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Electricity reform and retail pricing in Texas

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ABSTRACT

Electricity market reforms have pursued two goals, both aimed at increasing economic efficiency. The first is to ensure that suppliers minimize costs. The second is to make prices more reflective of marginal costs. We use data from Texas to examine whether post-reform retail prices have better reflected wholesale prices, and whether reform has reduced retailer costs. We find clear evidence of both outcomes in competitive market areas but not in non-competitive areas supplied by municipally-owned utilities or co-operatives.

1. Introduction

Electricity market reform has, to varying extents, unbundled traditional vertically integrated electric utilities and facilitated entry by firms competing at either or both the wholesale and retail levels. According to the U.S. Energy Information Administration (EIA), by 2015 over 20% of U.S. electricity sales came from retail power marketers or retail energy providers. Most evaluations of the reforms have focused on wholesale markets, where there are substantial opportunities for effective competition in generation and consequent cost savings. However, some desired efficiency gains from the reforms require retail prices to faithfully reflect wholesale prices. In this paper, we use data from Texas to evaluate the effect of reforms on the retail market.

The Texas Legislature initiated electricity market deregulation with the Public Utility Regulatory Act of 1995, amended by Senate Bill 373, which allowed for competition in the wholesale market. Texas Senate Bill 7, passed in 1999, further reformed the Electric Reliability Council of Texas (ERCOT) electricity market by "unbundling" vertically integrated utilities into three separate entities: a power generation company, a transmission and distribution utility and a retail electric provider. Utilities overseen by local political authorities, such as municipally-owned utilities and electric cooperatives, were given a choice to "opt-in" to competition, but were not required to do so. Most entities that were given a choice remained non-competitive.[1] Consumer choice of retail suppliers commenced in January of 2002 but, to incentivize market entry, over the next five years successors of former incumbents faced transitory provisions such as mandated price caps or "price-to-beat".

Zarnikau (2008) claimed that "the ERCOT market is generally considered to be the most successful of the restructured electricity markets in North America", with more retail competition than any other market in the U.S. or Canada (DEFG, 2015). Active customer participation in the Texas market is remarkable. According to the Public Utility Commission of Texas (PUCT, 2017), as of March 2016, 92% of all customers have exercised their right to choose an electricity supplier. ERCOT (2016) notes that retail choice consumers buy about 75% of all electricity sold in Texas.

A study commissioned by the Texas Coalition for Affordable Power (TCAP, 2016) claims, on the contrary, that the Texas reform was ineffective. The study highlights that in the decade prior to deregulation average residential rates in Texas were 6.4% *below* the national average, but in the decade following it they were 8.5% *above*. While the study acknowledges that natural gas prices and higher transmission and distribution costs raised Texas prices, it also questions the benefits of competition.

We explore the effects of competition on Texas retail electricity markets using >15 years of post-reform monthly data on average prices

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[1] Hunter (2012) provides a more detailed history on Texas deregulation. Zarnikau (2005), Adib and Zarnikau (2006) and Zarnikau and Whitworth (2006) review the Texas reform. Intelometry (2008) describes the unbundling and subsequent firm restructuring and name changes.

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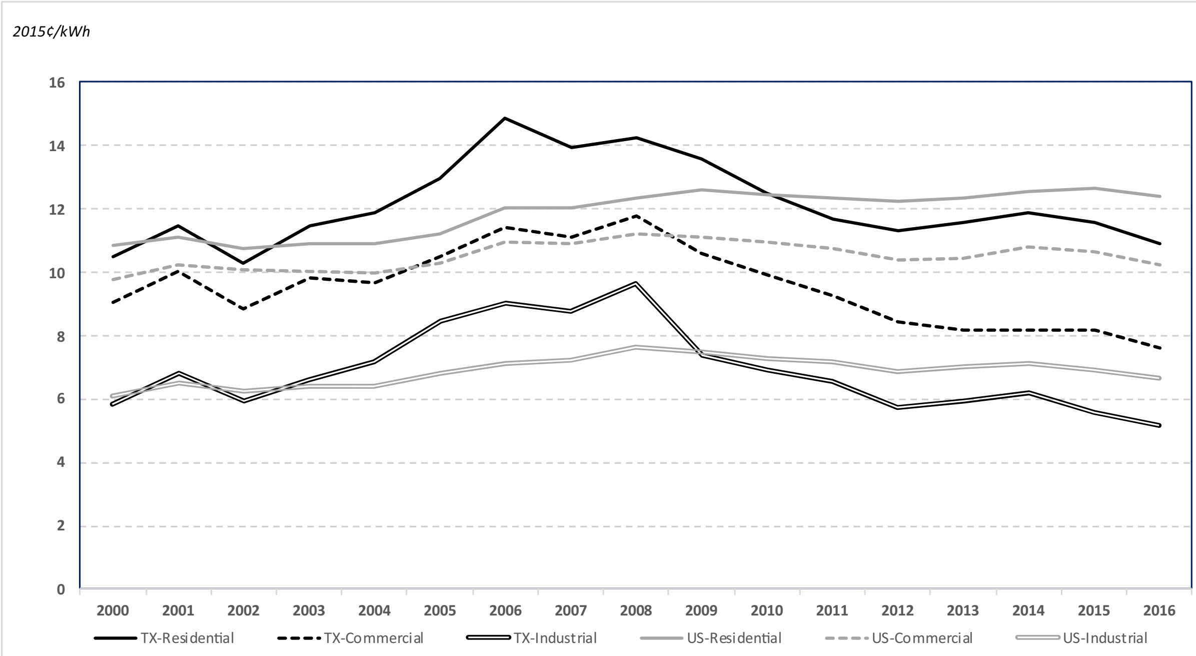

Fig. 1. Real U.S. and Texas electricity rates by sector, 2000–2016.
Source: Energy Information Administration.

across competitive and non-competitive market areas.[2] We find that residential rates in competitive market areas reflect wholesale rates with a declining gap between them, which is consistent with competition driving cost reductions. By contrast, residential rates in non-competitive areas generally do not reflect wholesale rates, and the gap between them generally has not been shrinking. Residential rates in areas with regional cooperatives, which still must compete for customers, behave more like those in competitive market areas.

We also examine site-specific load and billing data for several large commercial electricity consumers. The data reveal that the spread between residential and commercial prices is smaller in the non-competitive than in the competitive areas. Furthermore, since both residential and commercial rates have declined more rapidly in competitive areas in recent years, residential rates in competitive and non-competitive areas have tended to converge over time, while commercial rates across the two types of areas have tended to diverge. The likely explanation for these results is that commercial electricity consumers in non-competitive areas face prices above costs and thus are called upon to cross subsidize residential customers.

2. Background and literature

Historically, Texans have enjoyed lower retail electricity rates than the U.S. average. As Fig. 1 shows, however, the period from 2002 to 2010 was an exception. For the full period 2000–2016, while the Texas residential rate averaged \$0.003/kWh above the national rate, the commercial rate averaged \$0.010/kWh below the national rate and the Texas and national average industrial rates were virtually identical.

Since marginal generation comes from different types of plant in different parts of the nation, simple averages can be misleading. Fig. 2, and the fact that natural gas is the marginal fuel source in Texas, suggests that the significant increase in natural gas prices prior to the shale revolution largely explains the anomalously high Texas electricity prices from 2002 to 2010. Furthermore, Figs. 2 and 3 show that residential, commercial and industrial rates in Texas have all averaged below national rates (by \$0.006/kWh, \$0.019/kWh and \$0.009/kWh respectively) from 2009 to 2016 as natural gas prices have remained low.

