Technical Paper
The Fraser Institute

ENERGY SERIES

NUMBER 1 ✧ SEPTEMBER 2007

Ontario Industrial Electricity Demand Responsiveness to Price

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EXECUTIVE SUMMARY

Efficient markets require both demand- and supply-side responses to price fluctuations in order to dampen overall price volatility. More efficient markets will produce price signals that more accurately reflect the value of electricity resources and, in turn, generate investment that will ensure an adequate supply of electricity for consumers.

In March 2003, the second report of the Ontario wholesale electricity Market Surveillance Panel examined the extent of demand response since the market was opened in 2002. It noted that the full benefits of effective competition will not be realized unless a much greater portion of industrial electricity demand is price responsive. The present paper updates aspects of the 2003 analysis in order to determine whether industrial demand responsiveness has been strengthened and to compare such responsiveness in the iron and steel; pulp, paper and board mill; metal ore mining; motor vehicle manufacturing; and oil refining industries, which together represent about 80% of Ontario industrial electricity demand. Since this paper focuses on the narrow technical questions of whether, and to what extent, the price elasticity of Ontario's industrial electricity demand may have changed in recent years and the implications of the degree of demand response to price changes, the need for reforms or structural changes to Ontario's wholesale electricity market, including the present institutional arrangements, has not been addressed.

Essentially the same statistical approach was used here as for the 2003 study. As in that study, the price of electricity was found to be a significant determinant of electricity demand in most cases with the expected inverse relationship (higher prices mean less consumption).The results provided no evidence that the responsiveness of Ontario industrial demand to the price of electricity during time periods when demand is the strongest has strengthened since market opening except, perhaps, in the case of metal ore mining and motor vehicle manufacturing power demand. The electricity price appeared to matter most in the pulp and paper industry, perhaps because of the competitive pressures that industry is facing and the ability of some firms to reduce their electricity demand because of excess capacity. Demand in the petroleum refining industry appeared to be the least price sensitive, possibly because the increased cost of oil feedstock and other costs can be more readily passed on to consumers.

That little evidence of improved demand responsiveness was found is not surprising given that a series of special rebates, the availability of fixed-term contracts, and the impacts of peculiar rules governing the behaviour of the Independent Market Operator likely dulled market participants' sensitivities to electricity price increases.

If the government is serious about improving the efficiency of the electricity market, it must continue efforts to improve industrial demand responsiveness through the Ontario Power Authority's (OPA) Demand Response Program (DRP) and other means including market education programs. Also, it should remove and avoid rebates and special subsidies: consumers are unlikely to be concerned with higher electricity prices if they are being cushioned by subsidies.

INTRODUCTION

The Ontario wholesale electricity department was opened on May 1, 2002. Having observed experiences in other jurisdictions, the market designers no doubt expected that the market would gradually become more robust as market participants began to respond to high prices by reducing demand. Even if the demand response[1] were generally small, in terms of percentage of total demand, it would still dampen the severity of price spikes resulting from unforeseen events, such as unexpected outages or unusually hot or cold weather conditions. Demand response would not only result in lower market prices, thus benefiting consumers immediately, but reduce the requirements for peak generation, bringing cost savings to consumers over the longer term.

Further, demand responsiveness allows those responsible for transmission system planning to defer system expansions to some extent. As well, by reducing the need for generation capacity, demand response can have environmental benefits both by reducing emissions during peak periods and, indirectly, by causing loads to be more aware of their energy costs and of the need to conserve energy. In addition, it may be possible for demand response to be relied upon to provide ancillary services (FERC, 2006).

In October 2002, the first report of the Market Surveillance Panel contained a short section on the demand for electricity, which explained the difference between "dispatchable" and "non-dispatchable" industrial customers or "loads." Dispatchable loads participate directly in the wholesale market by making hourly bids to buy electricity and are capable of adjusting consumption in response to five-minute dispatch instructions from the system controller. Non-dispatchable loads simply draw electricity from the system as required and the price that they pay is the hourly wholesale market price. The report indicated that there were only two loads in the province that were "dispatchable" and that those two loads could not, together, muster a significant demand response (in relative terms compared with the overall market size) to price. But the report went on to point out that "about 90 market participants, large industrial concerns, are directly tied to the grid and account for about 15% of total consumption or roughly 3,000 megawatts (MW) in a typical peak hour ... They would be in a position to respond to changes in prices by altering their consumption, depending on the nature of their business and their evaluation of the impact of the price of electricity" (Market Surveillance Panel, 2002: 17).

The March 2003 Market Surveillance Panel report on the performance of the electricity market during the period from September 2002 to January 2003 noted that "the full benefits of effective competition are unlikely to be realized unless a much greater portion of the load is price responsive;" also, that "the potentially price responsive load [comprises] about 90 market participants—large industrial customers that are directly connected to the grid (15% of total load)" (Market Surveillance Panel, 2003: 96-97).

1 According to the United States Department of Energy, "demand response" means "changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized" (United States Department of Energy, 2006).

The March 2003 report summarized results from an analysis of the demand responsiveness to price of the total load of this group of large industrial customers. The Market Analysis Unit (MAU) of the Independent Market Operator (IMO), which conducted the statistical analysis, stated the following: "The analysis provides evidence that these customers did respond to real-time price increases by reducing their consumption in some peak periods during the summer. In all models tested the real-time price, the hourly Ontario energy price (HOEP plus uplift), had a negative coefficient and was statistically significant in the key peak hours of the day" (Market Surveillance Panel, 2003: 108).[2] Although not strong, the results of the MAU's statistical analysis of the relationship of load to the market price of electricity during the period from May to December of 2002 indicated that large industrial users were reducing their consumption to some extent in response to the higher HOEPs recorded during on-peak hours.

During the summer of 2006, when the Ontario government policy was beginning to focus on the potential for conservation and demand management measures for reducing electricity demand, and the Ontario Power Authority (OPA) was unveiling its Demand Response Program, considerable interest was expressed by both industry (Association of Major Power Consumers of Ontario [AMPCO]) and government (The Independent Electric System Operator [IESO]) in evaluating the responsiveness of load to price on the basis of the much greater volume of data that had become available since market opening. Important questions raised by AMPCO and IESO representatives during discussions with the authors were:

- How load-responsive is the Ontario industrial load?
- Does the data indicate that loads in some industrial sectors are more price-responsive than in others?
- Has the demand responsiveness of industrial load increased since market opening?
- Is industrial sector demand response greater during on-peak hours?

