing in each region.

Reliability Council of Texas. The two wholesale price series are merged to create the time series of zonal wholesale prices used in the analysis.

Figure 6. Annual Residential Electricity Rates (1000kWh load, 2015$) and Wholesale Electricity Prices (2015$), 2002-2016*



Data Sources: Nominal data collected from the Texas PUC and ERCOT and converted to real 2015$ using the US Consumer Price Index from the US Federal Reserve Database.

*Note the data are annual averages so do not depict the seasonality in rates in some non-competitive areas that is apparent in Figure 5.

The annual data in Figure 6 are presented for illustrative purposes only, but they do reveal some insights obtained from the statistical analysis of the monthly data below. To begin, the annual data indicate residential prices closely track wholesale prices in the competitive market areas, but generally do not in non-competitive areas. The data also indicate that residential rates were lower in competitive areas in 2016 than in 2002, but higher in non-competitive areas. In other words, (real) prices have generally declined since 2002 in competitive areas but increased in non-competitive areas. Of course, the rates to residential customers rose significantly in competitive areas relative to non-competitive areas through 2006 before beginning to track downward after 2008. This tends to match closely the patterns observed in wholesale prices, which, as discussed above, tended to track natural gas prices.

The second observation from Figure 6 is that while the gap between retail and wholesale rates has declined over the time horizon in competitive areas, it has generally widened in non-competitive areas. This indicates competition is driving the costs of providing electricity service down in competitive areas.

To further highlight these points, Table 1 presents some summary statistics for the data considered in this study. A few things from Table 1 and Figures 5 and 6 are worth highlighting and reiterating:

- The average rate paid for electricity by residential consumers in competitive areas has been higher than that paid by residential consumers in non-competitive areas.
- In 2002, the average price paid by residential customers in competitive areas was between two and three cents higher than the rates paid in non-competitive areas. This is before market reforms and retail competition could have had a material impact on the price paid by residential customers.
- In 2016, the average price paid by residential customers in competitive areas was roughly equal, in aggregate, to the average price paid in non-competitive areas, with some competitive areas actually seeing rates below those in non-competitive areas. In fact, in all competitive areas prices declined from 2002 to 2016, but they increased in non-competitive areas over the same time period.
- Wholesale prices declined from 2002 to 2016, which is generally consistent with trends observed in natural gas markets in Texas and across the country (not pictured).
- The declines in residential prices in competitive areas from 2002 to 2016 were generally larger than the declines in wholesale prices, which is consistent with efficiency gains and associated cost reductions in the competitive market.
- The volatility of residential prices (measured by standard deviation) in competitive areas has been higher than in non-competitive areas. Moreover, price volatility in competitive areas has generally mirrored wholesale price volatility in competitive areas, but the same is not true in non-competitive areas.
- The changes in wholesale and residential prices from 2002 to 2016, and the patterns of volatility in the price series, support the notion that residential prices better reflect wholesale prices in competitive areas. This result is consistent with electricity service providers acting in a competitive market and suggests that competitive markets have delivered what was intended.

While much insight can be gleaned from the summary statistics in Table 1, it is important to evaluate the data more rigorously. Therefore, to investigate the effects of market reform on price formation at the retail residential level, we estimate a model that stipulates the retail rate for residential customers is a function of the wholesale market rate and labor cost in the electric utility industry. We also account for a variety of other effects, summarized as:

- Regular seasonal influences on residential price relative to wholesale price are captured through monthly dummy variables;
- In several utility regions dominated by electricity cooperatives, infrequent periods of extremely low rates—occurring at most six times in a single utility region during the 15-year period under consideration—were observed, perhaps due to rate promotions or other marketing mechanisms;

- Finally, the "price-to-beat" mechanism is identified with a dummy variable that takes a value of one prior to January 2007 and zero thereafter. Similarly, a time variable is also introduced for the period prior to January 2007 and the period after to account for any tendency of the retail rate to drift relative to the wholesale rate during the different periods. (Note that this also accounts for the aforementioned criticism levied in Kang and Zarnikau [2009] regarding studies that focus on the period prior to 2007.)

Table 1. Summary Statistics of Data Presented in Figure 5

		Sample Average (Jan02-Dec16)	Std Deviation (Jan02-Dec16)	2002 Average	2016 Average	Rate Change (2002-2016)
Non-Competitive	SWPS	0.0967	0.0099	0.0835	0.1007	0.0171
	SWEP	0.0856	0.0127	0.0823	0.0942	0.0119
	Magic Valley	0.1069	0.0155	0.0910	0.0933	0.0023
	Upshur	0.0948	0.0090	0.0814	0.1021	0.0208
	Victoria	0.1110	0.0117	0.0957	0.1077	0.0120
	Austin Energy	0.1032	0.0074	0.0993	0.1005	0.0013
	CPS	0.0975	0.0095	0.0910	0.1055	0.0145
	San Marcos	0.0986	0.0093	0.0867	0.0912	0.0045
Competitive	AEP-CTX	0.1341	0.0250	0.1155	0.1047	-0.0108
	AEP-NTX	0.1297	0.0288	0.1143	0.1019	-0.0124
	Oncor	0.1228	0.0243	0.1090	0.0930	-0.0161
	Reliant/CPT	0.1311	0.0247	0.1125	0.1021	-0.0104
	TX-NM	0.1275	0.0220	0.1182	0.1000	-0.0182
Wholesale	Wholesale-West	0.0449	0.0214	0.0315	0.0216	-0.0099
	Wholesale-South	0.0459	0.0232	0.0294	0.0239	-0.0055
	Wholesale-North	0.0452	0.0217	0.0329	0.0219	-0.0110
	Wholesale-Houston	0.0464	0.0234	0.0323	0.0237	-0.0086

Data Sources: Nominal data collected from the Texas PUC and ERCOT and converted to real 2015$ using the US Consumer Price Index from the US Federal Reserve Database. Calculations by authors.

