DO INDUSTRIAL ENERGY CONSUMERS RESPOND TO PRICE SIGNALS IN THE RESTRUCTURED TEXAS ELECTRICITY MARKET?

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This paper analyzes the responsiveness of a sample of large industrial energy consumers in the Houston area to wholesale price signals in the restructured Electric Reliability Council of Texas (ERCOT) market. The preliminary statistical analysis presented here supports the contention that ERCOT has succeeded in establishing a market that facilitates the responsiveness of large industrial energy consumers to wholesale price signals. This has been achieved without reliance on "stand alone" demand response programs for this market segment.

INTRODUCTION

As noted by FERC (2002): "Demand response is essential in competitive markets, to assure the efficient interaction of supply and demand, as a check on supplier and locational market power, and as an opportunity for choice by wholesale and end-use customers." As electricity markets are redesigned to facilitate wholesale and/or retail competition, stakeholders and policymakers are faced with the challenge of ensuring that consumers are presented with accurate price signals and the appropriate incentives to react to those prices accordingly.

Texas has long appreciated the value of demand-side market resources. Prior to the full-scale restructuring of the ERCOT market[1] in January 2002, ERCOT relied upon roughly 3,500 MW of interruptible load, group load curtailment programs, direct load control, and other load management technologies to maintain reliability and provide a resource to the market. This traditionally high reliance on demand-side resources is largely due to a base of industrial facilities such as petroleum refineries, chemical production facilities, steel mills, and air separation facilities that can interrupt operations at a smaller cost than many other types of manufacturing facilities.

As the ERCOT market was redesigned in 1999 to 2001 to introduce retail competition and to refine wholesale operations, the preservation of demand-side resources and demand response became a policy objective. The Public Utility Commission of Texas

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[1] The ERCOT market serves about 80% of the electricity needs of Texas.

(PUCT) ordered ERCOT to "Develop new measures and refine existing measures to enable load resources a greater opportunity to participate in the ERCOT market." (PUCT, 2000)

The approach taken in ERCOT to facilitate the development of demand-side resources and demand response has been unique. While other markets have established "stand-alone" programs for demand-side resources, the ERCOT market rules are designed to encourage demand-side resources and demand response to compete head-to-head against supply-side alternatives. Curtailable and interruptible energy consumers compete in the competitive markets for balancing energy and ancillary services that were initially designed for supply-side resources (i.e., power generation companies).

Has ERCOT succeeded in the establishment of a market that permits demand-side resources an opportunity to compete against supply-side alternatives and that facilitates appropriate responses to price signals? Restructuring has impacted different sectors and technologies very differently. Direct load control efforts have not successfully made the transition to the new market structure. (Zarnikau, 2004) Thermal energy storage devices have not proven economically viable in the new market. Steel mills, due to the unpredictable nature of their load levels, are considered to be unfit to provide ancillary services and have also seen their interruptibility under-valued under the new market structure. Nearly 100 MW of group load curtailment programs are no longer in operation. It is unknown whether industrial and commercial energy consumers formerly served under real-time pricing tariffs or curtailable load tariffs are still responding to price signals.

However, on a positive note, large industrial chemical and refinery loads with relatively predictable load patterns have prospered under the new market structure, and their interruptibility contributes over 1,500 MW of ancillary services (operating reserves) to the ERCOT market. Due to features of the new market structure, some larger energy consumers who were formerly insulated from wholesale price signals through regulated tariffs are now exposed to market-based wholesale market prices via creative contractual arrangements between retail electric providers and consumers.

When an industrial energy consumer formally offers its *interruptibility* to the ERCOT market as an ancillary service or offers to curtail its usage in order to provide an offset to balancing energy, then the quantity and price of this demand-side resource is known to the market. Thus, we know with certainty that well over 1,000 MWs of demand side resources (interruptible loads) are offering their interruptibility to the ERCOT market as an operating reserve during most hours. However, various forms of "voluntary demand response," also frequently occur. The market structure provides some incentives for consumers to reduce power purchases during peak or high-price periods. For example, a large industrial energy consumer's transmission charge is based upon the consumer's contribution to ERCOT's coincident peak demand in four summer months, so many consumers actively try to reduce energy consumption during expected peaks. Some industrial energy consumers rely on balancing energy (essentially, spot market power) to meet some or all of their electricity needs, actively monitor the 15-minute balancing energy prices, and reduce electricity purchases when prices exceed threshold levels. Other industrial consumers of energy participate in curtailment or scheduling programs that are established by their retail electric provider. These types of voluntary demand responses are based on confidential contractual relationships between a retail electric provider (REP) and its large energy consumers and not announced to the market. Anecdotal evidence suggests that many large industrial energy consumers are engaging in these types of behaviors and electricity procurement strategies. This paper is the first attempt to quantify the magnitude of this response.