The objectives of this paper are to answer these questions by updating aspects of the MAU's analysis of the responsiveness of Ontario industrial load that the Market Surveillance Panel reported in 2003 and to provide additional insights gained from similar analysis undertaken with disaggregated industrial load data. The paper also provides brief comments on aspects of Ontario load response policy. Since this paper focuses

2 "HOEP" is the hourly price that is charged to local distribution companies and other non-dispatchable loads. It is the arithmetic average of the 12 market-clearing prices that are determined immediately after the fact for every five-minute interval of every hour using an algorithm that takes generator offers to sell and price-sensitive loads' bids to buy and dispatches resources to achieve a supply-demand balance and resulting price. Hourly "Uplift" settlement charges are applied to all customers in the wholesale market. The IESO uses the revenue from the uplift charge to pay for operating reserves, any congestion management settlement credits owed to dispatchable resources, intertie offer guarantee payments, and other hourly incurred costs such as energy losses on the IESO-controlled grid.

on the narrow technical questions of whether, and to what extent, the price elasticity of Ontario's industrial electricity demand may have changed in recent years, and the implications of the degree of demand response to price changes, the need for reforms or structural changes to Ontario's wholesale electricity market, including the present institutional arrangements, has not been addressed.

FACTORS LIMITING INDUSTRIAL DEMAND RESPONSE IN ONTARIO

During the period from market opening until at least the spring of 2005, a number of changes were taking place in the electricity business environment in Ontario that could well have dulled the market participants' sensitivity to electricity price increases and their appetite for load curtailment and shifting. For example, at least during the first year following market opening, the availability of fixed-term power procurement contracts with marketers was increasing as marketing companies became more active in the province. This facilitated the hedging of price risk through forward transactions.[3] To the extent that they contracted with marketers or other agents for supply, the loads' price risk diminished and also, perhaps, their appetite for responding to rising electricity prices by reducing demand. Further, the various electricity rebates, especially the Business Plan Protection Rebate introduced in May 2003, substantially reduced consumers' electricity market price risk and could have dulled their interest in looking for ways to make significant and timely responses to price increases.

In addition, for some time after market opening, participants were faced with what came to be referred to as "counter-intuitive" pricing because of the manner in which the IMO was managing the market. For example, if load was greater than anticipated and the market-clearing price was moving up as a consequence, the IMO would at times offer operating reserves into the market at zero price, quickly sending the HOEP in the opposite direction and thereby changing the price signal. Until the market-operating rules were altered to prevent such behaviour (a process that was not completed until 2005), many market participants were unable to consider the HOEP as being a "real" price and to "read" the market correctly, especially during the peak summer load season.

Further, although there is some evidence (as indicated later in this report) that Ontario industrial customers who pay real-time prices are price responsive to some extent, time-based rates or special incentive schemes are generally required to elicit a significant demand response and Ontario is only in the early stages of developing such programs (FERC, 2006: 13). Together, these various factors suggest that Ontario market participants may be just beginning to give serious consideration to demand response possibilities.

3 Unfortunately data on the number of fixed-price contracts in place and the volumes of electricity involved are not available.

RECENT DEMAND RESPONSE INITIATIVES

In order to encourage demand response, the IESO initiated a "transitional demand response program" (TDRP) in the spring of 2005, in which eight applicants were selected to participate. No new applicants were accepted under the program after the end of that year. The eight qualifying participants had the option of curtailing their load under the program until the April 2007 expiry date. However, the most that they could curtail load at any one time was 5 MW each. The Market Surveillance Panel Report of June 2006 indicates that the IESO's program could only have had a very limited impact on price, if any, during the period from April 2005 to December 2005 because of the limited extent of participation. In fact, the maximum reduction in load during a single hour under the TDRP was 20 MW (Market Surveillance Panel, 2006: 110).

The Conservation Bureau of the Ontario Power Authority (OPA) launched a Demand Response Program (DRP) of its own in June 2006 (Ontario Power Authority, 2006a). By end of year 2006, in excess of 200 MW nameplate capacity was subscribed to the program with significant participation from the pulp and paper sector. To that point, the maximum response under the program in a given hour was recorded during hour ending 15 on Tuesday, August 1, 2006, when 182 MW of load was curtailed (Ontario Power Authority, 2006a; conversation with staff). At less than 1% of peak load, this was a long way from the demand response resource potential of 3% to 7% of peak load found in most North American Electric Reliability Council regions, as reported in a recent survey conducted by the Federal Energy Regulatory Commission (FERC, 2006). Nevertheless, it is a start.

A main objective of the OPA is to enlist additional market participants in its DRP. In this regard, the OPA is targeting plants that have sufficient process flexibility to facilitate load curtailment and also situations that lend themselves to intra-day load shifting and short-term peak load shedding. The OPA has published an achievable goal of between 199 and 546 MW of "demand management" load reductions, including mostly industrial demand response but also some savings from residential sector time of use switching, by 2010. This would amount to between 0.7% and 2.0% of peak load (Ontario Power Authority, 2006b: 28, table 3.3). This degree of load responsiveness would be below the 5% of peak load amount that is generally regarded as necessary to "balance" the market. However, it would be close to the minimum level reported for North American Electric Reliability Council (NERC) regions (FERC, 2006).

One road block to the development of load responsiveness could be the electricity price rebate announced for the pulp and paper industry (Ontario, Office of the Premier, 2006). Firms in this industry have been responsible for most of the OPA's DRP success to date because of excess electricity capacity resulting from the downsizing of operations. Ordinarily, the introduction of a new rebate (or announcement that an existing rebate program will be continued) could be expected to soften an industry's drive to control and reduce operating costs, including the cost of electricity consumption. However, as a condition of eligibility for rebates under the Northern Pulp and Paper Electricity Transition Program (in which $140 million in "electricity relief" is being made available during the next three years to "transition to greater efficiency"), a pulp and paper mill must submit an implementation plan that describes how the mill will lower its electricity costs during the three-year period (Ministry of Natural Resources, 2006). That condition may actually increase the pulp and paper companies' level of interest in the DRP program.

ELECTRICITY DEMAND IN FIVE MAJOR INDUSTRIES

To facilitate an updated and more detailed analysis of price responsiveness, the IESO provided industrial hourly load data for 47 companies, classified according to the five industrial groups indicated in table 1. Together, these five groups represent about 81% of total Ontario industrial load and 13% of total intra-Ontario load.