We also considered accounting for the development, through 2013, of the competitive renewable energy zones' (CREZ) transmission capacity to connect wind energy resources in West Texas to load centers in Central and East Texas.[12] However, any cost impacts from the CREZ transmission infrastructure should be captured in wholesale prices. In fact, the impacts not only of transmission upgrades but also new generation capacity anywhere in ERCOT should be reflected in the wholesale electricity rates.

[12] In 2005, the Texas Legislature mandated the Texas PUC to work with ERCOT in identifying areas with the greatest wind generation potential. Those regions—totaling five across West Texas and the Panhandle—were designated as the CREZ. Subsequently, transmission plans were developed to deliver the electricity generated in those areas to load centers in Central and East Texas. The plan included about 2,400 miles of new transmission lines at a cost of about $7 billion, and was completed in 2013.

As noted above, in the competitive case where the firm is a price-taker, the retail price should be a function of the wholesale price, the cost of transmission and distribution, and any other firm-specific operating costs. As such, we estimate for each region *i* the following equation:

$$p_{t,i}^{res} = \alpha_0 + \alpha_1 p_{t-1,i}^{res} + \alpha_2 p_{t,i}^{w} + \alpha_3 w_{t,i} + \alpha_4 D^{pb} + \alpha_5 t_1 + \alpha_6 t_2 + \alpha_{7\to 17} D^m + \alpha_{18\to k} D_i^{pro} + \varepsilon_{t,i}\,.$$

The included variables (prices and wages in real terms) are defined as follows:

- $p_{t,i}^{res}$ denotes the residential electricity rate in region *i* at time *t*,
- $p_{t,i}^{w}$ denotes the wholesale electricity rate in region *i* at time *t*,
- $w_{t,i}$ denotes the labor rate in region *i* at time *t*,
- t_1 denotes the time trend from January 2002 through December 2006,
- t_2 denotes the time trend from January 2007 through December 2016,
- D^{pb} is the "price- to-beat" dummy variable that takes a value of one for all dates prior to January 2007 and zero thereafter,
- D^m is a vector of monthly dummy variables capturing seasonal variation, and
- D_i^{pro} is a dummy variable specific to region *i* (some regions only) that takes a value of one if very low outlier rates are observed in region *i*, perhaps due to promotions or rebates, and is zero otherwise.

Lastly, α_n are the coefficients to be estimated and $\varepsilon_{t,i}$ is an error term. We estimate the above equation for each region simultaneously using the seemingly unrelated regression (SUR) estimator, which accounts for correlation in the error terms across equations.[13]

We expect, *a priori*, that a firm acting as a price-taker will be adequately described by the above estimated equation. However, a firm in a non-competitive region will likely price its electricity sales differently as it may maximize an alternative objective function including as arguments, for example, rents on its own generation resources or political support for its politician monitors. In that case, the above estimated equation may not adequately describe the pricing behavior of firms in non-competitive areas.

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[13] Ordinary least squares (OLS) on each individual equation yields consistent parameter estimates, but SUR is more efficient. We expect the error terms to be contemporaneously correlated since some explanatory variables omitted from the equation may affect many regions at the same time. SUR and OLS are equivalent when the OLS error terms are uncorrelated across equations or when each equation contains the exact same regressors.

IV. Results

Table 2 gives parameter estimates for the above model.[14] Note that Table 2 presents the results for the residential sector for consumers with a greater than 1000kWh load. The results for the 500kWh consumers are included in an appendix, but, aside from the constant term in the regression, are not very different from the results in Table 2. The difference in the estimated constant term for the two categories of customers suggests that residential consumers across the entire state face block declining rates, but the lack of difference among the other parameters suggests relative price movements are consistent across residential customer classes within each utility area.

The parameter estimates indicate strong similarities across competitive areas. In fact, estimates of the effects of wholesale prices, labor costs, the price-to-beat mechanism, observed efficiency gains, and path dependence for residential prices are all very uniform. Moreover, there appears to be little regular seasonal influence on pricing that is not already accounted for in the wholesale market.

By contrast, the results indicate that non-competitive areas vary significantly from each other and from competitive areas. In general, pricing in non-competitive areas does not tend to conform to the model of a price-taking firm presented in the previous section. Indeed, in some non-competitive areas, confounding effects mask any statistically significant relationship between retail price and wholesale price.

Regarding the influence of each variable, we begin by noting that lagged residential price was highly significant in every case. This indicates a strong path dependency in retail price formation. No other estimated parameter was highly significant in all regions.

As for wholesale price effects, only three non-competitive regions—SWPS, Magic Valley, and CPS—showed a positive statistically significant influence of the wholesale price on residential price. The parameter estimate on wholesale price for Austin Energy was statistically significant but negative, thereby indicating a major inconsistency with the paradigm of a price-taking electricity provider. Residential prices in the remaining non-competitive regions—SWEP, Upshur, Victoria, and San Marcos—yielded no statistically significant influence of wholesale price. All the competitive regions in the sample—AEP-CTX, AEP-NTX, Oncor, Reliant/CPT, and TX-NM—revealed a positive and statistically significant influence of wholesale prices on residential rates.

[14] Data diagnostic testing was also performed. Augmented Dickey Fuller tests for unit roots indicated that each of the included time series variables—real residential rates, real wholesale rates, and real labor rates— is stationary (results available upon request). We also considered pooling the data and estimating a panel, but the data fails hypothesis testing of poolability. This is discussed in the text.

Labor rates were positive and statistically significant in all the competitive regions, but in only one non-competitive region—SWEP—while being negative and significant in another—CPS. Again, this provides evidence that electricity providers in competitive market areas are behaving exactly as predicted by economic theory, while electricity providers in non-competitive market areas conform to an alternative paradigm. In short, market reform appears to be delivering what was anticipated in competitive market areas.