Woo and Zarnikau (2009) make a related point. They present a theoretical economic model showing that rate reduction following deregulation depends on post-reform marginal costs being below average costs. They note that increasing natural gas prices invalidated this assumption for Texas at the time they were writing.

Borenstein and Bushnell (2015) similarly argue that marginal generation costs determine rates in restructured electricity markets. After noting that marginal supply in U.S. wholesale markets often comes from natural gas generators, they showed that U.S. electricity rates have been more affected by natural gas prices than restructuring.

If these arguments are correct, as markets continue to become more competitive, the wholesale price of electricity should better track the natural gas price.[3] Since natural gas is the marginal fuel in the competitive wholesale market in Texas, we implicitly account for natural gas price movements by including wholesale prices in our analysis.

We also note from Fig. 3 that by 2016 the discount for Texas consumers had dipped to \$0.015/kWh, \$0.026/kWh and \$0.015/kWh in the residential, commercial and industrial sectors, respectively. We argue later that competition likely explains the larger discount in commercial rates than in residential or industrial rates.

Extensive research has examined the impact of electricity market reform on rates. “Most studies conclude that there have been some efficiency gains, but the subject of whether retail prices have fallen has been contentious” (Blumsack et al., 2008). Texas has been cited as an example with mixed post-restructuring results.

The (TCAP, 2016) study discussed above shows that, after restructuring, residential customers in non-competitive areas of Texas on average enjoyed lower rates than those in competitive areas. However, the study makes no attempt to assess whether rates in the areas that later became competitive were higher *before* the reforms were introduced. The study also ignores the likelihood that, since competition

[2] Papers using a related approach include Joskow (2000) and Hortaçsu et al. (2015).

[3] Other factors, such as policies promoting renewables, may also take greater precedence over time. Pfund and Chhabra (2015) and Tra (2016) discuss the impact of the growth of renewables on electricity prices.

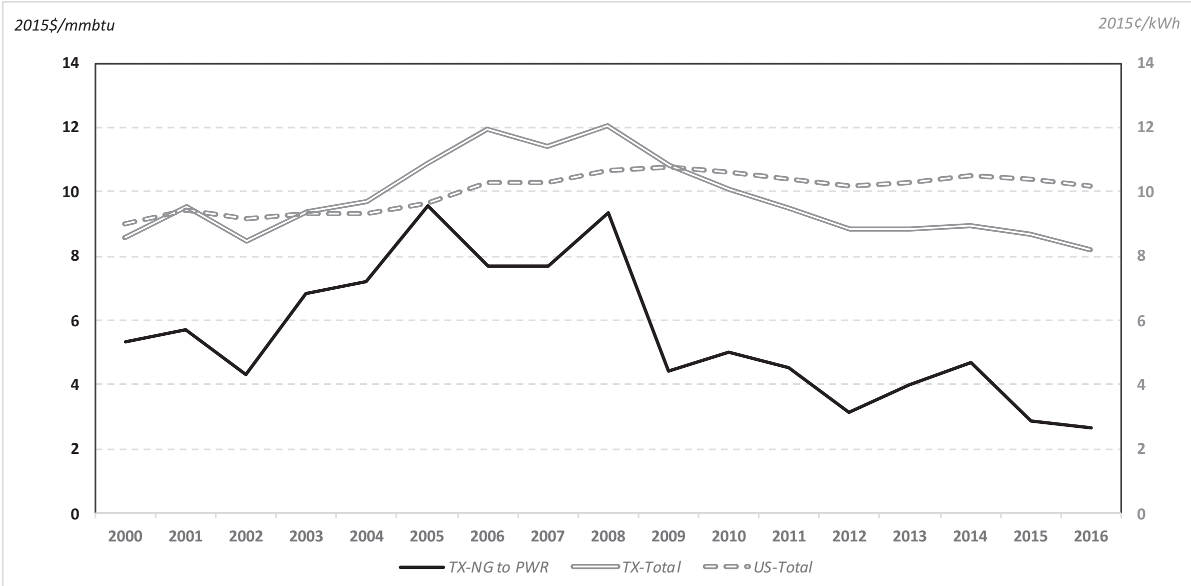

Fig. 2. Real electricity rates and natural gas price in Texas, 2000–2016.
Source: Energy Information Administration.

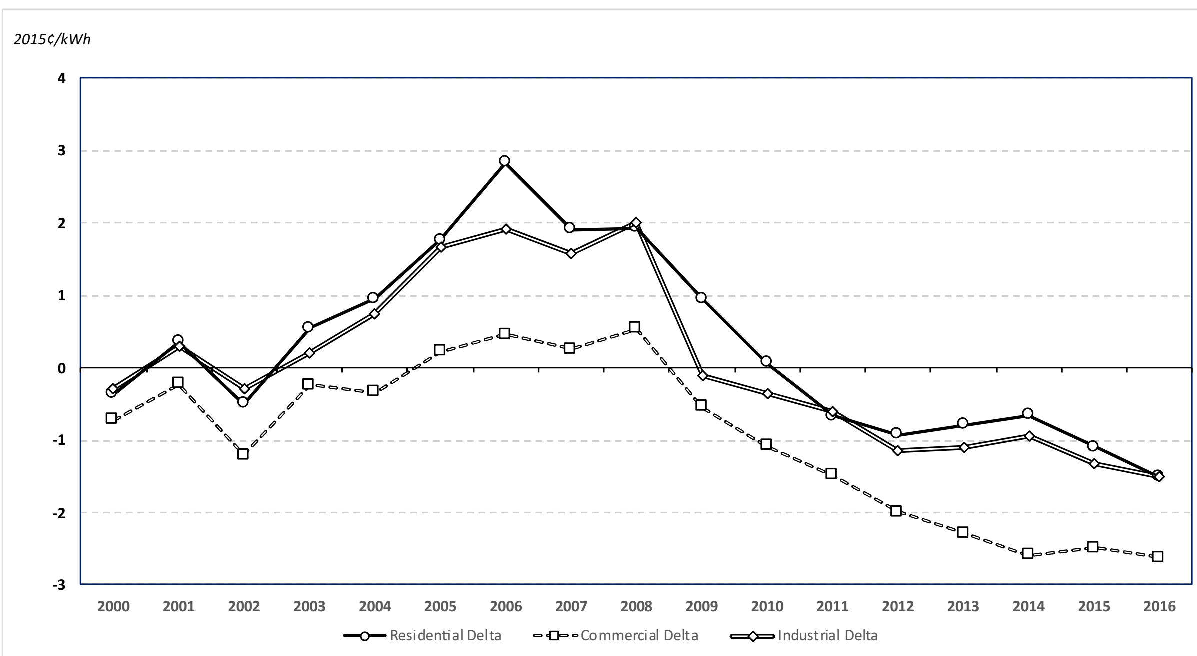

Fig. 3. Electricity rate differences – Texas minus U.S., 2000–2016.
Source: Energy Information Administration.

tends to eliminate cross-subsidies, other customers might cross-subsidize residential rates more in non-competitive areas. Although cross-subsidies are good for residential customers, they are likely to lead to inefficient resource deployment and use.

Measuring the success of market restructuring solely in terms of its effect on retail rates may be misleading for other reasons. In particular, previous studies have credited the Texas restructuring with increasing consumer choice and adding a variety of new products and services including customizable rates (see (Rai and Zarnikau, 2016) and (Goett et al., 2000)), increasing diversity in the generation mix (Zarnikau, 2011), and achieving energy efficiency and other environmental goals (Zarnikau et al., 2015).[4] Our data does not allow us to say anything about such claims.