TABLE 1: THE INDUSTRIAL GROUPS EXAMINED

	Sept. 2002 Load (MWhs)	**% Share**
Iron & Steel	420,542	20.7
Pulp, Paper and Board Mills	569,066	28.0
Metal Ore Mining	348,745	17.1
Motor Vehicle Manufacturing	144,819	7.1
Petroleum Products Manufacturing	160,299	7.9
Other	392,092	19.3
Total Industrial Market Participant Load	2,035,563	100.0

In each of the five major industries, for which hourly electricity demand data was provided, electricity requirements are a function of unique industrial processes and schedules, including vacation practices that have been established through time with the major trade unions involved. For this reason, electricity demand patterns may be dramatically different among the various types of plants that comprise power demand in a single industry. In fact, strong electricity requirements in some types of plants may be at least partially masked when demand for the industry is estimated through aggregation of demand in many types of activities. For this reason, even though electricity demand may be somewhat price responsive in the case of a particular plant, the electricity requirements of the industry as a whole may be less price sensitive.

Ontario industrial load declined by about 10% from the June-August period of 2002 to the same three-month period of 2006 (table 2). The decline was led by a 24% reduction in electricity demand in the pulp and paper industry and a drop of almost 10% in the motor vehicle manufacturing load. "Other" industrial demand declined by about 11%. Metal ore mining was the only industrial group to register an increase in load over this period.

TABLE 2: ONTARIO'S INDUSTRIAL LOAD IN 2002 AND 2006 COMPARED

	Average Hourly Industrial Load (MWs) in Ontario			
	June–August 2002	**June–August 2006**	**Change**	**% Change**
Pulp, paper, and paper board	786.4	600.7	–185.7	–23.6
Iron and steel and ferro alloys	538.3	530.2	–8.1	–1.5
Metal ore mining	444.5	459.5	15.0	3.4
Motor vehicle manufacturing	189.7	171.6	–18.1	–9.5
Petroleum and coal products	225.3	213.3	–12.0	–5.3
Other	561.0	497.3	–63.7	–11.4
Total	2,745.2	2,472.6	–272.6	–9.9

Pulp Paper and Paper Board Manufacturing

The decline in load in the pulp, paper, and paper board manufacturing industry has resulted from cutbacks in operations due to strong competition from US mills. In part at least, this may be attributed to the appreciation of the Canadian dollar in terms of the US dollar. In spite of this decline, the industry still represents the largest industrial load group in Ontario with about a 25% share. Whether or not business conditions have caused industry participants to be more responsive to high electricity prices than before is unclear from casual inspection of the data. However, it does appear that the flagging business environment has made the industry somewhat amenable to load curtailment. This is evidenced by the substantial interest in the Ontario Power Authority's Demand Response Program introduced during August 2006 to the pulp, paper, and paper board manufacturing industry.

Iron and Steel Manufacturing

The Ontario iron and steel industry has the second largest electricity demand among the various industry groups. Examination of the data indicates that the industry's load is about the same now as when the market opened. The considerable fluctuation in the electricity demand of this group through the period suggests that there could have been some load response activity. However, casual inspection of the data provided no clear evidence of this.

Metal Ore Mining

Electricity demand in the Ontario metal ore mining industry fluctuates with business conditions (metal prices) and other special factors such as labour disputes. The activity level is also affected to some extent by seasonal conditions and vacation periods. The industry ranks third, after pulp and paper and iron and steel, in electricity requirements. Review of the data provided no obvious indication of demand responsiveness to price. However the load is large enough, and the cost factor significant enough, for market participants to benefit from responding to high prices when they have the flexibility to do so.

Motor Vehicle Manufacturing

In the Ontario motor vehicle manufacturing industry, electricity requirements and the variability of demand are substantially different in engine, casting, paint, and assembly plants. Engine plants have a proportionately high electricity demand (approximately 80%) and low (20%) gas demand because of their high machinery requirements. They are, therefore, very sensitive to the price of electricity, especially when it comes to location decisions. On the other hand, assembly, casting, and paint plants may rely on natural gas for 80% or more of their energy requirements. Regardless of the energy source, energy reliability is critical because even a minor interruption can be very costly in a labour-intensive assembly site operation, given that workers must be paid even when production is interrupted. In some plants, the total energy usage may be the sum of requirements over two or three shifts, while in others only one shift may be operating.

Review of the data indicates that motor vehicle electricity demand regularly falls off during the last two weeks of December and the first two weeks of July because of vacation times. There are also distinct intraweekly demand patterns because the number of operating shifts typically falls during weekends. However, apart from gyrations on account of these factors, few unusual or unexplainable swings in demand that might be attributable to load curtailment arising from electricity price spikes were apparent in the data. *A priori*, it appeared that electricity demand in the Ontario motor vehicle manufacturing industry is relatively insensitive to high electricity prices.

Petroleum Product Manufacturing (Oil Refining)

Electricity demand by Ontario's oil refineries appears to have been quite steady since market opening with distinct weekly and less obvious seasonal fluctuations. There have been periods from one to three months duration when demand has declined to a lower than normal level because of temporary plant shutdowns and then recovered.

METHODOLOGY

The general approach taken to test the sensitivity of electricity demand in each of the industrial groups identified above was to use multivariate regression analysis with respect to hourly data through two 15-month periods, the first and last such 15-month periods for which the IESO provided data. Period 1 is the period from market opening on May 1, 2002 until July 31, 2003; Period 2 is the period commencing June 1, 2005 and ending August 31, 2006. The analysis was carried out separately for both on-peak and off-peak periods. The IESO's definitions of on-peak and off-peak periods were used. On-peak hours are non-holiday weekday hours eight through 23. Off-peak hours include holiday and weekend hours and hours one to seven and 24 on all weekdays.

As in the similar analysis reported by the Market Surveillance Panel in 2003, the hourly Ontario electricity price (HOEP) determined in the wholesale market operated by the IESO, the HOEP plus hourly Uplift, and the 3-hour pre-dispatch price were tested

(Market Surveillance Panel, 2003: 96–100).[4] Other explanatory variables tested in various specifications of electricity demand for each industrial group were the price of natural gas, temperature variables, hourly, monthly, and quarterly dummy variables, and lagged consumption and price variables.

The electricity demand specification used was essentially the same as that used for the analysis undertaken by the Market Assessment Unit (MAU) as described in the Market Surveillance Panel report referred to above. That is, hourly demand expressed as a function of a constant term, an hourly electricity price variable, hourly consumption lagged one hour, and monthly dummy variables. The dummy variables were intended to capture the impact on demand of swings in industrial activity through the course of the year on account of seasonal changes, industrial vacation practices, and weather (temperature) conditions.[5]

RESULTS OF THE ANALYSIS

In general, the HOEP plus Uplift price variable performed as well as HOEP and both variables performed considerably better than the 3-hour pre-dispatch price in preliminary regression analysis. For this reason, only the regression results obtained using the HOEP plus hourly uplift are reported here.