The impact of the "price-to-beat" mechanism was estimated as a three-pronged effect in order to capture any effects it may have had on pricing until January 2007 and thereafter. In the competitive market areas, the statistically significant parameter estimate for the dummy variable, D^{pb}, indicates that the price-to-beat mechanism reduced the residential price for a given wholesale price and labor rate. However, the positive and statistically significant slope parameter on the time trend, t_1, indicates that residential rates were generally increasing relative to wholesale rates and labor rates from January 2002 through December 2006. Given the fact that wholesale power prices were increasing over this period, the implication is that residential rates were actually increasing faster than wholesale rates during this time. However, after January 2007 the paradigm shifted in a statistically significant way. Namely, the negative and statistically significant coefficient on the time trend for January 2007 through December 2016, t_2, indicates that the residential price in competitive areas was declining relative to wholesale price and the labor rate. Given the fact that wholesale rates were declining over this period, the implication is that residential rates were falling faster. This result is consistent with electricity service providers experiencing cost reductions in dimensions other than the wholesale cost of electricity.

In the non-competitive areas, by contrast, the parameter estimates on D^{pb}, t_1, and t_2 are inconsistent across regions. For example, in SWPS, SWEP, Upshur, and San Marcos, the only statistically significant parameter estimate is on the time trends, and the parameters are positive. This indicates that residential prices in these areas generally increased relative to the wholesale price of power and labor costs throughout the time period under consideration. Since these entities own generating assets, some of this could be related to increased power purchases from the wholesale market. This could happen, for example, if the average cost of the entity's generation resources is lower than the cost of the marginal resource available in the wholesale market. As previously noted, the TCAP analysis suggested that increasing transmission costs over time could also explain the divergence between retail price and costs, although it is not clear why such an effect would be restricted to non-competitive markets. The exact explanation remains a matter of conjecture since data to test competing hypotheses was not available.

The remaining non-competitive regions—Magic Valley, Victoria, and Austin Energy—are similar to the competitive market areas with regard to the parameter estimates on D^{pb}, t_1, and t_2, with Magic Valley exhibiting the same patterns revealed by the competitive areas. Victoria and Austin Energy have patterns similar to those exhibited in competitive areas until January 2007, but neither shows statistically significant evidence of residential price reductions relative to wholesale price and labor rates after January 2007. Thus, the same type of cost reduction evidenced for competitive areas is not revealed in the analysis for Victoria and Austin Energy. Lastly, the patterns for the estimated coefficients for CPS stand in stark contrast to the other regions, again indicating a very different paradigm at work in that market area.

The seasonal patterns are most statistically relevant for residential pricing in non-competitive areas. There is statistically significant evidence that residential prices are increased relative to wholesale prices in SWPS, SWEP, Austin Energy, and CPS during the summer months. This may be due to congestion constraints internal to these market areas. However, it also could be the result of price discrimination during high demand periods. Again, the data required to assess such competing hypotheses is not currently available.

In Magic Valley, Upshur, Victoria, and San Marcos, the data indicate that residential rates actually decline relative to wholesale prices during summer months.[15] Given there is some seasonality in wholesale price—it tends to rise in high demand months—this may be the result of price smoothing in these regions. In other words, residential rates generally do not fall during summer months; rather, they do not rise as much as wholesale price in high demand periods (so they fall *relative* to wholesale price). Lastly, in competitive market areas there is little evidence of seasonal effects, with different months—ranging from April to August—revealing any statistically significant influence on residential prices in some regions. This is consistent with the result that wholesale price movements capture seasonality in competitive markets, which is simply passed on to consumers. This is reinforced by the positive statistically significant relationships estimated between wholesale and residential prices across all competitive market areas.

A caveat for the analysis herein is that residents of areas with lower population density, for example in West Texas and South Texas, may see a greater portion of their bills reflect grid maintenance costs since grid costs *per customer* would be higher. This could reduce the influence of the wholesale price on residential rates, even in competitive areas. While this does not appear to be of concern in competitive areas, it may present an issue in non-competitive areas, especially rural cooperatives.

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[15] San Marcos reveals a statistically significant relationship in only one month, May, while Upshur does in two months, Victoria in four months, and Magic Valley in every month. Importantly, peak demand months during the summer time show up as statistically significant in Upshur (August) and Victoria (July, August, and September).

Table 2. Parameter Estimates (1000kWh Customers)