ERCOT MARKET RULES

While supply-side resources are required to follow ERCOT-approved schedules, consumers are free to deviate from scheduled load levels. Once a scheduling entity goes "out of balance," a payment or credit to the market is incurred. A scheduling entity may be rewarded for reducing load levels during high prices. How and whether an industrial energy consumer is compensated or credited for this demand response is a contractual matter between the customer and its REP, which normally provides scheduling services to the energy consumer.

"Passive load response" refers to a customer's deviation from its scheduled or anticipated load level in response to price signals in situations where the customer has not formally offered this response to the market as a "resource." If a QSE's actual load level turns out to be lower than its scheduled load level during a given 15-minute interval (while its actual generation is equal to its scheduled generation), then the scheduling entity is entitled to a payment or credit, based on the energy imbalance multiplied by the balancing energy market price. This provides loads with an incentive to respond to wholesale market prices. Loads (and their scheduling entities) are not penalized if they fail to follow their schedules, but will pay the market price for energy if loads are above their scheduled levels and will receive a credit or payment if loads are below their scheduled levels. However, ERCOT's system operators may adjust schedules if the observed deviations from schedules are too great.

QSE's are not required to schedule the full quantity of their anticipated generation requirements with bilateral contracts with generation companies. They may elect to purchase a share of their generation requirements from the balancing energy market. While this leaves the REP un-hedged and exposed to price fluctuations in the balancing energy market, many REPs find this strategy advantageous, particularly if they serve loads with some capability to reduce energy usage in the face of high market prices. While volatile, balancing energy prices tend to be lower than the cost of firm generation resources obtained from bilateral contracts.

Often, transmission charges are treated as "pass-through" costs in the contracts offered by REPs. Consequently, larger energy consumers may see direct benefits by avoiding the four summer peaks, which are used to allocate transmission costs to consumers and REPs.

If an energy consumer opts to offer its interruptibility into an ancillary services market, then its ability to react to wholesale price signals will be constrained. The load is then relied upon by ERCOT to meet operating reserves needs. If the load is providing responsive reserves, for example, then ERCOT will monitor the load's level every three seconds to ensure that the load is available for interruption should the system need to rely upon the interruption of the load to maintain frequency. Many Houston-area industrial loads are providing ancillary services to the market. Thus many of the Houston area's most flexible, interruptible, or potentially price elastic electric loads will not react to prices. The benefits of maintaining a flat or predictable load level while providing their interruptibility as an operating reserve outweighs the anticipated benefits that they would realize from reacting to balancing energy prices.

Anecdotal evidence suggests that many industrial energy consumers are responding to price signals. Consultants now offer "4-CP forecasting models," to assist industrial energy consumers in the avoidance of transmission charges. Many consumers purchase a portion of their energy requirements directly from the balancing energy pool, and curtail their usage whenever prices rise above pre-determined levels. However, no one has previously provided a formal statistical analysis of this behavior.

STATISTICAL ANALYSIS

To further explore and quantify the reaction of participants to changing hourly prices, some statistical analysis was performed. An econometric translog cost function methodology was adopted for this purpose. Price elasticities, measuring the average responsiveness of the twenty largest Houston-area industrial energy consumers to price changes, were estimated.