Temperature variables were tested as explanatory variables of industrial electricity demand. However, as in the MAU's 2003 analysis, they proved to be insignificant (Market Surveillance Review Panel, 2003). Hourly dummies instead of monthly dummies were also tested but did not improve the goodness of fit. Monthly dummy variables generally performed as well as, or better than, quarterly dummies.

The results for the on-peak hour regressions for both test periods that are summarized in the table 3 are generally comparable to the goodness of fit and findings in relation to the significance of price as an explanatory variable that the Market Surveillance Panel reported in 2003. The 2003 report provided results for a group of companies from a number of different industries. Thanks to the data provided by the IESO, this report provides results for the five industry groups referred to earlier plus "other" demand, which is the difference between the sum of demand in the five groups of industries and total demand. Results are also provided for total demand. A number of things are apparent from the regression results for the on-peak hours.

4 As noted in an earlier footnote, the hourly uplift charges levied by the IESO provide revenue to pay for the cost of operating reserves, congestion management credits owed to dispatchable resources, intertie offer guarantees and other costs.

5 In future analyses of this kind, if the main objective is to compare elasticities between industries, consideration might be given to augmenting the basic model by including a variable that reflects the cost of electricity in each industry as a proportion of total costs. Because demand in industries in which the cost of electricity is more important would be expected to be more sensitive to price changes than in other industries, with this adjustment, the differences in elasticities would then reflect factors other than the relative importance of electricity in the cost structure.

TABLE 3: REGRESSION RESULTS FOR ON-PEAK HOURS DURING PERIOD 1 AND PERIOD 2

Model: demand = f (constant, lagged Dd, HOEP plus uplift, monthly dummies)
Period 1 runs from May 1, 2002 to July 2003; Period 2, from June 2005 to August 2006.

			Price Variable	
Industry Group	**Period**	**Adjusted R^2**	**Coefficient**	**"t" Statisitic**
Iron and steel	1	0.748	−0.042	−5.676
	2	0.716	−0.038	−4.058
Metal ore mining	1	0.983	−0.004	−1.606
	2	0.960	−0.017	−4.584
Pulp and paper	1	0.851	−0.058	−9.218
	2	0.837	−0.105	−10.949
Motor vehicle manufacturing	1	0.979	−0.002	−1.530
	2	0.976	−0.007	−4.355
Petroleum products	1	0.981	0.000	−0.689
	2	0.994	0.000	−0.536
Other	1	0.922	−0.012	−6.154
	2	0.952	0.004	2.135
Total	1	0.924	−0.102	−8.781
	2	0.865	−0.141	−9.289

- The price variable had the anticipated negative sign and was significant in both periods in the case of iron and steel, metal ore mining, pulp and paper, motor vehicle, and total electricity demand. Price was not significant in the case of petroleum refining electricity demand.

- The price coefficient was greatest in the estimates for pulp and paper electricity demand, ranging from −0.06 to −0.11. It was −0.04 in both periods in the case of iron and steel. Although significant, the price variable was noticeably smaller in the case of metal ore mining (especially during the second period) and in motor vehicle manufacturing. For industrial demand in total, the price coefficient ranged between −0.10 and −0.14.[6]

6 These elasticities are in line with examples cited in Federal Energy Regulatory Commission, 2006.

- For pulp and paper and total industrial electricity demand, where the price coefficient is indicated as being the largest and most significant, price was a bit more significant in Period 2, although the overall goodness of fit was somewhat weaker. The level of significance of the price variable was also greater in Period 2 in the case of metal ore mining and motor vehicles but not in the case of iron and steel.

- Based on the somewhat stronger "t" statistics on the price variable in Period 2 in the case of pulp and paper mills, metal ore mining, and motor vehicle production, one might argue that price response has become greater since Period 1. However, such an argument would be tenuous given that the overall goodness of fit is somewhat poorer, in most cases, in the second period.

The overall conclusion is that, as indicated in the Market Surveillance Panel's Report of March 2003, the price of electricity is a significant determinant of electricity demand during on-peak hours in most cases with the expected negative sign (Market Surveillance Panel, 2003).[7] Further, of the industries examined, the price of electricity appears to matter most in the pulp and paper industry and least in the petroleum industry. That the pulp and paper industry appears to be the most price responsive of the five major industries examined is perhaps not surprising given the competitive pressures that that industry is facing and the ability of firms to reduce load in some cases because of excess capacity. On the other hand, it appears that the petroleum industry is less price sensitive, perhaps because increases in the price of crude oil and other costs can be more readily passed on to consumers. Also, it is difficult to alter the capacity utilization rate of a given refinery within a relatively short period of time.

The regression analysis results reported here cannot be taken as providing evidence that the responsiveness of Ontario industrial demand to the price of electricity during on-peak hours has strengthened since market opening except, perhaps, in the case of metal ore mining and motor vehicle manufacturing power demand. In both cases the price variable is negatively signed in the regressions for both periods but much more significantly in Period 2. However, in each case, the overall goodness of fit is a bit weaker in Period 2.

Similar analysis for off-peak hours indicated that, except for iron and steel electricity demand, the price variable was not significant and did not have the anticipated negative sign. In the case of pulp and paper, the price variable was significant in both Period 1 and Period 2, but with a positive sign. From this, one can conclude that, as expected, there is some demand responsiveness during on-peak hours, when price pressures generally occur. For off-peak periods, there was little evidence of demand responsiveness to price changes. This indicates that when prices are "normal" and not shifting much from the "norm," as most likely during off-peak weekday hours and weekend and holiday periods, there is little incentive for consumers to alter demand.

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7 In the 2003 results, the regressions were carried out first with respect to all hours (both on-and off-peak hours together and then, separately for particular hours of the day including both on-peak and off-peak days).

OTHER SENSITIVITIES

Altered Definition of Period 1

It was hypothesized that the policy announcement of November 2002, according to which most Ontario consumers were to be sheltered from the full impact of the wholesale market price, may have fundamentally altered the way in which industrial customers regarded HOEP plus Uplift and reduced their sensitivity to price changes. For this reason, on-peak period regression results for a shorter time period, ending November 30, 2002, were tested against the earlier Period 1 regression results. Use of the shorter time frame resulted in a slightly higher coefficient on the price variable, with greater significance, only in the case of the iron and steel and metal ore mining industrial groups. In all other cases, the price variable was less significant than with the original Period 1 definition. In addition, the overall goodness of fit was poorer with the shorter Period 1 definition. From this analysis, it was concluded that the responsiveness of load to price was generally not stronger during the shorter period.