		Non-Competitive Regions								Competitive Regions				
Variable	**Parameter**	**SWPS**	**SWEP**	**Magic Valley**	**Upshur**	**Victoria**	**Austin Energy**	**CPS**	**San Marcos**	**AEP-CTX**	**AEP-NTX**	**Oncor**	**Reliant/CPT**	**TX-NM**
Constant	α_0	0.010878	-0.003829	0.086885	0.007998	0.056994	0.050135	0.083617	0.022316	-0.004216	-0.018176	-0.012130	-0.008362	-0.013392
	std err	0.010557	0.013368	0.019734	0.005381	0.013420	0.010509	0.014705	0.011846	0.016782	0.029089	0.008187	0.009170	0.008713
$L.p^{res}$	α_1	0.689333	0.574643	0.496620	0.871785	0.703378	0.479151	0.275170	0.837823	0.817673	0.640333	0.859447	0.853703	0.884540
	std err	0.027846	0.036824	0.039190	0.023004	0.026420	0.045629	0.049503	0.027058	0.016644	0.028641	0.012854	0.013172	0.013180
p^w	α_2	0.033535	-0.021604	0.178873	0.012773	0.006654	-0.040879	0.085994	0.013307	0.044858	0.072210	0.065241	0.060644	0.060832
	std err	0.018891	0.024426	0.031585	0.009910	0.020097	0.015916	0.022468	0.018986	0.024927	0.041491	0.011457	0.011300	0.011729
w	α_3	0.000008	0.000016	-0.000014	0.000001	-0.000010	0.000003	-0.000018	-0.000003	0.000019	0.000041	0.000017	0.000016	0.000016
	std err	0.000006	0.000007	0.000010	0.000003	0.000007	0.000005	0.000007	0.000006	0.000009	0.000016	0.000005	0.000005	0.000005
D^{pb}	α_4	-0.001950	0.000988	-0.014228	0.000343	-0.011549	-0.004110	0.011229	-0.003460	-0.011390	-0.020354	-0.006340	-0.007383	-0.004440
	std err	0.001940	0.002465	0.003847	0.000992	0.002590	0.001846	0.002617	0.002305	0.003428	0.005672	0.001827	0.002012	0.001830
t_1	α_5	0.000121	0.000084	0.000137	0.000029	0.000127	0.000148	-0.000103	0.000076	0.000194	0.000489	0.000123	0.000143	0.000076
	std err	0.000036	0.000043	0.000062	0.000019	0.000041	0.000033	0.000043	0.000040	0.000057	0.000104	0.000030	0.000033	0.000030
t_2	α_6	0.000030	0.000021	-0.000067	0.000023	-0.000013	-0.000013	0.000122	-0.000009	-0.000092	-0.000169	-0.000060	-0.000063	-0.000049
	std err	0.000013	0.000017	0.000025	0.000008	0.000016	0.000012	0.000019	0.000015	0.000023	0.000038	0.000012	0.000013	0.000012
Feb	α_7	0.000284	0.006678	-0.006330	-0.000631	-0.000982	-0.000629	0.001349	-0.001459	0.000405	-0.000214	-0.000095	0.000812	0.000007
	std err	0.001528	0.001913	0.002704	0.000766	0.001785	0.001406	0.001969	0.001702	0.002448	0.004224	0.001195	0.001333	0.001272
Mar	α_8	-0.000130	0.005011	-0.004392	-0.000481	-0.001182	-0.000861	0.005487	-0.000600	0.001916	-0.003404	-0.000093	0.000357	-0.000578
	std err	0.001525	0.001929	0.002699	0.000765	0.001784	0.001404	0.001968	0.001700	0.002445	0.004218	0.001194	0.001332	0.001271
Apr	α_9	-0.000346	0.007579	-0.004104	-0.000556	0.000854	-0.001196	0.003083	0.000016	0.005061	0.005803	0.000659	0.001266	0.000028
	std err	0.001526	0.001907	0.002701	0.000765	0.001784	0.001404	0.001990	0.001700	0.002445	0.004220	0.001194	0.001333	0.001271
May	α_{10}	-0.000526	0.020898	-0.004583	-0.000045	-0.002319	0.005911	0.004717	-0.003485	-0.001741	0.002491	0.001633	0.002327	0.001153
	std err	0.001527	0.001903	0.002710	0.000765	0.001795	0.001408	0.001988	0.001706	0.002453	0.004221	0.001194	0.001335	0.001271
Jun	α_{11}	0.008315	0.013402	-0.006124	-0.000968	-0.001648	0.008380	0.013404	-0.002598	0.002173	0.000979	0.002696	0.001455	0.000798
	std err	0.001536	0.002008	0.002730	0.000768	0.001804	0.001454	0.002013	0.001719	0.002466	0.004242	0.001197	0.001339	0.001275
Jul	α_{12}	0.002246	0.013808	-0.005328	0.000464	-0.003355	0.005380	0.012098	0.001264	0.000973	0.000004	0.000104	0.000096	-0.000882
	std err	0.001550	0.002027	0.002714	0.000769	0.001791	0.001517	0.002131	0.001710	0.002452	0.004261	0.001198	0.001336	0.001278
Aug	α_{13}	0.000994	0.011045	-0.012466	-0.001221	-0.003795	0.005635	0.005679	-0.001738	-0.001368	-0.002252	-0.001300	-0.002081	-0.002686
	std err	0.001634	0.002103	0.002762	0.000792	0.001825	0.001547	0.002178	0.001741	0.002494	0.004404	0.001217	0.001354	0.001303
Sep	α_{14}	0.003988	0.011875	-0.010947	-0.000670	-0.003556	0.004756	0.007802	-0.001450	-0.001004	-0.003360	-0.000621	-0.000924	-0.000733
	std err	0.001533	0.002001	0.002693	0.000765	0.001782	0.001505	0.002058	0.001703	0.002447	0.004227	0.001195	0.001334	0.001273
Oct	α_{15}	-0.004860	0.010049	-0.014071	-0.000153	-0.002546	-0.001524	0.001247	-0.001054	-0.000441	-0.000649	-0.000388	-0.000483	-0.000436
	std err	0.001539	0.002000	0.002780	0.000765	0.001783	0.001501	0.002049	0.001705	0.002449	0.004229	0.001195	0.001335	0.001273
Nov	α_{16}	-0.001028	-0.003472	-0.006714	-0.001555	-0.000953	-0.004504	0.000969	-0.001522	0.000936	0.000547	0.001128	0.001681	0.000604
	std err	0.001525	0.001975	0.002672	0.000756	0.001950	0.001401	0.001960	0.001709	0.002418	0.004233	0.001181	0.001318	0.001257
Dec	α_{17}	0.002624	0.004591	-0.006597	-0.000269	0.003333	-0.001530	-0.000610	0.001506	-0.000839	0.000701	-0.000224	-0.000064	-0.000855
	std err	0.001558	0.001937	0.002739	0.000778	0.001823	0.001428	0.002003	0.001733	0.002488	0.004297	0.001215	0.001356	0.001293
	R^2	0.827	0.835	0.772	0.947	0.829	0.740	0.667	0.762	0.929	0.842	0.982	0.977	0.976

Note: Parameter values in gray are not statistically significant at a 10% level. Parameter values in blue are statistically significant at the 10% level, parameter values in red are statistically significant at the 5% level, and parameter values in black are statistically significant at the 1% level. Parameter estimates for the D_i^{pro} are not reported, but are significant at the 1% level and are available upon request.