[4] Bae et al. (2014) and Christensen Associates Energy Consulting LLC (2016) discuss benefits and costs of retail competition. The website www.powertochoose.com lists retail energy providers, plans and rates.

3. A simple model of electricity retailing

Consider first a competitive retailer selling electricity, e_j, to group j consumers at rates, r_j, that it takes as given. Assume that the firm can generate its own power, q_o, or purchase power, q_o, from the wholesale market at a wholesale market price, p_w, that it also takes as given.[5] Assume that it pays a transfer price, p_o, for power received from its own generators. The firm also pays for transmission and distribution services, and other costs of operations including labor. Different customer groups are often supplied at different voltage levels, while other costs of servicing customers also may differ by group. Hence, we assume that transmission and distribution costs, $\tau(e_1, \dots, e_n)$, and other costs, $w(e_1, \dots, e_n)$, are general functions of the supplies to different customer groups.

Assume that the firm maximizes profits from all electricity sales:

$$\max_{e_j} \sum_{j=1}^{n} r_j e_j - (p_w q_w + p_o q_o + \tau(e_1, \dots, e_n) + w(e_1, \dots, e_n))$$

subject to the constraints

$$\sum_{j=1}^{n} e_j = q_w + q_o \quad \text{with} \quad e_j, q_w, q_0 \geq 0.$$

Using $q_w = \sum_{j=1}^{n} e_j - q_o$, first order necessary conditions for an interior maximum are

$$\frac{\partial \pi}{\partial e_j} = r_j - p_w - \frac{\partial \tau}{\partial e_j} - \frac{\partial w}{\partial e_j} = 0 \quad \forall \quad j = 1, \dots, n$$

and

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

Notice, that this implies

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

In other words, the supply to customer group j will equate the gap between the retail and wholesale prices to the marginal transmission and operating costs, $\partial\tau/\partial e_j + \partial w/\partial e_j$. Modifying this static analysis to include investments aimed at lowering transmission and operating costs would reduce the gap between retail and wholesale prices over time.

The first order conditions for an interior solution also imply that the firm will equate its marginal generating price to the wholesale market price. Since the firms in our sample always purchase power from the wholesale market, this is the only relevant solution and we henceforth ignore the choice of generation.

We next consider a municipally-owned retailer granted a monopoly franchise to supply a local market. The firm can now choose the rate, r_j, for consumers in group j, although it faces a demand curve given as $d_j(r_j)$ with $d_j{}'(r_j) < 0$. We continue to assume that the firm remains small in the wholesale market and therefore takes the wholesale market price, p_w, as given. For simplicity, we also assume that the firm does not own any generating capacity and thus faces the constraint

$$q_w = \sum_{j=1}^{n} e_j = \sum_{j=1}^{n} d_j(r_j).$$

The firm's profits thus can be written as

$$\pi(r_1, \dots, r_n) = \sum_{j=1}^{n} (r_j - p_w) d_j(r_j) - \tau(d_1(r_1), \dots, d_n(r_n)) - w(d_1(r_1), \dots, d_n(r_n)).$$

We assume that the municipal government prevents the firm from maximizing profits. Nevertheless, higher profitability remains important, since any profit returned to the municipality allows other political goals to be pursued. Conversely, losses made by the municipally-owned retailer would have to be financed by other taxes, which would be politically unpopular.

The firm also may be pressured to redistribute costs across consuming groups. Specifically, we assume that the political support, or political opposition, of consumer group j depends positively on the consumer surplus that group j obtains from their electricity consumption, such that

$$C_j = \int_0^{d_j(r_j)} d_j^{-1}(e)\,de - r_j d_j(r_j)$$

with $d_j^{-1}(e)$ equal to the inverse demand curve for consumer group j, giving the price they would pay for a consumption level of e.

In summary, the municipally-owned retailer chooses $r_1, \dots, r_n$ to maximize a "political support" function $V(\pi, C_1, \dots, C_n)$ with $\partial V/\partial \pi > 0$ and $\partial V/\partial C_j > 0$ for each j.[6] After simplifying, the first order conditions now imply.

$$\frac{\partial V}{\partial \pi}\left(d_j(r_j) + d_j{}'(r_j)\left[r_j - p_w - \frac{\partial \tau}{\partial r_j} - \frac{\partial w}{\partial r_j} \right] \right) = \frac{\partial V}{\partial C_j} d_j(r_j) \quad \forall \quad j = 1, \dots, n$$

Noting the elasticity of demand for consumer group j can be expressed as

$$\varepsilon_j = -\frac{r_j}{d_j(r_j)} d_j{}'(r_j) > 0,$$

the first order condition can be written as a difference between price and marginal cost

$$\frac{r_j - p_w - \frac{\partial \tau}{\partial e_j} - \frac{\partial w}{\partial e_j}}{r_j} = \left(1 - \frac{\frac{\partial V}{\partial C_j}}{\frac{\partial V}{\partial \pi}} \right) \frac{1}{\varepsilon_j}.$$

Thus, if the consumer surplus of group j is more (less) important in the political support function than the overall profitability of the firm, the price charged to group j will be less (greater) than the marginal cost. The proportionate amount of the subsidy (or implicit tax) for consumer group j will also depend inversely on the elasticity of demand.

Since local households have many local voters, we might expect households to be the most favored group politically and to receive a subsidy in the form of prices below the marginal cost of supply. Commercial customers (such as retail establishments, service providers and the like) may, on the other hand, be less favored politically and thus face a price above the marginal cost of supply. Furthermore, if they need to do business in the local region, and they have few substitutes for electricity purchased from the grid, they will have low demand elasticities. The implication is that they may face a relatively high implicit "electricity tax." By contrast, industrial consumers may have higher demand elasticities since

[5] While separating generation from retail electricity supply is a key part of the reform process some vertically integrated firms remain.

[6] This follows a similar approach used by Hartley et al. (2008) to model the competing objectives of National Oil Companies (NOCs) subject to political influence.

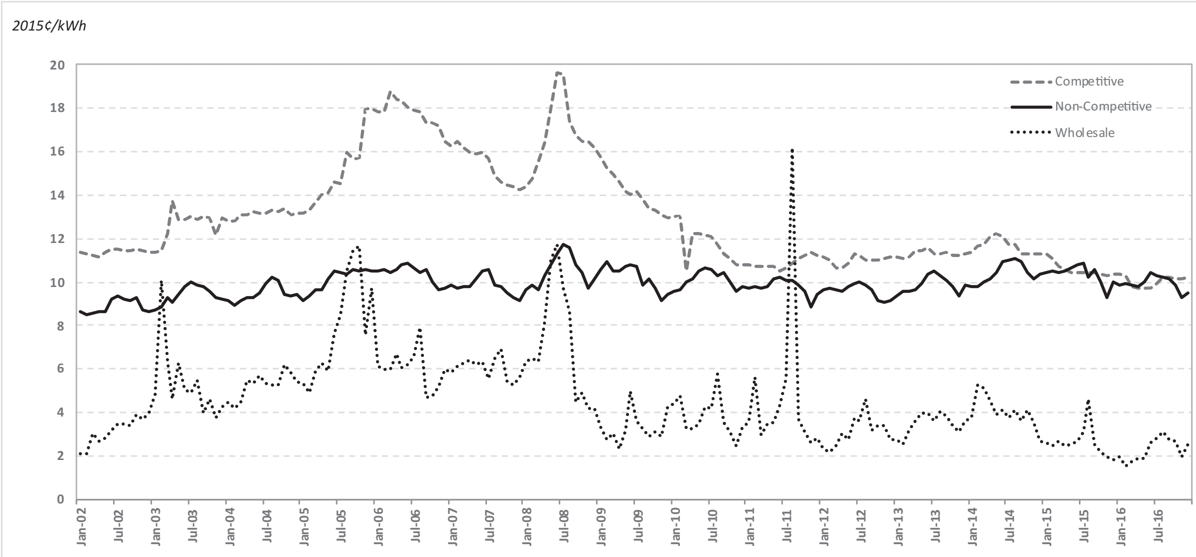

Fig. 4. Monthly average residential electricity rates (1000 kWh load, 2015¢) and wholesale electricity prices (2015¢), Jan2002–Dec2016.
Data sources: Nominal data collected from the Texas PUCT and ERCOT and converted to real 2015¢ using the U.S. Consumer Price Index from the U.S. Federal Reserve Database.

they can often buy wholesale, generate on-site, or relocate to avoid higher electricity prices. The model then implies that industrial consumers are likely to face prices close to the marginal cost of supply regardless of their political influence.