Comparison of Periods with Different Price Performances

The period from July 2005 to September 2005 had 61 occurrences in which the HOEP exceeded $200/MWh, whereas the same three-month period of 2004 had none. Regression analysis results for the two periods were compared to determine whether demand in any of the industrial groups was more price responsive during the summer of 2005, when the average HOEP was greater than during the summer of 2004, and there were a considerable number of price hikes.

- For iron and steel electricity demand, the HOEP plus uplift price variable had the expected negative sign and the same coefficient in both time periods and was clearly significant in the 2005 period, but not in the 2004 period (“t” statistic of 2.8 vs. 0.6).

- In the case of pulp and paper electricity consumption, the price variable was negatively signed in both cases but the level of significance was much greater in the 2005 period (“t” statistic of 7.6 vs. 2.8).

- For motor vehicle electricity demand, the price variable was negatively signed and significant in the 2005 period but not in 2004.

- For total industrial demand, the coefficient on the price variable was negatively signed and with about the same value in both periods; however, the level of significance was clearly stronger in the 2005 case (“t” statistic of 6.3 vs. 1.6)

- With metal ore mining demand for electricity, the price variable was negatively signed in both cases and the level of significance was virtually the same in the two cases.

- In the case of refining electricity demand, the price variable was negatively signed but clearly insignificant in both years. As with the earlier test results, the electricity price did not appear to matter in the case of refinery power demand.

The improved results for the summer of 2005 analysis relative to the results for the summer of 2004 for iron ore, pulp and paper, motor vehicles, and total industrial electricity demand, suggest that price was a more important determinant of electricity demand for those three groups during the 2005 period.

August 2002 versus August 2006

The two fifteen-month time periods used for the basic comparisons may have been too long for meaningful comparison of price sensitivity trends given the many other factors that were affecting industrial demand, especially the many changes in government policy and rebates that were taking place. For this reason, estimated demand/price relationships for just the months of August 2002 and August 2006 were compared.

It was hypothesized that demand might have been more responsive during August 2006 than during the same month in 2002 because of increased awareness on the part of market participants of the potential benefits of temporary load shedding or shifting, and opportunities for curtailing load that became available under the Ontario Power Authority's Demand Response Program beginning in July 2006 (Ontario Power Authority, 2006a). In fact, the regression analysis results for August 2006 confirm that the HOEP plus Uplift variable was a much more significant determinant of electricity demand in the case of the pulp, paper, and paper board; metal ore mining; motor vehicle; "other" industrial; and total industrial demand categories than in August 2002. With iron and steel electricity demand, the price variable was negatively signed and significant in the estimate for August 2002, but not in the 2006 estimate. With petroleum product manufacturing, the price variable was insignificant in both cases.

While the results were mixed, they would appear to confirm the hypothesis that, for most of the industry groups tested, electricity demand was more responsive to the price of electricity in August 2006 than in August 2002. That this was the case for pulp and paper is not surprising because all of the firms that applied to participate in the OPA's demand response program were from that industry.

THE ELECTRICITY REBATES AND THEIR IMPACT

Since the Ontario wholesale electricity market was opened in May 2002, the market has been overlaid with a complex set of rebates or subsidies that has raised doubts regarding the validity of the HOEP or HOEP plus Uplift variables as effective market price signals. The strength of HOEP plus Uplift minus Rebates as an explanatory variable was tested in order to determine whether rebates effectively weakened the role of the price of electricity in the model of electricity demand employed earlier. The rebates and the methods according to which values were assigned to them in each case in order to construct the HOEP plus Uplift minus Rebates variable are described below.

Market Power Mitigation Agreement Rebate

In May 2002, upon market opening, the Market Power Mitigation Agreement (MPMA) was in effect, whereby Ontario Power Generation (OPG) was obliged to pay the IMO a rebate for ultimate distribution to most customers in order to address the potential for OPG to exercise market power. Essentially, the rebate was calculated as the excess, if any, of the average hourly spot price over $38/MWh in relation to OPG energy sales subject to the rebate mechanism.

Two MPMA Rebate payments were made to market customers in relation to the first year in which the market was opened. These were made via credits on customers' regular invoices issued at the end of April and July 2003, respectively. The first payment was in relation to the period May 2002 through January 2003. The average rebate amount during that period was $6.58/MWh, according to information provided by the IESO. The average rebate with respect to the second part of the period, February to April 2003, was $21.31/MWh. Accordingly, hourly "credits" of these amounts were deducted from HOEP plus Uplift for the May 2002 through April 2003 period to adjust the market price variable for the rebates received.[8]

Because the rebate amounts were uncertain at the outset, and the credits did not become known until well after the time periods to which they applied, it was not clear whether they would have had much impact on the response of industrial demand to price. However, the fact that the intent and mechanisms for "payback" were announced publicly well in advance of when customers' invoices were actually credited, suggests that the rebates could have dampened demand response to some extent.

Business Protection Plan Rebate

In March 2003, the Government of Ontario announced a Business Protection Plan Rebate (BPPR) according to which market participants using 250,000 kWh or more of electricity per year were entitled to receive rebates equivalent to 50% of the amount by which the average monthly spot wholesale price of electricity exceeded $38/MWh (Ontario Power Generation, 2003: 11). Rebates under this arrangement replaced the MPMA Rebate program as of May 1, 2003. The BPPR program was in effect until the end of March 2005.

Rebate amounts per megawatt hour for each quarter commencing May–July 2003, as calculated by the IESO, were deducted from HOEP plus Uplift during the period in which the BPPR rebate program was in effect to calculate the HOEP plus Uplift minus Rebates variable.

8 The information pertaining to how the market protection mitigation agreement rebates were calculated and when the rebate payments (credits) were made to customers' accounts was provided by the IESO or calculated from that information.

OPG Rebate

Another rebate, labeled the "OPG Rebate," became effective in April 2005. This rebate effectively replaced the method of distribution of MPMA payments received from OPG that had been in effect under the BPPR mechanism. Essentially, the OPG Rebate is based on OPG revenues from non-prescribed or unregulated generation. Market participants receive payments based on their pro-rata share of the total quantity of electricity withdrawn.