It should be noted for completeness that we also considered other model specifications. For example, we considered a pooled approach using panel data, but the data across all market areas rejects poolability. Interestingly, the competitive market areas do not reject poolability when considered as a set independent of the non-competitive areas, suggesting competition drives retail rates to reflect wholesale rates, which themselves are driven by competition and regional arbitrage. In other words, pricing in the competitive areas appears to be driven by a common data-generating process—the wholesale market—whereas pricing in the non-competitive areas does not. Indeed, tests for pooling only the data in non-competitive areas indicated the data cannot be pooled, so panel analysis is inappropriate for non-competitive market areas.

V. A Note on Commercial Electricity

As mentioned above, we have begun collecting site-specific load and billing data from commercial electricity users in Texas.[16] Aggregate data from the Texas PUC is available for commercial and industrial electricity users in non-competitive areas, but we lacked similar information for those users in competitive areas. Moreover, the data reported by the PUC is in aggregate. More detailed consumer-specific information for large electricity users is valuable because it allows a direct comparison of load and billing for a homogeneous consumer and consumer groups across different market areas. The data indicated in Figure 7 represents over 760 locations across competitive and non-competitive market areas since January 2005. We are working to expand this dataset to include additional large commercial users, but some interesting insights are already emerging.

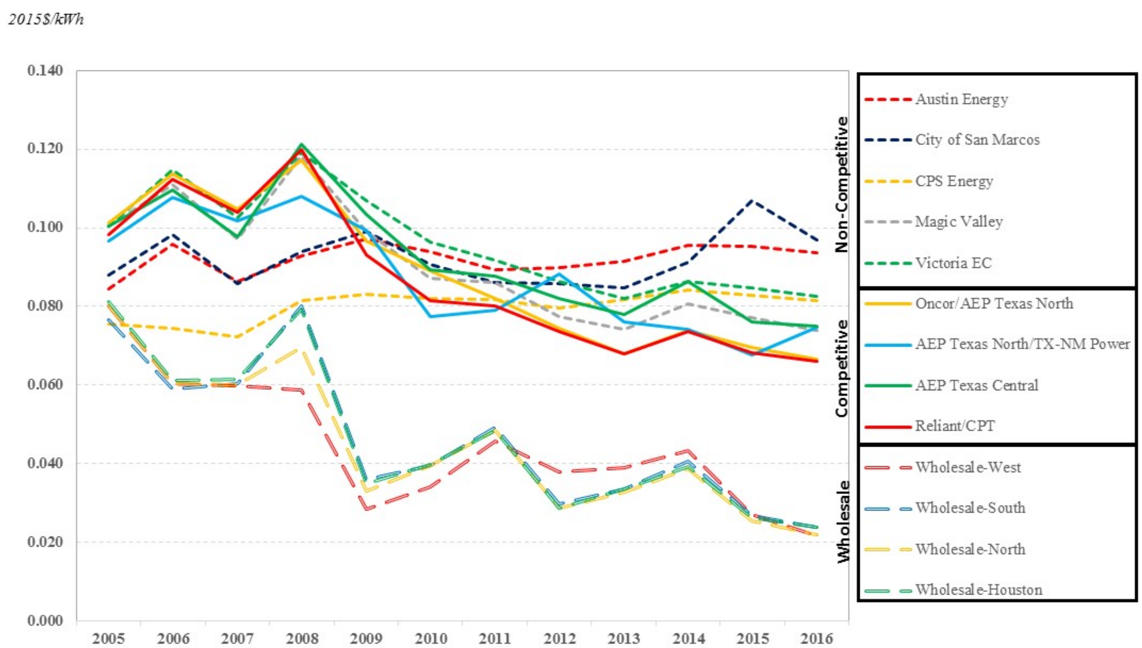
The site-specific load and billing data are collected from commercial users under a confidentiality agreement with Rice University. These data are used to calculate implied rates by location (bill divided by load), $p_{i,t}^{com}$, and then a weighted-average price for each region, $\overline{p}_{i,t}^{com}$, is calculated where the weight for each location is taken to be the share of regional load at a specific site, $\theta_{i,t}$. We then plot $\overline{p}_{i,t}^{com}$, calculated as $\overline{p}_{i,t}^{com} = \sum \theta_{i,t} p_{i,t}^{com}$, in Figure 7. For a quality check, we also compared the average price data for locations in non-competitive regions to data reported by the Texas PUC. The PUC data are area-wide regional aggregates whereas our data are for specific commercial customers in the market region, so they do not match exactly. Nevertheless, the annual averages match within half a cent in every year from 2005 through 2016.

We see in Figure 7 that there is generally less separation between the commercial rates in competitive and non-competitive market areas. However, the commercial rates in competitive market areas have followed a pattern similar to wholesale rates, while the same is not true in non-competitive areas. In fact, for the data we have collected to date,

[16] Note that the data collected is subject to a confidentiality agreement with Rice University. Hence, it cannot be distributed or shared.

commercial rates in competitive market areas have fallen relative to rates in non-competitive market areas, and are now generally lower.

Figure 7. Annual commercial electricity rates across market areas, 2005-2016*



Data sources: See text for description

*Commercial data for 2016 are incomplete, so year-to-date data is indicated. Also, note the data are annual averages so do not depict the seasonality in rates in some non-competitive areas.

Table 3 indicates some summary statistics for the data presented in Figure 7. Interestingly, we see that the commercial price in a couple of non-competitive market areas—Magic Valley and Victoria—is similar to the data for competitive market areas with regard to both volatilities and averages. This may indicate that those electricity cooperatives more closely model themselves after competitive electricity providers in an effort to attract a larger customer base.