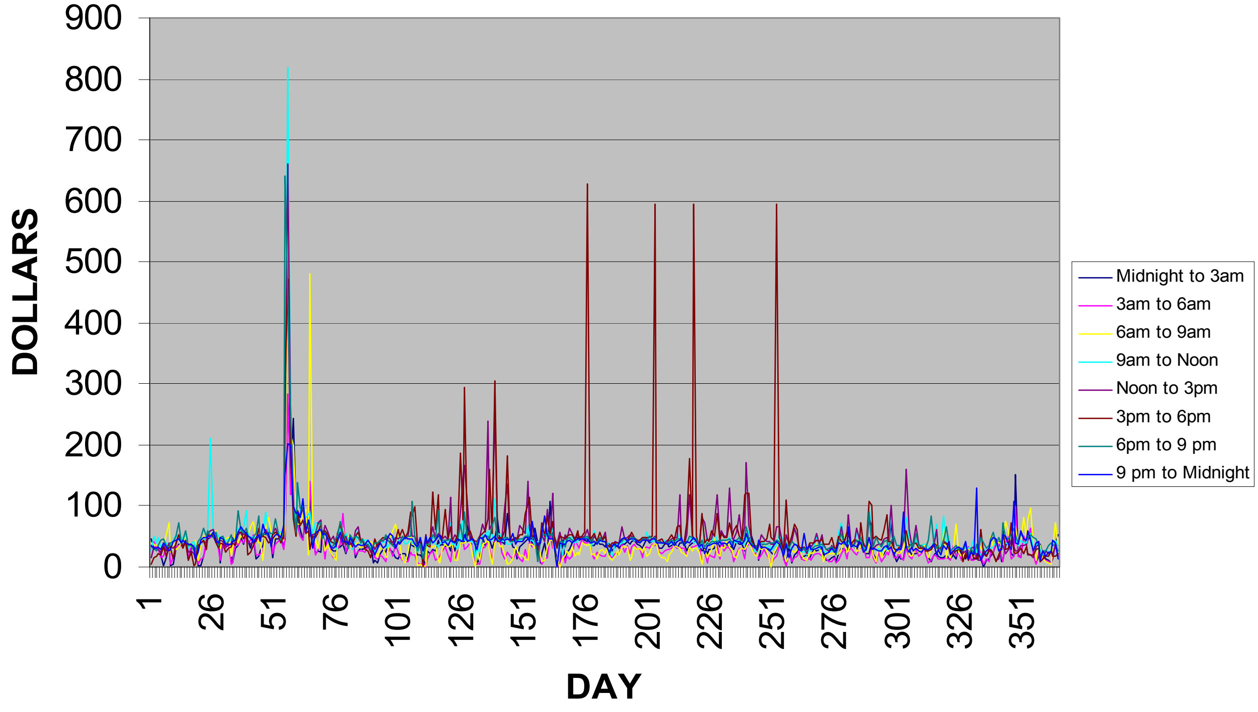
In the statistical approach adopted here, electricity consumed in different time periods is treated as different inputs into the participant's production function. The degree to which the quantity demanded in different time periods are substitutes (or compliments) is measured empirically. A translog cost function (see Diewert and Wales, 1987) was assumed, following Zarnikau (1990).

DATA SOURCES

The Houston area is home to most of the largest industrial energy consumers in the restructured ERCOT market. Hourly energy consumption data for the twenty largest industrial energy consumers in the Houston area were obtained from CenterPoint Energy, the provider of transmission and distribution services in the Houston area. The actual identity of these energy consumers was not revealed, and no attempt has been made to discover their identity. The hourly data were converted into a time series of energy consumption in each three-hour interval for the year 2003.

The wholesale price (market-clearing price) of electricity in ERCOT's balancing energy market for the Houston Zone in 2003 in dollars per MWh was obtained from ERCOT's web site. The 15-minute data were converted into a time series of electricity prices in each three-hour interval. Transmission prices, based on the costs that are assigned to industrial consumers that purchased electricity during the four summer coincident peaks, are added to the balancing energy prices. Figure 1 graphically depicts the resulting price series. Prices spiked in late February, when an ice storm moved through North and Central Texas. The short price spikes during the summer months during the late afternoon (3 p.m. to 6 p.m. period) represent the transmission prices.

Figure 1.
PRICES BY PERIOD



Hourly temperature data for Houston in 2003 were obtained from the National Oceanic and Atmospheric Administration. Cooling degree hours was calculated using a base temperature of 65 degrees F. These data were converted into a time series of cooling degree hours for each three-hour block.

The daily price of natural gas on the NYMEX Exchange in 2003 was also included as a variable, to account for possible fuel switching behavior. Many of the largest industrial energy consumers in the Houston area have cogeneration facilities fueled with natural gas. Thus, it is conceivable that an energy consumer could adjust cogeneration levels and/or switch between electricity and natural gas in order to minimize energy costs.