A cooperative will fall between the competitive profit-maximizing firm and the municipally-owned utility. While it may be the dominant firm in its local market and be pressured to subsidize households, it also must compete with private firms. This would raise ε_j and reduce the amount of cross-subsidization the cooperative can implement.

4. Data and estimated equation for residential prices

We obtained monthly aggregated residential electricity bill data for 2002–2016 from Electric Utility Bill Comparison published by the Rate Regulation Division of the Public Utility Commission of Texas (PUCT, 2017). Although the subsequent analysis focuses on the 1000 kWh residential customer group, the billing data for both 500 kWh and 1000 kWh groups were obtained and normalized by the load classification to yield an effective average rate for each group.[7] All pricing and cost data were converted to real 2015$, using the U.S. Consumer Price Index from the U.S. Federal Reserve as deflator.

The data come from eight non-competitive market areas[8] – investor-owned utilities Southwestern Public Service (SWPS) and Southwestern Electric Power (SWEP); electricity cooperatives Magic Valley EC, Upshur EC, and Victoria EC; and municipally-owned utilities Austin Energy, CPS Energy, and the City of San Marcos – and five competitive market areas – AEP Texas Central, AEP Texas South, Oncor, Reliant/CenterPoint, and Texas-New Mexico Power. To construct complete time series in the competitive areas, series were merged to allow for ownership changes. Specifically, TXU was linked with Oncor, Reliant was linked with CenterPoint, Central Power and Light was linked with AEP Texas Central, and West Texas Utilities was linked with AEP Texas North.

Figs. 4 (monthly averages across groups) and 5 (annual averages across firms) graph averages of the resulting time series of prices. While these averages are easier to interpret visually, we use the monthly data by firm in the statistical analysis. Table 1 presents summary statistics for the monthly data.

Figs. 5 and 6 and Table 1 also include four zonal wholesale price series. Prior to the end of November 2010, these are zonal 15-minute wholesale electricity prices taken from the Balancing Market Prices for Energy and Resource archived datasets (ERCOT, 2017a). From the beginning of December 2010 they are nodal hourly day-ahead market prices taken from the Day-Ahead Market Information portal (ERCOT, 2017b). The latter were converted to zonal prices and merged with the former to create the series used in the analysis.

The annual data in Fig. 5 show that residential prices closely track wholesale prices in the competitive, but not in the non-competitive, areas. Thus, like wholesale prices, competitive area residential rates rose significantly relative to non-competitive area rates through 2006 before declining from 2008. From 2002 through 2016, competitive area residential rates decreased, while non-competitive area rates increased.

The volatility (standard deviation) of competitive area residential prices also generally mirrored wholesale price volatility, and hence exceeded volatility of non-competitive area prices. This again supports the notion that residential prices more faithfully reflect wholesale prices in competitive areas.

The declining gap between competitive area retail and wholesale rates shown in Fig. 5 and Table 1 suggests that competition is reducing costs in competitive areas. In contrast, the gap has generally widened in non-competitive areas.

As reported by TCAP (2016), the *average* residential rate has been higher in competitive than in non-competitive areas. In 2002, before market reforms and retail competition could have had a material impact, residential customers in subsequently competitive areas paid between two and three cents more than residential customers in subsequently non-competitive areas. By 2016, however, residential customers in competitive and non-competitive areas paid approximately

[7] Rates constructed in this way are only approximate because the load in the different categories generally will not be 500kWh or 1000kWh. Moreover, the billing data include non-commodity costs, such as fees for various services. Note that dividing by a constant does not alter the conclusions of the statistical analysis.

[8] Incomplete time series data forced us to exclude some additional non-competitive market areas in Texas, including Pedernales EC, one of the largest electricity cooperatives in the nation. Since we use ERCOT wholesale prices, we also excluded areas within Texas, but outside ERCOT.

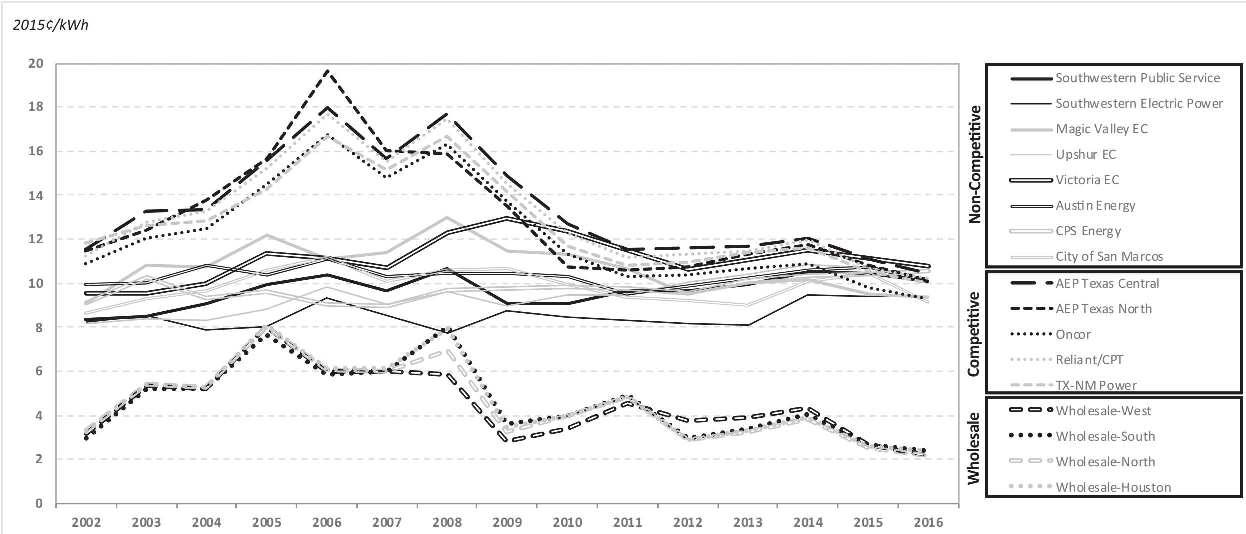

Fig. 5. Annual residential electricity rates (1000 kWh load, 2015¢) and wholesale electricity prices (2015¢), 2002–2016.
Data sources: Nominal data collected from the Texas PUCT and ERCOT and converted to real 2015¢ using the U.S. Consumer Price Index from the U.S. Federal Reserve Database.

the same average price, and some competitive area rates were below those in non-competitive areas.[9]

To verify the insights from the graphs and summary statistics, and to measure how multiple variables affect prices, we proceed to an econometric analysis. From the simple model in Section 3, the retail price should depend on the wholesale price, the cost of transmission and distribution, and any other firm-specific operating costs. Apart from wholesale electricity, labor is the other main input purchased by electricity retailers. To measure labor cost in the Texas utility industry we used the average weekly wage in the trade, transportation and utilities sector for the state of Texas from the U.S. Bureau of Labor Statistics Quarterly Census of Employment and Wages. We then deflated by the CPI to obtain real wages. To allow for the fact that many full-time employees are hired under contracts that periodically adjust wages to labor market conditions, we used the average over the previous 12 months as the cost of labor.