We also see that since January 2005, the commercial rates for Austin Energy, CPS, and San Marcos have generally been less volatile than in other regions, but the rates have slightly increased through 2015 and are now higher across the board than rates in competitive market areas. Regarding competitive market areas, the general tendency for commercial customer rates has been to follow the wholesale market, which is similar to the outcome seen in the analysis of residential rates. Again, this is evidence that market reform has delivered exactly what was intended with regard to electricity pricing.

Table 3. Summary Statistics of Data Presented in Figure 7*

		Sample Average (Jan05-Dec15)	Std Deviation (Jan05-Dec15)	2005 Average	2015 Average	Rate Change (2005-2015)
Non-Competitive	Magic Valley	0.0917	0.0165	0.1005	0.0738	-0.0266
	Victoria	0.0974	0.0141	0.1003	0.0826	-0.0177
	Austin	0.0920	0.0045	0.0843	0.0935	0.0092
	CPS	0.0799	0.0070	0.0754	0.0814	0.0060
	San Marcos	0.0918	0.0090	0.0880	0.0969	0.0088
Competitive	AEP-NTX/TX-NM	0.0887	0.0181	0.0965	0.0747	-0.0218
	AEP-CTX	0.0938	0.0163	0.1003	0.0748	-0.0255
	Oncor/AEP-NTX	0.0900	0.0187	0.1013	0.0666	-0.0347
	Reliant/CPT	0.0884	0.0194	0.0981	0.0660	-0.0321
Wholesale	Wholesale-West	0.0467	0.0226	0.0801	0.0269	-0.0531
	Wholesale-South	0.0483	0.0249	0.0765	0.0269	-0.0496
	Wholesale-North	0.0469	0.0231	0.0800	0.0255	-0.0545
	Wholesale-Houston	0.0485	0.0252	0.0811	0.0262	-0.0549

Data sources: See text.

*Commercial data for 2016 are incomplete, so calculations through 2015 are reported.

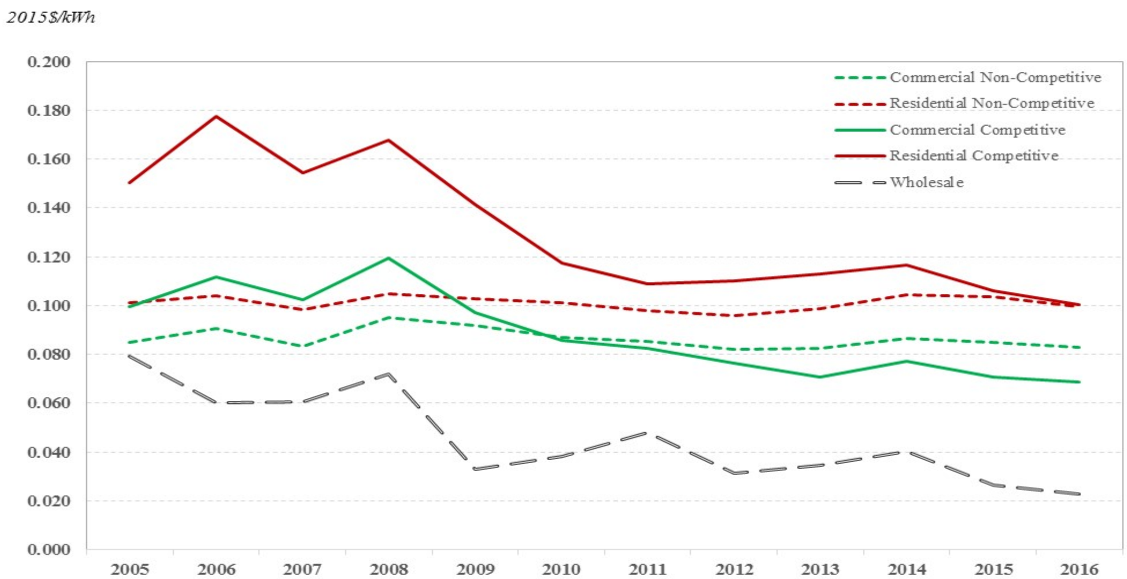
In Figure 8, we have graphed a composite price for commercial electricity for competitive and non-competitive market areas alongside a composite price for residential electricity for competitive and non-competitive market areas and a composite wholesale price. The composite prices are averages across market areas for the data in the sample. These are meant to be illustrative only. In particular, the data highlight an important point about relative pricing across sectors in competitive versus non-competitive areas. Namely, the spread between residential and commercial prices in non-competitive areas is much smaller than in competitive areas. Moreover, while residential rates across market areas have converged over the sample period (see above for more discussion), commercial rates have diverged, with those in competitive areas seeing a growing discount relative to non-competitive areas. Indeed, a similar phenomenon is observable on a national level (see Figures 1 through 3).

While there may be multiple explanations for the observations based on Figures 7 and 8, the data are consistent with a policy of cross-subsidizing residential customers with higher rates on commercial customers in non-competitive market areas. Such a policy is possible if a particular customer class has a lower elasticity of demand, meaning they are more subject to price discrimination with limited price responsiveness.[17] Such might be the case for commercial customers because relocating their business activities away from their customers or employees in response to a change in energy price can compromise the firm's economic model. Discriminatory pricing would be more likely in a regulated market

[17] For studies of cross-subsidization evidence between customer groups, see, for example, Steiner (2001), Hattori and Tsutsui (2004), and Erdogdu (2011). For studies of cross-subsidization between electricity sectors, see, for example, Eid, Guillén, Marín, and Hakvoort (2014), EEI (2013), and Pérez-Arriaga, et al. (2013).

area than in a competitive one because competition should force all electricity providers to charge prices that reflect the overall marginal cost of service.