The OPG Rebate has been in effect for three distinct periods, each requiring a slightly different calculation. During the period from April 1, 2005 to December 31, 2005, the total OPG rebate amount for a given hour was calculated by multiplying the difference between the HOEP for that hour and $47/MWh by 85% of OPG's energy generation from non-prescribed assets. For the period from January 1, 2006 to April 30, 2006, the rebate also incorporated amounts determined in an OPA auction for OPG output. Since May 1, 2006, the OPG Rebate has been calculated for each 12-month settlement period with interim quarterly payments. The OPG Rebate rates provided by the IESO were deducted from HOEP plus Uplift for the purpose of the analysis reported in this section.[9]

Global Adjustment Rebate

The global adjustment (GA) rebate began January 1, 2005 and, like the OPG rebate, is still in effect. GA is the difference between total payments made to certain contracted or regulated generators/demand management projects and offsetting market revenues. The IESO calculates the GA each month, taking into account the quantity of each type of regulated or contracted investment injected into the grid, the cost of that generation, and any offsetting revenues. The monthly GA rates calculated by the IESO were used.[10]

Total Rebates Relative to HOEP

In total, the rebates averaged 14% of the hourly wholesale market price during the May 2002 through August 2006 period. However, as indicated by figure 1, the rebates were much greater on a percentage basis during the periods of high electricity prices during 2003 and 2005, at times being as large as 30% of HOEP plus Uplift.

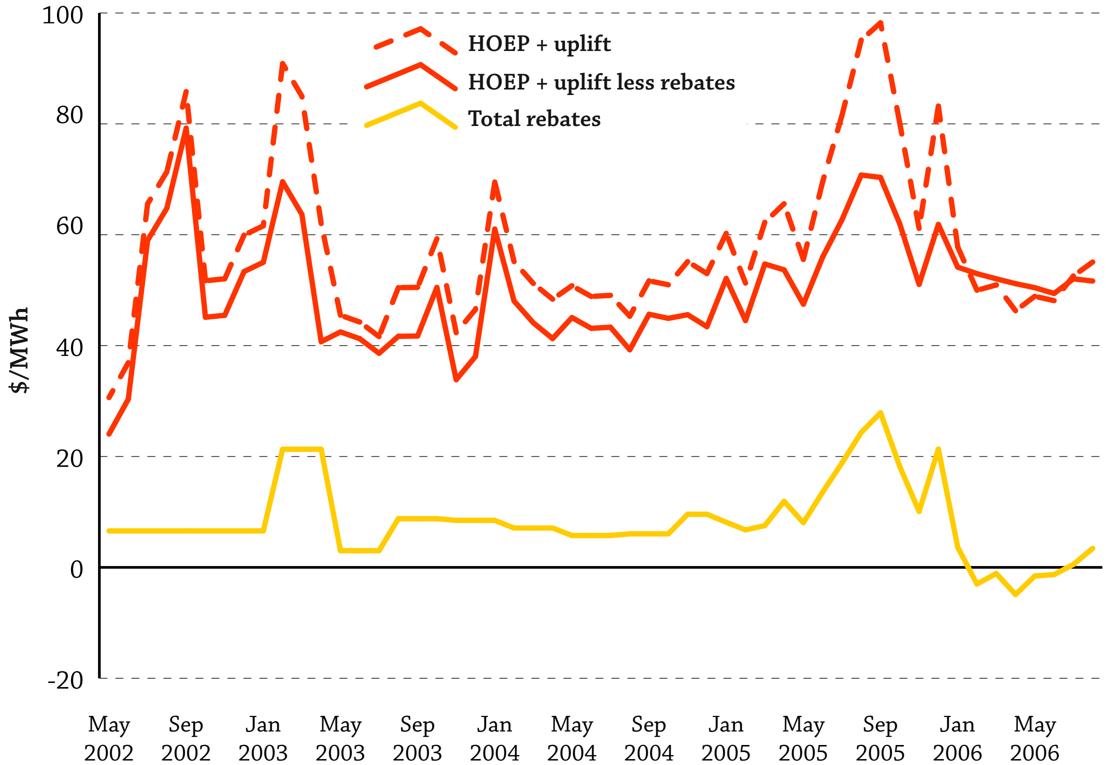
There was considerable uncertainty throughout the period as to precisely how large the rebates would be (mainly because the rebates were a function of the market price) and as to when market participants' invoices would be credited with the rebate amounts. In fact, the first rebates were not paid until the end of April 2003.[11] In spite of this, because they knew that they would be protected to a large extent from price spikes by rebates, it would have been expected that industrial electricity consumers would be less concerned with price developments, and less apt to feel compelled to find ways to reduce demand in response to price spikes, than otherwise.

9 The information and data pertaining to the OPG rebate were provided by the IESO.

10 The information and data pertaining to the global adjustment rebate were provided by the IESO.

11 These first credits were in relation to the nine-month period from May 2002 to January 2003. Accordingly, the amount of the rebate per megawatt hour during that period was assumed to be constant.

FIGURE 1: WHOLESALE ELECTRICITY PRICES AND REBATES IN ONTARIO (2002–2006)



Source: data from the IESO.

The hypothesis that the rebate mechanism resulted in industrial consumers' demand for electricity being less sensitive to price was tested using regression analysis for the basic model specifications employed earlier, for pulp and paper, iron and steel, and metal ore mining during on-peak periods, with the HOEP plus Uplift price variable replaced by HOEP plus Uplift minus Rebates.

The demand response to price indicated in the original on-peak analysis for the two periods was neither more nor less robust when total rebates were subtracted from HOEP. This is perhaps because at the time that the consumption was incurred, the loads did not know precisely how large the rebates would be and when the credits for the rebates would appear on their invoices. In addition, because the rebates were calculated on a quarterly or monthly basis and HOEP plus Uplift is hourly, deducting the rebate amounts reduced the level of the hourly price variable used in the regressions but had no impact on the hourly fluctuations, except at month or quarter ends when the rebate amounts changed.[12]

12 The finding that rebates generally have no impact on the price elasticity should not be a surprise given that the elasticity is calculated at the mean of the HOEP. By subtracting rebates we change the mean HOEP but nothing about the quantities is changed. As long as the change in the mean price is small there will not be much change in the elasticity.

ECONOMETRIC ISSUES

As noted earlier, the ordinary least squares (OLS) regression methodology used for this study is the same approach as the Independent Market Operator's Market Analysis Unit used in its 2003 analysis of price responsiveness. Further, the model specification, which uses a lagged dependent variable, is essentially the same as one of the specifications that the MAU found yielded the best results.

If serial correlation exists in the presence of a lagged dependent variable OLS regression, this could result in bias in the estimated coefficients.[13] Also, if price is endogenously co-determined with demand, i.e., if there is a simultaneity problem, then parameter estimates obtained using OLS may be biased and inconsistent. Further, the fact that each industrial demand sub-group is modeled separately could cause the elasticity estimates that are derived from the coefficients on the price variable to be biased if the demand/price relationship in one industry sub-group is affected by developments in another. In addition, there may be other kinds of bias from omitted variables as, for example, if electricity demand in any of the industries examined is being affected by a phenomenon that is not specified in the model.