We included a set of monthly dummy variables to allow for seasonal influences on the pricing relationship. We also noticed infrequent periods of extremely low rates in several areas dominated by electricity cooperatives, perhaps reflecting rate promotions or other marketing initiatives. These occurred at most 6 times in a single area during the 15-year period. We included dummy variables to account for these outlier observations, which might otherwise bias parameter estimates.

Finally, the default to regulated rates from 2002 to 2005 and the "price-to-beat" program from 2005 to 2007 could have affected retail prices. Kang and Zarnikau (2009) showed that retail prices declined following the removal of the "price-to-beat" caps even though natural gas prices remained high during their study period. They criticized studies that did not allow for these programs. We thus add a dummy variable that is one prior to January 2007 and zero thereafter, and two different time trends before and after 2007 to allow different drifts in the relationship between the retail price and marginal costs.[10]

In summary, for each market area i we estimate the following equation

$$p_{it}^{res} = \alpha_0 + \alpha_1 p_{it-1}^{res} + \alpha_2 p_{it}^{w} + \alpha_3 w_{it} + \alpha_4 D^{pb} + \alpha_5 t_1 + \alpha_6 t_2 + \sum_{j=7}^{17} \alpha_j D_{j-6}^{m} + \sum_{j=18}^{k_i} \alpha_{ij} D_{j-17}^{pro} + u_{it}$$

where the included variables are defined in Table 2. The lagged dependent variable allows average residential prices to adjust gradually to changes in p^w or other costs.[11]

We expect the error terms to be contemporaneously correlated since omitted explanatory variables may simultaneously affect many market areas. We therefore estimate the equations using the seemingly unrelated regression (SUR) estimator.[12]

From Section 3, we expect the above equation to describe the behavior of retail prices in competitive market areas. In non-competitive areas, however, non-commercial factors omitted from the equation will likely reduce its explanatory power.

5. Results

Table 3 presents parameter estimates[13] of the model for consumers with greater than 1000 kWh consumption per month. These equations

[9] Areas that remained non-competitive after deregulation chose to retain that status. It is possible, therefore, that factors that explain their prior status or their choice, rather than competitiveness and local political oversight, could explain the different post-deregulation price histories of the two types of areas. However, the reasons why areas differed in status at the time of deregulation goes back >50 years. Furthermore, the econometric analysis shows strong conformity of pricing behavior in the competitive areas and strong dissimilarity between those areas and the non-competitive ones. Given the disparities between competitive areas with regard to characteristics other than subsequent market structure, it would seem that different market and governance structures are the most likely explanation for different outcomes in the two types of areas.

[10] In 2005, the Texas legislature mandated added competitive renewable energy zones (CREZ) transmission capacity to deliver wind generation from West Texas and the Panhandle to load centers in Central and East Texas. About 2400 miles of new transmission lines were completed in 2013 at a cost of around $7 billion. While wholesale prices reflect marginal transmission costs, the capital costs of the CREZ lines were covered by a levy on local wires companies that was passed through to final consumers. More generally, transmission and distribution charges by local wires companies, which are overseen by the PUCT, tended to increase retail relative to wholesale prices over our sample period. Not allowing for this would strengthen our finding that competition has tended to reduce the gap between retail and wholesale prices.

[11] Augmented Dickey Fuller tests indicated that none of the included time series variables has a unit root.

[12] Ordinary least squares (OLS) on each equation yields consistent parameter estimates, but SUR is more efficient. SUR and OLS are equivalent when the OLS error terms are uncorrelated across equations or when each equation contains the exact same regressors, which is not true in our case.

[13] To save space, parameter estimates for the promotion dummies are not reported.

Table 1
Summary statistics of data presented in Fig. 4.
Data sources: Nominal data collected from the Texas PUCT and ERCOT and converted to real 2015¢/kWh using the U.S. Consumer Price Index from the U.S. Federal Reserve Database. Calculations by the authors.

		Sample average (Jan02–Dec16)	Std deviation (Jan02–Dec16)	2002 average	2016 average	Rate change (2002–2016)
Non-competitive	SWPS	9.67	0.99	8.35	10.07	1.71
	SWEP	8.56	1.27	8.23	9.42	1.19
	Magic Valley	10.69	1.55	9.10	9.33	0.23
	UpShur	9.48	0.90	8.14	10.21	2.08
	Victoria	11.10	1.17	9.57	10.77	1.20
	Austin Energy	10.32	0.74	9.93	10.05	0.13
	CPS	9.75	0.95	9.10	10.55	1.45
	San Marcos	9.86	0.93	8.67	9.12	0.45
Competitive	AEP-CTX	13.41	2.50	11.55	10.47	−1.08
	AEP-NTX	12.97	2.88	11.43	10.19	−1.24
	Oncor	12.28	2.43	10.90	9.30	−1.61
	Reliant/CPT	13.11	2.47	11.25	10.21	−1.04
	TX-NM	12.75	2.20	11.82	10.00	−1.82
Wholesale	Wholesale-West	4.49	2.14	3.15	2.16	−0.99
	Wholesale-South	4.59	2.32	2.94	2.39	−0.55
	Wholesale-North	4.52	2.17	3.29	2.19	−1.10
	Wholesale-Houston	4.64	2.34	3.23	2.37	−0.86