RESULTS

Simple inspection of the data suggests that some of the twenty energy consumers actively respond to price signals. For example, Figure 2 depicts the load patterns of one of the customers, Customer 6, during the four Tuesdays in September. The customer correctly anticipates the peak period during that month, and reduces its consumption in order to reduce its transmission costs.

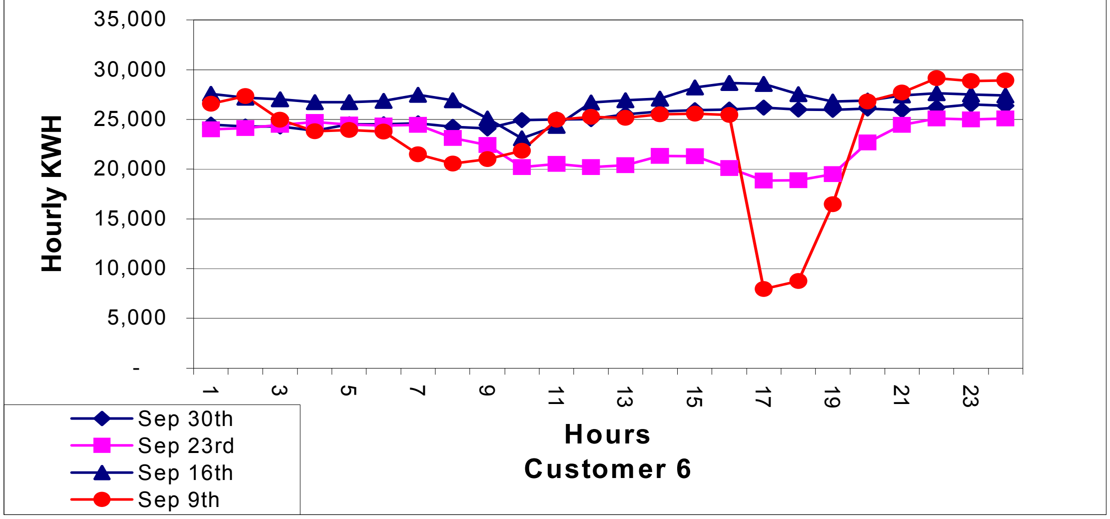


Figure 2
September 2003
(Peak Day: Tuesday, September 9th at 17:00 Hours)

Table 1 presents the estimated own-price elasticities, evaluated at the mean of each input vector for time periods A (midnight to 3 a.m.), B (3 a.m. to 6 a.m.), C (6 a.m. to 9 a.m.), D (9 a.m. to noon), E (noon to 3 p.m.), F (3 p.m. to 6 p.m.), G (6 p.m. to 9 p.m.), and H (9 p.m. to midnight). Thus "ETAA" represents the own-price elasticity associated with the first period of the day.

The own-price elasticity values are almost consistently negative for all the consumers in the sample. Values tend to be slightly higher, in absolute values, in the later two periods. Generally, these values are higher than were expected. Further research will explore whether these relatively high values may be attributable to the assumed functional form of the cost function. Prior studies have warned of problems with translog functions when the degree of substitutability among inputs is close to zero and the price variation in the sample data is large (e.g., Woo, 1985).