Because of the possibility that the estimated coefficients may be biased, the results of the analysis must be interpreted with caution. Certainly, any policy recommendations that are based on the estimates of the price elasticities should be conditioned by the fact that the results may be flawed to some extent. A more detailed discussion of the econometric issues is provided in the Appendix: Econometric Issues.

DEMAND RESPONSE POLICY RECOMMENDATIONS

A number of observations fell out of this work. These suggested a number of recommendations for those involved in determining and implementing Ontario electricity market policy, as follows.

- According to information provided by the OPA regarding the extent of involvement in its DRP, Ontario industrial demand response to the price of electricity is generally not strong enough to provide the degree of protection against price spikes during on-peak hours that the recent FERC study suggests is needed to ensure a "balanced" market (FERC, 2006). This indicates that greater effort is needed to encourage industry to participate in demand response programs.

- The disaggregated industry data indicate that the pulp and paper, and iron and steel industries are more sensitive to electricity prices than the metal ore and mining, motor vehicle manufacturing, and oil refining industries. For this reason, the OPA should

13 As discussed in the Appendix: Econometric Issues, a test for serial correlation did not identify it as a problem.

focus much of its attention on firms in the pulp and paper and iron and steel industries as it strives to expand involvement in its fledgling DRP. The OPA should not , however, go overboard in this direction. There are two reasons for this. First, as discussed in the Appendix, the estimated price coefficients (i.e., the price elasticities) may be too large because of the effects of variables omitted from the model specification. Second, the subsidies being offered to the pulp and paper mills to encourage them to minimize their electricity costs, and therefore become better able to compete internationally, may be sufficient to gear them towards significant efficiency improvements, in which case the OPA's limited resources may best be targeted at other industries.

- Metal ore mining load represents about 19% of Ontario industrial load. Although the degree of price responsiveness appears to be weaker than in the pulp and paper and iron and steel industries, companies involved in metal ore mining are also candidates for OPA's DRP.

- Together, the motor vehicle manufacturing and oil refining industries constitute about 16% of Ontario electricity demand. The general lack of demand responsiveness in these industries probably reflects the characteristics of the industrial processes that are employed at various sites. In the aggregate, however, demand response is the outcome of the responsiveness at many plant sites throughout the industrial sector. The OPA, therefore, should not simply write the motor vehicle and refining industries off as unlikely prospects but, rather, meet with representatives of the various companies to determine the possibility for enlisting specific plants in the DRP.

- Approximately 20% of Ontario industrial electricity demand is in industries other than the five major industries for which the IESO provided hourly data. This "other industrial" group represents a greater share of industrial power demand in that province than motor vehicle manufacturing and petroleum refining electricity demand combined. Companies in the "other industrial" category, whose processes lend themselves to temporary load shifting or postponement, must also be of considerable interest to OPA officials seeking to expand the load response program.[14]

- Rebates and subsidies do not contribute to an efficient electricity market because they blunt meaningful price signals. This is because consumers who, in the absence of subsidies, might be expected to respond to high prices either do not respond at all or do not respond to nearly the same extent. It is not surprising that Ontario's demand response has been weak during most of the period since market opening, given the extent to

14 One must not lose sight of the fact that recommendations pertaining to which industries offer the most potential for improved demand responsiveness that are based on the results of the statistical analysis need to be carefully interpreted because of the risk that the elasticities implied by the coefficients on the price variables may be biased because of estimation error. This is discussed in some depth in the Appendix: Econometric Issues.

which industrial electricity consumers have been shielded from the market price, especially while the Business Protection Plan Rebate was in effect. If the government of Ontario is serious about promoting an efficient wholesale market, it should, therefore, review the existing rebate and subsidy programs with a plan to eliminating them. This includes the special assistance recently extended to the pulp and paper industry. Firms are unlikely to find demand response programs attractive as long as they are benefiting from special electricity price subsidies. The most sensible policy would be to avoid the use of subsidies for any reason. However, if subsidies are to be used, then they should target changes in the orientation of load that would make price sensitivity more, rather than less, likely.

- The ability to rely on a significant load response based on agreements with a large number of industrial loads can reduce the need for both incremental peak period generation capacity and transmission system expansions and upgrades, and therefore result in cost savings to all customers. For this reason, the government should continue to raise the level of awareness of the existing DRP and of the importance of load response, and to explore means of making the DRP more attractive by, for example, including options for intra-day load shifting.

CONCLUSIONS

The results of the analysis reported here indicate that the price of electricity has been a significant determinant of electricity demand during on-peak hours in much of the period since market opening in most of the major industrial demand groups. High prices have tended to reduce demand somewhat during on-peak periods. This generally supports the findings of the analysis undertaken by the MAU in 2003, in relation to aggregate major industrial firm data for the period May 2002 through December 2002 (Market Surveillance Panel Report, 2003).[15]

Of the industries examined, the price of electricity appears to matter most in the pulp and paper industry and least in the petroleum industry. That the pulp and paper industry appears to be the most price-responsive of the five major industries examined is not surprising given the competitive pressures that that industry is facing and the ability of firms to reduce load, in some cases, due to of excess capacity. On the other hand, the relative lack of price sensitivity in the petroleum industry may reflect the fact that increases in the price of crude oil and other costs can be readily passed on to consumers in that industry; and also that refinery capacity utilization rates cannot be altered quickly.

The results of the regression analysis for two separate 15-month periods, one immediately following the opening of the market and one representing the last 15

15 In the 2003 results, the regressions were carried out first with respect to all hours (both on-peak and off-peak hours together and then, separately for particular hours of the day including both on-peak and off-peak days).

months for which the disaggregated data were available, provided no evidence that the responsiveness of Ontario industrial electricity demand to the price of electricity during on-peak periods has strengthened since market opening. This finding was not altered when the first period was shortened to run only until November 2002, when the government announced that many industrial consumers would be sheltered from much of the impact of fluctuations in the wholesale market price.

The analysis for off-peak periods indicated that, except for iron and steel electricity demand, the price variable was not significant with the anticipated negative sign. In general, this suggests that during periods when electricity prices tend to move very little from what industrial consumers come to regard as "normal," such as during off-peak weekday, weekends, and holidays, there is simply less evidence of price sensitivity.