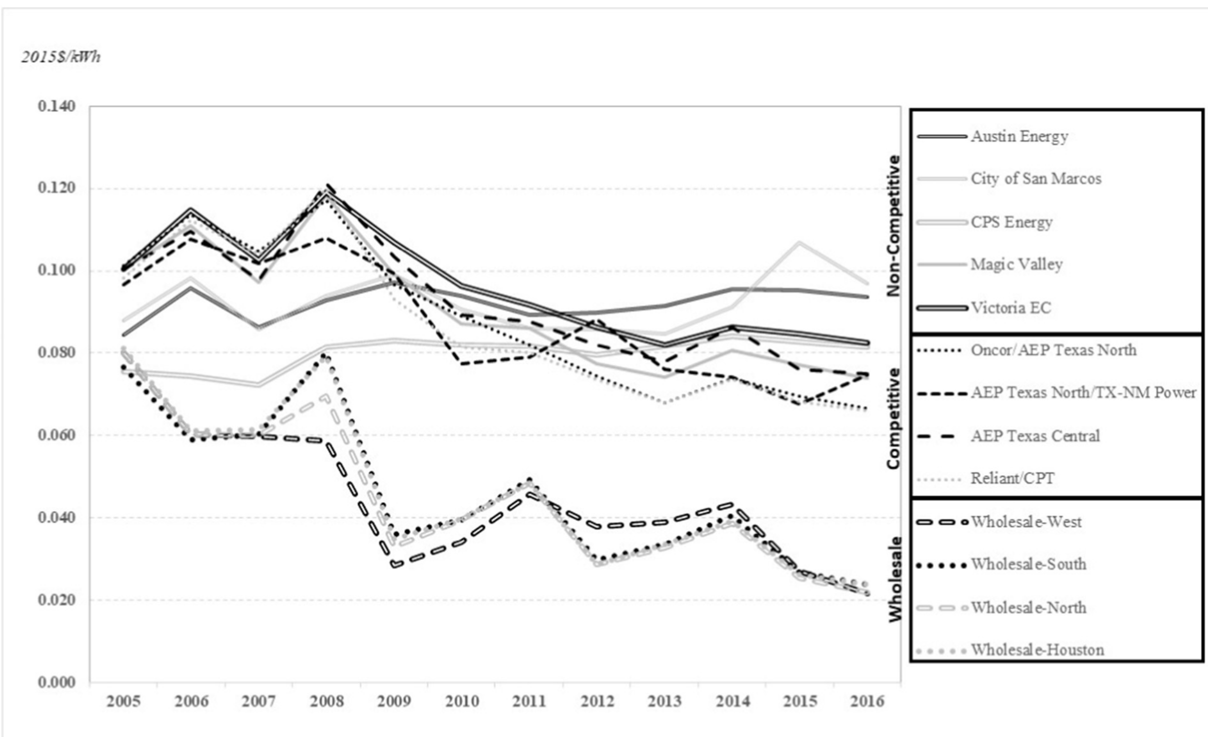

Fig. 6. Annual commercial electricity rates across market areas, 2005–2016.* *Commercial data for 2016 are incomplete, so year-to-date data is indicated.
Data sources: See text for description.

were estimated together with a corresponding set of equations for the 500 kWh customers while allowing contemporaneous correlations in the error terms across all equations. The results for the 500 kWh consumers are not very different from the results in Table 3 aside from the constant term in the regression.[14]

Estimates of the effects of wholesale price, labor costs, the price to beat mechanism (including the two time trends) and the adjustment speed (reflected in the coefficient on the lagged dependent variable) are all very uniform across competitive areas. Moreover, the seasonal

Table 2
Definitions of the variables included in the regression equation.

Variable	Definition
p_{it}^{res}	Real residential electricity price in area i in month t
p_{it}^{w}	Real wholesale electricity price in month t for zone where i is located
w_{it}	Average real wage for electricity industry workers in area i over the 12 months to month t
t_1	Time trend from January 2002 through December 2006
t_2	Time trend from January 2007 through December 2016
D^{pb}	The "price to beat" dummy variable that takes a value of one for all dates prior to January 2007 and zero thereafter
D^{m}	A vector of monthly dummy variables
D_j^{pro}	A vector of dummy variable specific to area i (some market areas only) that takes a value of one if very low outlier rates are observed in area i in month t perhaps due to promotions or rebates, and is zero otherwise

14 These are available at https://www.bakerinstitute.org/research/electricity-reform-and-retail-pricing-texas/. Differences in the estimated constant terms for the two customer categories likely reflect the block-declining rates faced by most Texas households. The other parameters suggest relative price movements are consistent across customer classes within each area.

Table 3
Parameter estimates (1000 kWh customers).

Variable	Parameter	Non-competitive areas								Competitive areas				
		SWPS	SWEP	Magic Valley	Upshur	Victoria	Austin Energy	CPS	San Marcos	AEP-CTX	AEP-NTX	Oncor	Reliant/CPT	TX-NM
Constant	α_0	1.09	−0.383	**8.69*****	0.800	**5.70*****	**5.01*****	**8.36*****	**2.23****	−0.422	−1.82	−1.21	−0.836	−1.34
	std err	1.06	1.34	1.97	0.538	1.34	1.05	1.47	1.18	1.68	2.91	0.819	0.917	0.871
$L.p^{res}$	α_1	**0.689*****	**0.575*****	**0.497*****	**0.872*****	**0.703*****	**0.479*****	**0.275*****	**0.838*****	**0.818*****	**0.640*****	**0.859*****	**0.854*****	**0.885*****
	std err	0.0278	0.0368	0.0392	0.0230	0.0264	0.0456	0.0495	0.0271	0.0166	0.0286	0.0129	0.0132	0.0132
p^w	α_2	**0.0335***	−0.0216	**0.179*****	0.0128	0.00665	**−0.0409*****	**0.0860*****	0.0133	**0.0449***	**0.0722***	**0.0652*****	**0.0606*****	**0.0608*****
	std err	0.0189	0.0244	0.0316	0.00991	0.0201	0.0159	0.0225	0.0190	0.0249	0.0415	0.0115	0.0113	0.0117
w	α_3	0.752	**1.61****	−1.36	0.104	−0.990	0.254	**−1.81****	−0.251	**1.88****	**4.11*****	**1.69*****	**1.62*****	**1.61*****
	std err	0.566	0.720	1.01	0.285	0.678	0.523	0.742	0.623	0.914	1.61	0.450	0.501	0.477
D^{pb}	α_4	−0.195	0.0988	**−1.42*****	0.0343	**−1.15*****	**−0.411****	**0.0112*****	−0.346	**−1.14*****	**−2.04*****	**−0.634*****	**−0.738*****	**−0.444****
	std err	0.194	0.247	0.385	0.0992	0.259	0.185	0.262	0.230	0.343	0.567	0.183	0.201	0.183
t_1	α_5	**0.0121*****	**0.00837****	**0.0137****	**0.00291***	**0.0127*****	**0.0148*****	**−0.0103****	**0.00763****	**0.0194*****	**0.0489*****	**0.0123*****	**0.0143*****	**0.00757*****
	std err	0.00361	0.00431	0.00623	0.00185	0.00411	0.00328	0.00433	0.00398	0.00568	0.0104	0.00297	0.00328	0.00300
t_2	α_6	**0.00300****	000213	**−0.00672*****	**0.00230*****	−0.00132	−0.00130	**0.0122*****	−9.32E-04	**−0.00918*****	**−0.0169*****	**−0.00602*****	**−0.00627*****	**−0.00488*****
	std err	0.00125	0.00170	0.00246	7.58E-04	0.00158	0.00122	0.00185	0.00148	0.00227	0.00376	0.00124	0.00133	0.00124
Feb	α_7	0.0284	**0.668*****	**−0.633****	−0.0631	−0.0982	−0.0629	0.135	−0.146	0.0405	−0.0214	−0.00949	0.0812	7.39E-04
	std err	0.153	0.191	0.270	0.0766	0.179	0.141	0.197	0.170	0.245	0.422	0.119	0.133	0.127
Mar	α_8	−0.013	**0.501*****	**−0.439***	−0.0481	−0.118	−0.0861	**0.549*****	−0.0600	0.192	−0.340	−0.00926	0.0357	−0.0578
	std err	0.153	0.193	0.270	0.0765	0.178	0.140	0.197	0.170	0.244	0.422	0.119	0.133	0.127
Apr	α_9	−0.0346	**0.758*****	−0.410	−0.0556	0.0854	−0.120	0.308	0.00162	**0.506****	0.580	0.0659	0.127	0.00276
	std err	0.153	0.191	0.270	0.0765	0.178	0.140	0.199	0.170	0.245	0.422	0.119	0.133	0.127
May	α_{10}	−0.0526	**2.09*****	**−0.458***	−0.00451	−0.232	**0.591*****	**0.472****	**−0.349****	−0.174	0.249	0.163	**0.233***	0.115
	std err	0.153	0.190	0.271	0.0765	0.180	0.141	0.199	0.171	0.245	0.422	0.119	0.133	0.127
Jun	α_{11}	**0.832*****	**1.34*****	**−0.612****	−0.0968	−0.165	**0.838*****	**1.34*****	−0.260	0.217	0.0979	**0.270****	0.145	0.0798
	std err	0.154	0.201	0.273	0.0768	0.180	0.145	0.201	0.172	0.247	0.424	0.120	0.134	0.127
Jul	α_{12}	0.225	**1.38*****	**−0.533****	0.0464	**−0.335***	**0.538*****	**1.21*****	0.126	0.0973	3.60E-04	0.0104	0.00958	−0.0882
	std err	0.155	0.203	0.271	0.0769	0.179	0.152	0.213	0.171	0.245	0.426	0.120	0.134	0.128
Aug	α_{13}	0.0994	**1.10*****	**−1.25*****	**−0.122***	**−0.379****	**0.563*****	**0.568*****	−0.174	−0.137	−0.225	−0.130	−0.208	**−0.269****
	std err	0.163	0.210	0.276	0.0792	0.183	0.155	0.218	0.174	0.249	0.440	0.122	0.135	0.130
Sep	α_{14}	**0.399*****	**1.19*****	**−1.09*****	−0.0670	**−0.356****	**0.476*****	**0.780*****	−0.145	−0.100	−0.336	−0.0621	−0.0924	−0.0733
	std err	0.153	0.200	0.269	0.0765	0.178	0.150	0.206	0.170	0.245	0.423	0.119	0.133	0.127
Oct	α_{15}	**−0.486*****	**1.00*****	**−1.41*****	−0.0153	−0.255	−0.152	0.125	−0.105	−0.0441	−0.0649	−0.0388	−0.0483	−0.0436
	std err	0.154	0.200	0.278	0.0765	0.178	0.150	0.205	0.171	0.245	0.423	0.119	0.133	0.127
Nov	α_{16}	−0.103	**−0.347***	**−0.671*****	**−0.156****	−0.0953	**−0.450*****	0.0969	−0.152	0.0936	0.0547	0.113	0.168	0.0604
	std err	0.153	0.197	0.267	0.0756	0.195	0.140	0.196	0.171	0.242	0.423	0.118	0.132	0.126
Dec	α_{17}	**0.262***	**0.459****	**−0.660****	−0.0269	**0.333***	−0.153	−0.0610	0.151	−0.0839	0.0701	−0.0224	−0.00640	−0.0855
	std err	0.156	0.194	0.274	0.0778	0.182	0.143	0.200	0.173	0.249	0.430	0.121	0.136	0.129
	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:
* Statistically significant at the 10% level.
** statistically significant at the 5% level.
*** statistically significant at the 1% level.