Table 1
Estimated Own-Price Elasticities

Consumer	ETAA	ETAB	ETAC	ETAD	ETAE	ETAF	ETAG	ETAH
1	-0.169	-0.248	-0.262	-0.179	-0.326	-0.360	-0.476	-0.343
2	-0.225	-0.196	-0.227	-0.190	-0.298	-0.375	-0.488	-0.349
3	-0.184	-0.217	-0.226	-0.184	-0.308	-0.361	-0.493	-0.382
4	-0.089	-0.249	-0.227	-0.190	-0.316	-0.363	-0.500	-0.367
5	-0.269	-0.247	-0.172	-0.126	-0.393	-0.377	-0.441	-0.401
6	-0.178	-0.210	-0.245	-0.134	-0.216	-0.388	-0.624	-0.586
7	-0.171	-0.212	-0.226	-0.174	-0.342	-0.399	-0.487	-0.375
8	-0.261	-0.358	-0.402	-0.196	-0.325	-0.325	-0.372	-0.341
9	-0.215	-0.207	-0.206	-0.179	-0.306	-0.366	-0.501	-0.343
10	-0.231	-0.260	-0.252	-0.147	-0.407	-0.364	-0.424	-0.375
11	-0.212	-0.211	-0.231	-0.187	-0.349	-0.358	-0.476	-0.376
12	0.062	-0.107	-0.086	-0.143	-0.263	-0.327	-0.623	-0.474
13	-0.125	-0.148	-0.180	-0.128	-0.349	-0.320	-0.515	-0.480
14	-0.189	-0.245	-0.238	-0.157	-0.416	-0.371	-0.432	-0.363
15	-0.142	-0.185	-0.198	-0.161	-0.397	-0.350	-0.460	-0.389
16	-0.130	-0.167	-0.199	-0.109	-0.166	-0.388	-0.647	-0.406
17	-0.202	-0.225	-0.234	-0.164	-0.405	-0.379	-0.441	-0.358
18	-0.199	-0.239	-0.250	-0.142	-0.305	-0.327	-0.526	-0.408
19	-0.296	-0.399	-0.375	-0.214	-0.313	-0.301	-0.346	-0.313
20	-0.100	-0.173	-0.125	-0.157	-0.317	-0.358	-0.515	-0.446
AverageValue	-0.176	-0.225	-0.228	-0.163	-0.326	-0.358	-0.489	-0.394
Highest Value	0.062	-0.107	-0.086	-0.109	-0.166	-0.301	-0.346	-0.313
Lowest Value	-0.296	-0.399	-0.402	-0.214	-0.416	-0.399	-0.647	-0.586

Cross-price elasticities were also calculated, and a summary is provided in Table 2. As alternative or substitute inputs to the customer's production function, positive cross-price elasticities between the electricity inputs in different time periods would generally be expected. Yet, consumption, particularly in adjacent periods, may be complements. Rigidities in production scheduling within labor shifts may account for some of the negative cross-price elasticity estimates. A mix of negative and positive cross-price elasticities were estimated.

Table 2
Estimated Cross-Price Elasticities
For 20 Houston Area Industrial Energy Consumers

	ETAAB	ETAAC	ETAAD	ETAAE	ETAAF	ETAAG	ETAAH	ETABC	ETABD	ETABE	ETABF	ETABG	EGABH	ETACD
AverageValue	0.06	0.10	0.15	0.14	0.16	0.13	0.16	0.04	0.07	-0.01	0.02	-0.02	0.01	0.05
Highest Value	0.12	0.36	1.37	0.62	1.81	0.61	1.76	0.11	0.11	0.03	0.04	0.00	0.04	0.10
Lowest Value	-0.27	-0.25	-0.30	-0.13	-0.41	-0.38	-0.44	-0.40	0.05	-0.04	0.00	-0.05	-0.01	0.02

	ETACE	ETACF	ETACG	ETACH	ETADE	ETADF	ETADG	ETADH	ETAEF	ETAEG	ETAEH	ETAFG	ETAFH	ETAGH
AverageValue	-0.139	0.031	-0.017	0.014	0.006	-0.065	0.133	0.003	-0.118	0.533	-0.169	-0.118	0.633	-0.102
Highest Value	0.075	0.052	0.018	0.051	0.058	-0.034	0.289	0.055	-0.079	0.636	-0.115	-0.069	0.744	0.010
Lowest Value	-0.011	0.002	-0.075	-0.024	-0.105	-0.097	0.047	-0.039	-0.215	0.455	-0.239	-0.203	0.574	-0.215

While some of the high own-price elasticity values deserve further examination, these preliminary results suggest that the largest electricity consumers in the Houston area do indeed respond to wholesale price signals in a rational manner.

Yet, the similarities in the estimated elasticity values are much greater than anticipated. Inspection of the raw data and a recognition that some of these industrial firms have opted to provide responsive reserves (which would then limit their responsiveness to price signals) suggests that the range of elasticity values estimate here may be too low. That is, some of the consumers should have own-price elasticity values much closer to zero. Present research is focused on re-estimating the elasticity values using alternative assumptions regarding the structure of the underlying cost function, including generalized symmetric McFadden and generalized Leontief forms.

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