Comparison of regression results for the summer period of 2005, when electricity prices were generally much higher and more volatile than during the same period of 2004, with results for the summer of 2004, indicated that industrial demand was somewhat more responsive to electricity price movements during the more recent period. This suggests that demand response may be expected to increase when prices are higher. It may also reflect the fact that the Business Protection Plan Rebate was terminated in March of 2005, which increased loads' exposure to fluctuations in the market price. Further, by the summer of 2005 the market rules that had led to claims that movements in the HOEP were "counter-intuitive" had been largely revised.

Comparison of regression estimates of industrial electricity demand for August 2002 and August 2006 indicated that the HOEP plus Uplift was a much more significant determinant of electricity demand in the case of the pulp, paper, and paper board, metal ore mining, motor vehicle, "other" industrial, and total industrial demand categories in August 2006 than in August 2002, but not in the case of iron and steel and petroleum product electricity demand. While mixed, the results appear to confirm the hypothesis that electricity demand was generally more responsive in August 2006. This could reflect increased awareness on the part of market participants of the potential benefits of temporary load shedding or shifting, and opportunities for curtailing load because of the OPA's Demand Response Program that commenced July 2006.

The hypothesis that the rebates resulted in industrial consumers' demand for electricity being less sensitive to price was tested by running regressions with the basic model specification employed for the two-period analysis for pulp and paper, iron and steel, and metal ore mining during on-peak periods with the HOEP plus Uplift price variable replaced by HOEP plus Uplift minus Rebates. The demand response to price indicated in the two periods was neither more nor less robust when the rebates were deducted than in the original analysis. This may be because when the consumption was incurred, the loads did not know precisely how large the rebates would actually be and when the credits for the rebates would appear on their invoices. In addition, because the rebates were calculated on a quarterly or monthly basis and HOEP plus Uplift, hourly, deducting the rebate amounts reduced the level of the hourly price variable used in the regressions by amounts that were fixed for extensive periods of time but did not affect the hourly fluctuations.

A number of policy recommendations were put forward. For example, the government should continue to raise the level of awareness of the existing DRP and of the importance of load response, as well as to make the DRP more attractive by, for example, including options for intra-day load shifting. Further, as it strives to expand involvement in its DRP, the OPA should focus much of its attention on the pulp and paper and iron and steel industries because demand responsiveness appears to be greatest in those industries.[16] The OPA should also focus on companies in the metal ore mining industry and on firms in the "other industrial" category, both of which are areas in which some price responsiveness was identified by the analysis.

While opportunities for demand response may not be as great in the motor vehicle manufacturing and oil refining industries, there may be opportunities to enlist plants in those industries that employ processes that are somewhat amenable to short-term electricity supply disruptions in the DRP.

Rebates and subsidies do not contribute to the workings of an efficient electricity market because they blunt price signals. If the government of Ontario is serious about improving the efficiency of the wholesale market, it should review existing rebate and subsidy programs with a view to eliminating them. This includes the special assistance recently extended to the pulp and paper industry in northern Ontario unless the program is truly an effective means of enticing firms to transitioning to minimizing their electricity costs. Firms are unlikely to find demand response programs attractive as long as they benefit from electricity price subsidies.

This paper has focused on the narrow technical questions of whether, and to what extent, the price elasticity of Ontario's industrial electricity demand may have changed in recent years and the implications of the degree of demand response to price changes. The analysis centres around estimates and comparisons of the price elasticity of Ontario's industrial electricity demand. The need for reforms or structural changes to Ontario's wholesale electricity market, including the present institutional arrangements, has not been addressed.

16 The OPA should not limit itself to pursuing firms in those industries since the potential benefits may not be as great as the price elasticities imply if, in fact, they are biased. Also, the pulp and paper mills in northern Ontario may already be bent on minimizing their electricity costs because of the manner in which the subsidy program is structured.

APPENDIX: ECONOMETRIC ISSUES

Ordinary least squares (OLS) multivariate regression analysis was used to estimate the price elasticities upon which the analysis and policy recommendations discussed in the paper depend. Under certain circumstances, OLS methodology can lead to inconsistent and biased estimates of the coefficients on the independent variables, including the coefficients on the price variables from which the price elasticities are derived. Some of the reasons for parameter bias and some actions that were taken to test for some forms of bias are discussed below.

Serial Correlation

Serial correlation can arise because of dynamic misspecification, functional misspecification or omitted variables. In the presence of a lagged dependent variable and serial correlation, OLS estimation generates inconsistent and biased coefficient estimates. In such cases, the Durbin-Watson statistic does not provide an indication of autocorrelation because the lagged dependent variable is correlated with the contemporaneous error in the regression equation. For this reason, a Lagrange Multiplier test for serial correlation was undertaken. This indicated that serial correlation was not a problem and, therefore, that the coefficients are unlikely to be biased for that reason.

Simultaneity

Another potential cause of parameter bias in regression analysis is the presence of endogenous co-determination or simultaneity between the dependent variable and one of the independent variables. In the model specification that was used for the analysis, consumption of electricity in the current period was assumed to be a function of the price of electricity during the same period, lagged demand, and other variables. It is unclear whether the results reported in the study are biased because of simultaneity. However, the possibility of such bias may require the use of a different estimation strategy in future research as, for example, a model in which demand is specified as a function of lagged price rather than price during the current period.

Omitted Variables

Biased coefficients can also result from omitted variables. An example of this is where the elasticity of electricity demand with respect to price is being estimated separately for each of a number of major industries. If factors underlying the demand for electricity in one or more of the other industries that are involved in the electricity market are not represented in the model for the particular industry, bias can result.

Another form of bias from omitted variables in this case could arise from the omission of a variable affecting electricity demand in the industry in question, such as increased foreign competition. For example, increased competition from foreign companies could result in reduced sales, lower production, and lower electricity demand. If the “competition” variable were omitted, then the coefficient on another variable with a negative sign, such as price, could be overestimated.

To check for the presence of omitted variable bias, the estimated price coefficients for each of the six sub-categories of on-peak industrial demand were summed and compared with the price coefficient estimated in the regression result for total industrial demand. The fact that the sum of the price coefficients was about the same as the price coefficient in the total demand equation suggests that the results for the sub-categories are not biased. However, this could simply be the result of offsetting errors—with some coefficients being biased upwards and others, downwards. Anyone interpreting the study results, therefore, still needs to be aware that the indicated price elasticities could be biased because of the effects of omitted variables.

This brief review of the reasons that the estimated coefficients could be biased, and the likely extent, is far from conclusive. It does, however, suggest that the indicated price elasticities could be over- or understated to some extent and, therefore, that caution should be exercised in basing recommendations and policy recommendations on the study findings.

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ISSN

1913-553X

Date of issue

September 2007

Editing, design, and production

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