Table 4
Summary Statistics of Data presented in Fig. 6[a].
Data sources: See text. Converted to real 2015¢/kWh using the U.S. Consumer Price Index from the U.S. Federal Reserve Database.

		Sample average (Jan05–Dec15)	Std deviation (Jan05–Dec15)	2005 average	2015 average	Rate change (2005–2015)
Non-competitive	Magic Valley	9.17	1.65	10.05	7.38	−2.66
	Victoria	9.74	1.41	10.03	8.26	−1.77
	Austin Energy	9.20	0.45	8.43	9.35	0.92
	CPS	7.99	0.70	7.54	8.14	0.60
	San Marcos	9.18	0.90	8.80	9.69	0.88
Competitive	AEP-NTX/TX-NM	8.87	1.81	9.65	7.47	−2.18
	AEP-CTX	9.38	1.63	10.03	7.48	−2.55
	Oncor/AEP-NTX	9.00	1.87	10.13	6.66	−3.47
	Reliant/CPT	8.84	1.94	9.81	6.60	−3.21
Wholesale	Wholesale-West	4.67	2.26	8.01	2.69	−5.31
	Wholesale-South	4.83	2.49	7.65	2.69	−4.96
	Wholesale-North	4.69	2.31	8.00	2.55	−5.45
	Wholesale-Houston	4.85	2.52	8.11	2.62	−5.49

[a] Commercial data for 2016 are incomplete, so calculations through 2015 are reported.

effects are largely insignificant in all these areas. By contrast, residential prices in the non-competitive areas behave differently from each other and also very differently from residential prices in the competitive areas. Reinforcing these observations, we found that a test for pooling the competitive market areas alone is not rejected. The test does reject, however, when any one non-competitive area, or all non-competitive areas, are added to the competitive ones.

The estimated contemporaneous covariance matrix (not reported) reinforced the finding of similarly behaved residential prices in competitive areas only. The errors in the competitive areas had positive correlations from 0.3 to almost 1.0, suggesting similar omitted variables across those areas. By contrast, the non-competitive area correlations were mostly <0.1 in magnitude and many were negative.

The coefficient on the lagged dependent variable is the only highly significant coefficient in all market areas. Its value indicates relatively slow to modest speeds of adjustment of residential prices to new shocks.

Wholesale prices p^w have a statistically significant positive effect on residential rates in all competitive areas, consistent with the model of a profit-maximizing price-taking retailer. The estimated coefficients on p^w from the five competitive areas imply a short-run elasticity evaluated at the variable means that ranges from a low of 0.13 to a high of 0.21 with an average of 0.17. Using also the estimated coefficients on $L.p^{res}$ the long-run elasticities range from 0.58 to 1.50 with an average of 1.05. The effect of p^w was positive and statistically significant in only three non-competitive areas – SWPS, Magic Valley, and CPS. For Austin Energy the coefficient was statistically significant but negative, while it was not statistically significant in the remaining non-competitive areas – SWEP, UpShur, Victoria, and San Marcos. These results are consistent with the suggestion in Section 3 that providers in non-competitive areas maximize something other than profits.[15]

A positive and statistically significant effect of real wages in all of the competitive areas also is consistent with the model discussed in Section 3.[16] However, the coefficient was positive and significant only in one non-competitive area – SWEP – while being negative and significant in another – CPS.

The statistically significant negative coefficient on in the competitive market areas 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 coefficient on the time trend, t_1, indicates that residential rates generally increased relative to (increasing) wholesale rates and labor rates from January 2002 through December 2006. Conversely, the negative and statistically significant coefficient on the time trend, t_2, indicates that the residential price in competitive areas declined relative to (declining) wholesale price and the labor rate from January 2007 through December 2016.[17]

The parameter estimates on D^{pb}, t_1 and t_2 are inconsistent across the non-competitive areas. While Magic Valley exhibits the same pattern as the competitive areas, the estimated coefficients in CPS are opposite in sign to those in the competitive market areas. Victoria and Austin Energy are similar to the patterns exhibited in competitive areas until January 2007, but neither shows statistically significant negative effects after January 2007. In the remaining non-competitive areas – SWPS, SWEP, UpShur and San Marcos – only the parameter estimates on the time trends are statistically significant, and both are positive. This indicates that residential prices in these areas generally increased relative to the wholesale price and labor costs throughout the period. Increasing transmission costs over time, as claimed in the TCAP study referenced earlier, could explain these results. Since these entities all own generating assets, another explanation could be changes in the proportion of self-generated power differing in average cost from the marginal resource supplying the wholesale market. Unfortunately, data to test these and other possible explanations were not available.

Finally, statistically significant monthly seasonal patterns appear mostly in non-competitive areas. In SWPS, SWEP, Austin Energy and CPS, residential prices tend to increase relative to the higher wholesale price in high demand summer months. Possible explanations include congestion constraints internal to these market areas, or more price discrimination, during high demand periods. In Magic Valley, UpShur, Victoria and San Marcos, residential rates tend to decline relative to wholesale prices during summer months.[18] A possible explanation is that wholesale price changes are smoothed over time. Lastly, the paucity of seasonal effects in the competitive market areas is consistent with residential prices reflecting wholesale prices, including seasonality in the latter.

6. Commercial electricity prices

The PUCT has aggregate data for commercial and industrial electricity users in non-competitive areas only. However, we also collected a

[15] In non-competitive rural cooperatives with lower population density, such as those in West and South Texas, higher grid maintenance costs per customer could reduce the influence of the wholesale price.