Figure 8. Average Rates Across Sectors by Aggregate Market Area*



Data sources: See text for description

*Commercial data for 2016 are incomplete, so year-to-date data is indicated. Also, note that the data presented are the respective annual averages across all competitive and non-competitive areas. Therefore, the data are representative and do not capture seasonal variations in rates or the disparity in rates within the non-competitive areas in particular.

We are continuing to collect data from large commercial consumers across the state of Texas. Subsequent analysis will further evaluate the evidence that commercial users are being billed in a way that effectively cross-subsidizes residential users. It should be noted that while such a pricing policy may seem viable and perhaps even desired, particularly if residential consumer welfare is prioritized by the electricity service provider, it may be myopic as it ignores the adjustments that commercial entities can make. Specifically, while many commercial entities are not likely to relocate on the basis of higher electricity rates, they may be able to offset electricity costs through investments in on-site generation. As more commercial users are incentivized to move off grid, the local electricity service provider will be forced to raise rates to other customers in order to cover its costs. A cross-subsidized rate to residential customers thus may be unsustainable.

VI. Concluding Remarks

Passage of Senate Bill 7 in 1999 launched Texas electricity market reform, but substantive changes did not begin until 2002. The evolution of wholesale and retail electricity market prices since has been dynamic, but competition has yielded an outcome consistent with what economic theory predicts. Namely, retail prices have declined relative to wholesale prices in competitive market areas.

At the residential level, prices were much higher in competitive areas than in non-competitive areas when reforms were first implemented—but they have since fallen to a point of parity with non-competitive market areas. This outcome highlights the importance of evaluating market dynamics over time rather than focusing on sample averages. Thus, residential consumers in competitive areas paid a higher average price for electricity from January 2002 through December 2016 than did customers in non-competitive areas. But this fact masks the underlying trends that market reforms have wrought. While the average price paid by residential customers in 2002 in areas that subsequently became competitive was between two and three cents higher than the rates paid in areas that remained non-competitive, this was before competition could have had any impact. More importantly, residential prices declined in all competitive market areas from 2002 to 2016, while they increased in all non-competitive market areas over the same time period. As a result, by 2016, the average price paid by residential customers in some competitive market areas was lower than the average price paid in non-competitive market areas.

In addition, while wholesale electricity prices declined from 2002 to 2016, with a significant increase in the interim, the declines observed in residential prices in competitive market areas were generally larger than the declines in wholesale prices. This is consistent with a market in which competitive electricity service providers are realizing efficiency gains and cost reductions.

Overall, the changes in wholesale and residential prices from 2002 to 2016, and the patterns of volatility in the price series, support the notion that retail prices clearly reflect wholesale prices in competitive market areas. Indeed, the econometric analysis consistently indicated a positive and statistically significant relationship between wholesale price and residential price across competitive market areas. This suggests that allowing competition in markets has delivered the intended result.

We also found that trends in the commercial electricity billing and load data that have been collected to date reveal an outcome that is consistent with the analysis of residential price data. The relative prices between the commercial and residential sectors across competitive and non-competitive market areas also support the notion that competition forces electricity service providers toward pricing power at overall marginal cost. While commercial rates in competitive areas track wholesale prices, the evidence is mixed in non-competitive market areas. This reinforces the results from the analysis of residential prices that a lack of competition allows greater divergence between price and marginal cost. Furthermore, the differences between residential and commercial prices in the two types of areas is consistent with non-competitive suppliers exercising a degree of market power to redistribute from commercial to residential customers. In particular, the data reveal that price reductions for commercial customers in non-competitive market areas have not generally been forthcoming, despite the fact that wholesale prices have declined.

In sum, the data analyzed herein support the notion that prices have behaved exactly as economic theory would indicate in competitive market areas. There are still research questions to be addressed. For example, more research is needed to understand the objective of suppliers in non-competitive areas. Multiple hypotheses could explain the pricing paradigms we have observed. One obvious challenge is in data collection, since data on electricity loads, which are necessary when considering non-competitive markets, may not be readily available for each market area. We endeavor to address this and other questions by collecting data from large commercial users across the state of Texas, which will provide a unique opportunity to more rigorously evaluate how individual sites compare across market areas.

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Appendix

Table A1. Parameter Estimates (500kWh Customers)