[16] The estimated coefficients on w in the competitive areas imply a short-run elasticity of real retail price with respect to the real wage, evaluated at the variable means, ranging from 0.0011 to 0.0028 with an average of 0.0015. Taking account also of the estimated coefficients on $L.p^{res}$ the long-run elasticities range from 0.0074 to 0.0095 with an average of 0.0081.

[17] Using the estimated coefficients on t_2 in the competitive areas, the cumulative reduction, from January 2007 through December 2016, in retail relative to wholesale rates ranges from 0.6¢ to 2.0¢.

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

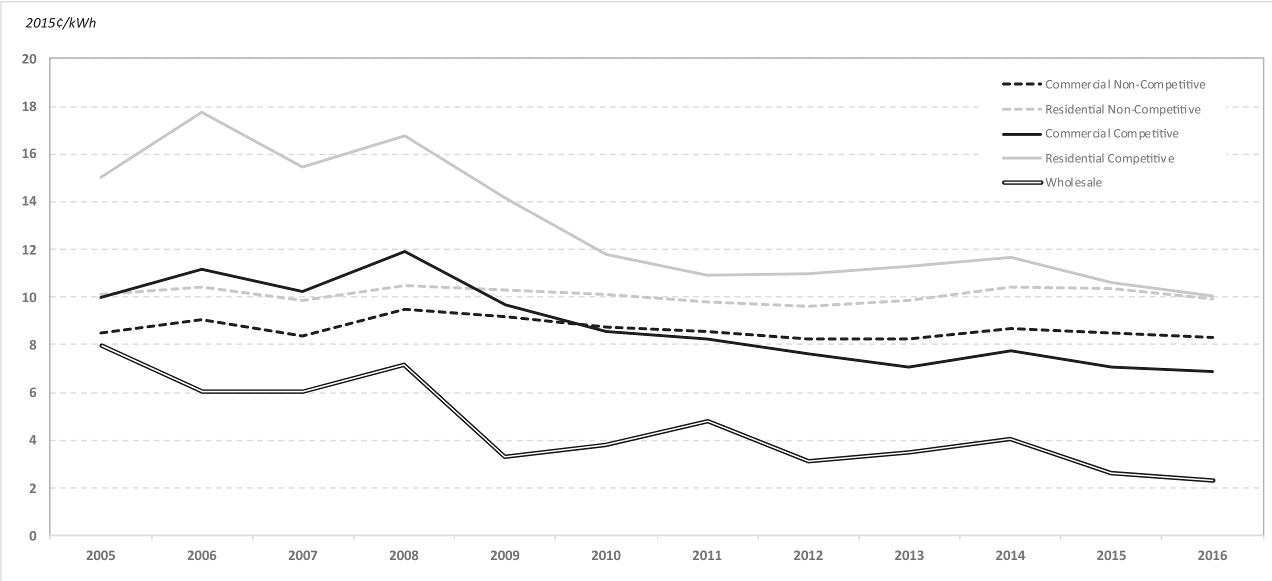

Fig. 7. Average rates across sectors by aggregate market area.* *Commercial data for 2016 are incomplete, so year-to-date data is indicated. Data sources: See text for description.

(non-representative) sample of site-specific load and billing data from several large commercial electricity users in Texas with facilities in both non-competitive and competitive areas.[19]

The billing data, representing over 760 locations across competitive and non-competitive market areas starting in January 2005, were converted to implied rates (bill divided by load) by location j in area i in month t, r_{jit}^{com}. For each area i, we then calculated a weighted-average price, $\overline{r}_{it}^{com} = \sum_j \theta_{jit} r_{jit}^{com}$, with weights, θ_{jit}, equal to the share in our data set of area i load consumed at site j. The average price reported by PUCT for all commercial customers in the non-competitive areas i matched our averages $\overline{r}_{it}^{com}$ in the same areas within half a cent every year from 2005 through 2016. Fig. 6 graphs $\overline{r}_{it}^{com}$ for different areas i.[20]

Fig. 6 reveals less separation between commercial rates in competitive versus non-competitive areas than we saw for residential rates. However, as with the residential rates, the commercial rates in competitive market areas have followed wholesale rates more closely. As a result, commercial rates in competitive market areas have fallen relative to rates in non-competitive market areas, and are now generally lower.

Table 4 presents some summary statistics for the data graphed in Fig. 6. The commercial prices in two non-competitive market areas dominated by cooperatives – Magic Valley and Victoria – have similar volatilities and averages to the data for competitive market areas. This may indicate that competition forces those cooperatives to behave more like profit-maximizing providers. We also see that the commercial rates in Austin Energy, CPS and San Marcos have generally been less volatile than in other areas, but they have slightly increased through 2015 and are now higher than rates in competitive market areas.

Fig. 7 graphs 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 weights in these composite prices are the load shares across market areas for the data in the commercial sample. The graphs highlight that the spread between residential and commercial prices in non-competitive areas is much smaller than in competitive areas.

The spread in the competitive areas suggests, as one would expect, that the marginal cost for serving commercial customers is below the marginal cost of serving residential customers. The smaller spread in the non-competitive areas then implies, consistent with the model presented in Section 3, that commercial customers cross-subsidize residential customers in those areas.

Fig. 7 also highlights that while residential rates across market area types converged over the sample period, commercial rates diverged. Figs. 1 and 3 presented earlier show that commercial rates in Texas as a whole declined relative to the national average from 2008. The results from Fig. 7 and Table 4 suggest that the competitive areas in Texas have been most responsible for this trend.

7. Concluding remarks

Many forces have affected the evolution of wholesale and retail electricity prices in Texas since major changes to the electricity market began in 2002. Nevertheless, increased competition appears to have had a discernible and significant effect in accord with economic theory.

Specifically, we found strong evidence that residential price movements more accurately reflected corresponding movements in wholesale prices in competitive market areas. Moreover, the difference between residential and wholesale prices declined on average over the period in the competitive market areas. These results are consistent with the hypotheses that competition drives prices to reflect marginal costs and drives firms to achieve efficiency gains and cost reductions.

Although residential prices were much higher in subsequently competitive than in subsequently non-competitive areas in 2002, declines in areas with retail competition and increases in non-competitive market areas had eliminated the gap by 2016. This outcome highlights the importance of evaluating market dynamics over time rather than focusing on simple averages.

We also found that commercial rates better track wholesale prices in competitive than in non-competitive market areas. There is also evidence of more cross-subsidization of residential by commercial customers in non-competitive areas.

More generally, our results are consistent with the hypothesis that greater political control and reduced competition allow more deviations between prices and marginal costs. The theoretical model we presented suggests that these deviations, or cross subsides between groups, will reflect differing political influence and elasticities of demand. While

19 A confidentiality agreement with Rice University prevents distributing or sharing the data.

20 The competitive areas in the commercial analysis do not correspond exactly to the areas in the retail analysis because we had to combine some areas with small sample sizes with neighboring areas facing the same wholesale power prices.

cross-subsidies of this sort may be politically optimal, they will lead to inefficient electricity use.

It may also be myopic to treat commercial entities as having a low elasticity of demand and thus rife for heavy taxation. Nowadays, many commercial entities may be able to offset electricity costs through investments in (subsidized) solar power or other onsite generation. As more commercial users are incentivized to buy less electricity from the grid, rates for other customers must rise to allow the local electricity retailer to cover its costs. Cross-subsidized rates to residential customers may therefore be unsustainable.

Uncited reference

Public Utility Commission of Texas (PUCT), 2015

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2018.12.024.

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