		Non-Competitive Regions								Competitive Regions				
Variable	**Parameter**	**SWPS**	**SWEP**	**Magic Valley**	**Upshur**	**Victoria**	**Austin Energy**	**CPS**	**San Marcos**	**AEP-CTX**	**AEP-NTX**	**Oncor**	**Reliant/CPT**	**TX-NM**
Constant	α_0	0.010132	-0.001537	0.100811	0.010376	0.054471	0.032376	0.095389	0.022736	-0.002627	-0.015108	-0.008929	-0.002375	-0.014455
	std err	0.010650	0.011392	0.019593	0.005566	0.013912	0.007814	0.014863	0.011891	0.017024	0.028435	0.008427	0.009545	0.009155
$L.p^{res}$	α_1	0.693943	0.628157	0.497465	0.871766	0.729213	0.642903	0.249113	0.841873	0.818640	0.656834	0.860657	0.858541	0.885477
	std err	0.027867	0.034009	0.038881	0.022767	0.025879	0.035520	0.052596	0.026689	0.016717	0.027370	0.012515	0.013186	0.013093
p^w	α_2	0.032988	-0.016704	0.178157	0.011390	0.005295	-0.024162	0.071334	0.014786	0.046827	0.078676	0.064246	0.059423	0.061037
	std err	0.019086	0.020734	0.030669	0.010087	0.020780	0.012127	0.022022	0.019044	0.025409	0.050135	0.011566	0.011572	0.012213
w	α_3	0.000008	0.000016	-0.000017	0.000000	-0.000007	0.000001	-0.000021	-0.000002	0.000017	0.000037	0.000015	0.000012	0.000016
	std err	0.000006	0.000006	0.000010	0.000003	0.000007	0.000004	0.000007	0.000006	0.000009	0.000016	0.000005	0.000005	0.000005
D^{pb}	α_4	-0.000932	0.001820	-0.012131	0.000573	-0.010903	-0.002828	0.011471	-0.003531	-0.009137	-0.013787	-0.005158	-0.006043	-0.003138
	std err	0.001948	0.002099	0.003685	0.001011	0.002672	0.001401	0.002580	0.002323	0.003394	0.005385	0.001784	0.001988	0.001793
t_1	α_5	0.000115	0.000054	0.000121	0.000028	0.000125	0.000111	-0.000077	0.000079	0.000190	0.000442	0.000124	0.000127	0.000067
	std err	0.000036	0.000036	0.000060	0.000019	0.000043	0.000025	0.000043	0.000040	0.000058	0.000101	0.000030	0.000033	0.000031
t_2	α_6	0.000039	0.000015	-0.000048	0.000030	-0.000008	-0.000001	0.000147	-0.000009	-0.000064	-0.000106	-0.000044	-0.000042	-0.000031
	std err	0.000013	0.000014	0.000024	0.000008	0.000016	0.000009	0.000019	0.000015	0.000022	0.000035	0.000012	0.000013	0.000012
Feb	α_7	0.000498	0.006245	-0.006328	-0.000229	-0.001429	-0.000864	0.001464	-0.001454	0.000481	-0.000365	0.000153	0.000781	0.000357
	std err	0.001542	0.001619	0.002628	0.000779	0.001845	0.001069	0.001931	0.001707	0.002483	0.004130	0.001228	0.001382	0.001338
Mar	α_8	0.000017	0.004324	-0.004414	-0.000487	-0.001625	-0.001003	0.008015	-0.000622	0.001929	-0.003306	-0.000114	0.000237	-0.000325
	std err	0.001540	0.001635	0.002622	0.000779	0.001844	0.001067	0.001931	0.001705	0.002480	0.004124	0.001227	0.001382	0.001337
Apr	α_9	-0.000215	0.007054	-0.004151	-0.000571	0.000314	-0.001313	0.002914	-0.000023	0.005105	0.005261	0.000642	0.001256	0.000118
	std err	0.001540	0.001615	0.002625	0.000778	0.001844	0.001067	0.001981	0.001705	0.002480	0.004126	0.001227	0.001382	0.001337
May	α_{10}	-0.000359	0.016081	-0.004648	-0.000069	-0.002789	-0.001114	0.005487	-0.003567	-0.001632	0.002131	0.001766	0.001896	0.001230
	std err	0.001542	0.001614	0.002633	0.000778	0.001856	0.001070	0.001954	0.001711	0.002488	0.004127	0.001227	0.001384	0.001337
Jun	α_{11}	0.008353	0.008912	-0.006216	-0.000989	-0.002327	0.002638	0.006226	-0.002623	0.002107	0.000381	0.002284	0.001158	0.000982
	std err	0.001550	0.001684	0.002652	0.000782	0.001865	0.001078	0.001986	0.001725	0.002501	0.004147	0.001230	0.001388	0.001341
Jul	α_{12}	0.002276	0.010102	-0.005453	0.000508	-0.003955	0.000137	0.007052	0.001212	0.000884	-0.000659	0.000126	-0.000269	-0.000824
	std err	0.001565	0.001686	0.002636	0.000783	0.001851	0.001077	0.001991	0.001715	0.002487	0.004165	0.001231	0.001385	0.001344
Aug	α_{13}	0.001024	0.006735	-0.012604	-0.001219	-0.004342	0.000217	0.002732	-0.001817	-0.001509	-0.002928	-0.001501	-0.002217	-0.002527
	std err	0.001649	0.001750	0.002683	0.000806	0.001886	0.001100	0.002039	0.001747	0.002530	0.004304	0.001250	0.001403	0.001370
Sep	α_{14}	0.004025	0.008083	-0.011119	-0.000728	-0.004103	-0.000315	0.002278	-0.001506	-0.001167	-0.003911	-0.000677	-0.001183	-0.000500
	std err	0.001547	0.001662	0.002616	0.000779	0.001841	0.001073	0.001961	0.001708	0.002482	0.004133	0.001228	0.001383	0.001339
Oct	α_{15}	-0.004827	0.006276	-0.015027	-0.000190	-0.003078	-0.004240	0.003449	-0.000945	-0.000478	-0.001169	-0.000240	-0.000542	-0.000209
	std err	0.001553	0.001661	0.002701	0.000779	0.001843	0.001073	0.001944	0.001711	0.002484	0.004136	0.001228	0.001384	0.001339
Nov	α_{16}	-0.000949	-0.002501	-0.006452	-0.001601	-0.001421	-0.001496	0.001028	-0.001553	0.000969	0.000396	0.001534	0.001664	0.000911
	std err	0.001540	0.001646	0.002601	0.000770	0.002017	0.001057	0.001924	0.001714	0.002452	0.004138	0.001214	0.001366	0.001322
Dec	α_{17}	0.002667	0.003659	-0.006458	-0.000303	0.002973	-0.001457	-0.000532	0.001457	-0.000678	0.000704	-0.000068	-0.000016	-0.000556
	std err	0.001572	0.001641	0.002661	0.000792	0.001882	0.001086	0.001965	0.001739	0.002524	0.004202	0.001249	0.001406	0.001361

Note: Parameter values in gray are not statistically significant at a 10% level. Parameter values in blue are statistically significant at the 10% level, parameter values in red are statistically significant at the 5% level, and parameter values in black are statistically significant at the 1% level. Parameter estimates for the D_i^{pro} are not reported, but are significant at the 1% level and are available upon request.